APPENDIX D
EVALUATION OF HUMAN HEALTH EFFECTS FROM FACILITY ACCIDENTS

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Appendix D presents an evaluation of the effects on human health from accidents associated with the disposition of surplus plutonium at facilities at the Savannah River Site (SRS) and Los Alamos National Laboratory (LANL). Section D.1 presents the basic methodologies used to identify and evaluate the potential accidents associated with facilities at SRS and LANL that would be used under the options and alternatives, including the No Action Alternative. Detailed accident scenarios and potential source terms are developed in Section D.1.5 for the SRS and LANL facilities. In many cases, if a facility could be used under different alternatives or options, there is little difference in the bounding accidents that might be associated with that facility. More typically, the only real change in the accident risks associated with the different surplus plutonium disposition alternatives or options at a facility would be the length of time that the facility might operate. Where it is reasonable to identify how options might change the type of accidents or their magnitude at a facility, those changes are identified. For example, accidents and source terms associated with the addition of metal oxidation operations at the Mixed Oxide Fuel Fabrication Facility (MFFF) and changes in the amount of pits processed at LANL between the No Action and action alternatives are explicitly identified in the appropriate sections to help the reader understand how the potential options and alternatives might change accident risks at a specific facility.

The potential radiological impacts for each of the SRS and LANL facilities that might be used for surplus plutonium disposition are identified in Section D.2. Section D.3 discusses the potential impacts of chemical accidents at these facilities and finds that, because of the nature of the operations, the impacts of accidents associated with the use of chemicals are generally limited to the immediate vicinity of the accident and present negligible risks to the public.

D.1 Impact Assessment Methods for Facility Accidents

D.1.1 Introduction

The potential for facility accidents and the magnitude of their consequences are important factors for making reasonable choices among the various surplus plutonium disposition alternatives in this *Final Surplus Plutonium Disposition Supplemental Environmental Impact Statement (SPD Supplemental EIS or SEIS)*. Guidance on the implementation of Title 40 of the *Code of Federal Regulations* (CFR) 1502.22, as amended (40 CFR 1502.22), requires the evaluation of impacts that have a low frequency of occurrence, but large consequences. Further, public comments received during the scoping process indicate the public's concern with facility safety and health risks and the need to address these concerns in the decisionmaking process.

Potential accidents are defined in existing facility documentation, such as safety analysis reports (SARs), documented safety analyses (DSAs), hazards assessment documents, and National Environmental Policy Act (NEPA) documents. The accidents include radiological and chemical accidents that have a low frequency of occurrence, but large consequences, and a spectrum of other accidents that have higher frequencies of occurrence and smaller consequences. The data in these documents include accident scenarios, materials at risk (MAR), source terms (quantities of hazardous materials released to the environment), and consequences.

In determining the potential impacts associated with facility accidents, this *SPD Supplemental EIS* considers two important concepts in the presentation of results: (1) consequences and (2) uncertainties and conservatism.

D.1.1.1 Consequences and Risks

Metrics commonly used in environmental impact statements (EISs) to present the potential impacts of accidents are consequences and risks. The consequences are the potential impacts that would result if the accident were to occur. Accident consequences may be presented as impacts on individuals or a specified population (e.g., residents within 50 miles [80 kilometers] of an accident and in terms of dose (e.g., rem or person-rem) or health effects (e.g., latent cancer fatalities [LCFs]). Risk is usually defined as the product of the consequences and estimated frequency of a given accident. The accident frequency is the number of times the accident is expected to occur over a given period of time (e.g., per year). In general, the frequency of design-basis and beyond-design-basis accidents is much lower than 1 per year and, therefore, is approximately equal to the probability of the accident over 1 year. If an accident is expected to occur once every 1,000 years (i.e., a frequency of 0.0010 per year) and the consequence of the accident is 5 LCFs, then the risk is $0.001 \times 5 = 0.005$ LCFs per year.

A number of specific types of risk can be directly calculated from the results of the MACCS2 [MELCOR Accident Consequence Code System] computer code (NRC 1990, 1998). The risk to a maximally exposed member of the public (MEI) can be calculated. The MACCS2 computer code yields a dose to the MEI; using the risk factor of 0.0006 LCFs per rem, the consequence in terms of the likelihood of an LCF can be calculated. The risk to this hypothetical individual is calculated by multiplying the consequence in terms of an LCF by the estimated accident frequency. For example, if an accident has an estimated frequency of 0.001 per year and the MEI dose from the accident is 1 rem, the risk to the MEI is $0.001 \times (1 \times 0.0006) = 6 \times 10^{-7}$ LCFs per year.

It is also possible to calculate population risk, which is the product of the total consequences experienced by the population and accident frequency.[1] For example, if an accident has a frequency of 0.001 per year and the consequence of the accident is 5 LCFs, then the population risk is $0.001 \times 5 = 0.005$ LCFs per year. Population risk is a measure of the expected number of LCFs experienced by the population as a whole over the course of a year.

D.1.1.2 Uncertainties and Conservatism

The analyses of accidents are based on calculations relevant to hypothetical sequences of events and models of their effects. The models provide estimates of the frequencies, source terms, pathways for dispersion, exposures, and effects on human health and the environment that are as realistic as possible within the scope of the analysis. In many cases, minimal experience with the postulated accidents leads to uncertainty in the calculation of their consequences and frequencies. This fact has prompted the use of models or input values that yield conservative estimates of consequence and frequency. All alternatives have been evaluated using uniform methods and data, allowing for a fair comparison of all alternatives.

Although average individual and population risks can be calculated from the information in this *SPD Supplemental EIS*, the equations for such calculations involve accident frequency, a parameter whose calculation is subject to considerable uncertainty. The uncertainty in estimates of the frequency of highly unlikely events can vary over several orders of magnitude. This is the reason accident frequencies are reported in this *SPD Supplemental EIS* qualitatively, in terms of broad frequency bins, as opposed to numerically. Similarly, any metric that includes frequency as a factor has at least as much, and generally more, uncertainty associated with it. Therefore, the consequence metrics have been preserved as the primary accident analysis results, and accident frequencies have been identified qualitatively, to provide a perspective on risk that does not imply an unjustified level of precision.

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[1] *Population data for each facility considered in this* SPD Supplemental EIS *can be found in Appendix C.*

D.1.2 Safety Strategy

D.1.2.1 General Safety Strategy for Plutonium Facilities

For general plutonium facilities like those evaluated in this *SPD Supplemental EIS*, the general safety strategy requires the following:

- Plutonium materials to be contained at all times with multiple layers of confinement that prevent the materials from reaching the environment.
- Energy sources large enough to disperse the plutonium and threaten confinement to be minimized.

This basic strategy means that operational accidents, including spills, impacts, fires, and operator errors, never have sufficient energy available to threaten the multiple levels of confinement that are always present within a plutonium facility. The final layer of confinement is the reinforced-concrete structure and the system of barriers and multiple stages of high-efficiency particulate air (HEPA) filters or, in some cases, an additional sand filter, that limit the amount of material that could be released to the environment even in the worst realistic internal events.

The operational events that present the greatest threats to confinement are large-scale internal fires that, if they did occur, could present heat and smoke loads that threaten the building's HEPA filter systems. For modern plutonium facilities, the safety strategy is (1) to prevent large internal fires by limiting energy sources, such as flammable gases and other combustible materials, to the point that a wide-scale, propagating fire is not physically possible and (2) to defeat smaller internal fires with fire-suppression systems.

Modern plutonium operations are designed and operated such that the estimated frequency of any large fire within the facility would fall into the "extremely unlikely" category and would require multiple violations of safety procedures to introduce sufficient flammable materials into the facility to support such a fire. Any postulated large-scale fire in a modern plutonium facility that would be expected to result in severe consequences if it occurred would be categorized as a "beyond-design-basis" event and would fall into the "beyond extremely unlikely" category.

Earthquakes present the greatest design challenges for these facilities due to the requirement to prevent substantial releases of radioactive materials to the environment during and after a severe earthquake. For safety analysis purposes, it is often assumed that, after a very severe earthquake that exceeds the design loading levels of the facility equipment, enclosures, and building structure and confinement, a substantial release of radioactive material within the facility would occur. This assumption allows designers and safety analysts to determine the additional design features that may be needed to ensure greater containment and confinement of the radioactive MAR, even in an earthquake so severe that major damage to a new, reinforced-concrete facility could occur. In these safety analyses, it is often assumed that major safety systems are not in place, such that estimates of the mitigation effectiveness of each of the safety systems (or controls) can be estimated.

The accident scenarios selected for inclusion in this *SPD Supplemental EIS* are those that would present the greatest risk of radiological exposure to members of the public. Because of the reinforced nature of the surplus plutonium disposition facilities, these scenarios all require substantial additions of energy, either from a widespread internal fire or through a severe natural disaster such as an earthquake so severe that building safety systems exceed their design limits and confinement of the plutonium materials within the building is lost. Thus, any of the accidents presented in this *SPD Supplemental EIS* with frequencies of 1 in 10,000 per year or less would fall into the "beyond-design-basis" category and have probabilities that would fall into the "extremely unlikely" or "beyond extremely unlikely" category. None of these postulated events is expected to occur during the life of the facilities.

D.1.2.2 Design Process

The proposed surplus plutonium disposition facilities would be designed to comply with current Federal, state, and local laws; U.S. Department of Energy (DOE) Orders; and industrial codes and standards. This would result in a plant that is highly resistant to the effects of natural phenomena, including earthquakes, floods, tornadoes, and high winds, as well as credible events as appropriate to the site, such as fire, explosions, and manmade threats.

The design process for the proposed facilities would comply with the current DOE or U.S. Nuclear Regulatory Commission (NRC) requirements for safety analysis and evaluation, such as those presented in DOE Order 420.1B or 420.1C (as applicable), (DOE 2005b, 2012e) and DOE-STD-1189-2008 (DOE 2008a), as applicable. These documents require the safety assessment to be an integral part of the design process to ensure compliance with all DOE construction and operation safety criteria by the time the facilities are constructed and in operation.

The safety analysis process begins early in the conceptual design with the identification of hazards that could produce unintended adverse safety consequences for workers or the public. As the design develops, hazard analyses are performed to identify events that could result in a release of hazardous material. The kinds of events considered include equipment failures, spills, human errors, fires, explosions, criticality, earthquakes, electrical storms, tornadoes, floods, and aircraft crashes. These postulated events become focal points for design changes or improvements to prevent unacceptable accidents. The analyses continue as the design progresses, their objective being to assess the need for safety equipment and the performance of such equipment. Eventually, the safety analyses are formally documented in safety-basis documents.

D.1.3 U.S. Department of Energy Facility Accident Identification and Quantification

D.1.3.1 Background

Identification of accident scenarios for the proposed facilities is fairly straightforward. The proposed facilities are straightforward and well understood, and their processes have been used in other facilities for other purposes. From an accident identification and quantification perspective, therefore, these processes are well known and understood. Very few of the proposed activities would differ from activities at other facilities.

New facilities would likely be designed, constructed, and operated to provide an even lower accident risk than other facilities that have been used for these types of processes. The new facilities would benefit from lessons learned in the operation of similar processes. They would be designed to surpass existing plutonium facilities in their ability to reduce the frequency of accidents and mitigate any associated consequences.

A large experience base exists for the design of the proposed facilities and processes. Because the principal hazard for workers and the public from plutonium is the inhalation of very small particles, the safety management approach that has evolved is centered on control of those particles. The control approach is to perform all operations that could release airborne plutonium particles in gloveboxes. A glovebox protects workers from inhalation of the particles and provides a convenient means for filters to collect any particle that becomes airborne. Air from gloveboxes, operating areas, and buildings is exhausted through multiple stages of HEPA filters (and possibly sand filters) and monitored for radioactivity prior to release from the building. These exhaust systems are designed for effective performance even under the severe conditions of design-basis accidents, such as major fires involving an entire process line.

While the new processes and facilities would be designed to reduce the risks of a wide range of possible accidents to a level deemed acceptable, some risks would remain. As with all engineered structures—e.g., houses, bridges, dams—there is some level of earthquake or high wind that the structure could not survive. While new plutonium facilities must be designed to very high standards—for instance, they must survive, with little plutonium release, a 1-in-10,000-years earthquake—an accident more severe than the design-basis can always be postulated. Current DOE standards require new facilities to be designed to prevent, to the extent possible, all credible process-related accidents, as well as to withstand, control, and mitigate such accidents should they occur. For safety analysis purposes, credible accidents are generally defined as accidents with frequencies greater than 1 in 1 million per year, including such natural phenomena as earthquakes, high winds, and flooding. The accidents considered in the design, construction, and operation of these facilities are generally called design-basis accidents.

In addition to the accident risks from the design-basis accidents, the new facilities would face risks from beyond-design-basis accidents. For most plutonium facilities, the design-basis accidents include all types of process-related accidents that have occurred in past operations, such as major spills, leaks, transfer errors, process-related fires, explosions, and nuclear criticalities. Certain natural-phenomenon-initiated accidents also meet the DOE design-basis criteria. For example, these facilities are designed to survive a design-basis earthquake as discussed above. However, all new plutonium facilities, as manmade structures, could collapse under the influence of a strong enough earthquake. Such an earthquake would be considered a beyond-design-basis earthquake and its frequency would be considered to range from "extremely unlikely" to "beyond extremely unlikely." For most new plutonium facilities, the worst possible accident would be a beyond-design-basis earthquake that results in partial or total collapse of the structure, followed by spills, possibly fires, and loss of confinement of the plutonium powder. External events, such as the crash of a large aircraft into the structure with an ensuing fuel-fed fire, are also conceivable. At most locations away from major airports, however, the likelihood of a large aircraft crash is less than 1 in 10 million per year.

The accident analysis reported in the *SPD EIS* is less detailed than a formal probabilistic risk assessment or facility safety analysis because it addresses bounding accidents (accidents with a low frequency of occurrence and large consequences), as well as a representative spectrum of possible operational accidents (accidents with a high frequency of occurrence and small consequences). The technical approach for the selection of accidents is consistent with the DOE Office of NEPA Oversight's *Recommendations for the Preparation of Environmental Assessments and Environmental Impact Statements* (DOE 2004b), which recommends consideration of two major categories of accidents: design-basis accidents and beyond-design-basis accidents.

D.1.3.2 Identification of Accident Scenarios and Frequencies

A range of design-basis and beyond-design-basis accident scenarios has been identified for each of the surplus plutonium disposition technologies (DOE 1999). For each technology, the process-related accidents possible during construction and operation of the facility have been evaluated to ensure that either their consequences are small or their frequency of occurrence is extremely low.

All of the analyzed accidents would involve a release of small, respirable plutonium particles or direct gamma and neutron radiation and, to a lesser extent, fission products from a nuclear criticality. Analyses of each proposed operation for accidents involving hazardous chemicals are reflected in the data reports supporting the *SPD EIS*. However, because the quantities of hazardous chemicals to be handled are small relative to those of many industrial facilities, no major chemical accidents were identified. The general categories of process-related accidents considered include the following:

- Drops or spills of materials within and outside the gloveboxes
- Fires involving process equipment or materials, as well as room or building fires
- Explosions initiated by the process equipment or materials or by conditions or events external to the process
- Nuclear criticalities

The SASSI Computer Code and Its Use at the Savannah River Site (SRS)

For seismic analysis and design of U.S. Department of Energy (DOE) high-hazard nuclear facilities, the System for Analysis of Soil-Structure Interaction (SASSI) computer code has been used to evaluate soil-structure interaction (SSI) effects between a building and its supporting soil. Users have observed that, under certain combinations of structure complexities and soil properties, a SASSI computational methodology called the subtraction method can provide suspect results. In addition, multiple versions of the code have been acquired and modified by different entities, giving rise to questions about software control and quality assurance (Christenbury 2011; Gutierrez 2014).

In response, DOE formed an SSI team with the intent of developing a complex-wide solution to issues associated with the SASSI subtraction method. The SSI team completed an assessment in July 2011. Based on what is known about SRS structures and soils and the results of the assessment, it is not believed that any SRS facilities have the combination of the types of structures and soils that would render them susceptible to the SASSI code technical issue. The SASSI code has not been modified at SRS, and it is believed that the code has been adequately controlled and meets current site software quality assurance requirements (Christenbury 2011; Gutierrez 2014).

Responding to a letter from the Defense Nuclear Facilities Safety Board regarding SASSI (DNFSB 2011), DOE provided a report addressing questions about SASSI technical and quality assurance issues. DOE also provided a report that was issued to field organizations that provides background on the subtraction method problems, recommendations for reviewing past SASSI analyses, and advice on avoiding subtraction method errors (DOE 2011c).

In December 2011, the SASSI verification and validation (V&V) project was initiated under joint sponsorship of the DOE Chief of Nuclear Safety (CNS) and the National Nuclear Security Administration. The first phase of the project is to demonstrate the validity of SASSI results for selected facilities and associated geologic properties. The second phase is to develop more extensive V&V test problems and solutions that apply to facilities across the DOE complex and would lead to the development of a guidance document for performing soil-structure interaction analyses (DOE 2013e).

The analyses considered synergistic effects and determined that the only significant source of such effects would be a seismic event (i.e., a design-basis seismic event or a seismically induced total collapse). The synergy would be due to the common-cause initiator (i.e., seismic ground motion). This was accounted for by summing population doses and LCFs for alternatives in which facilities would be located at the same site. Doses to the MEI were not summed because an individual would only receive a summed dose if the MEI were located along the line connecting the release points from two facilities and the wind were blowing along the same line at the time of the accident. The likelihood of this happening is very small.

For each of these accident categories, a conservative preliminary assessment of consequence was made and, where consequences were significant, one or more bounding accident scenarios were postulated. The building confinement and fire-suppression systems would be adequate to reduce the risks of most spills and minor fires. The systems would be designed to prevent, to the extent practicable, larger fires and explosions. Great efforts have always been made to prevent nuclear criticalities, which have the potential to kill workers in their immediate vicinity. In all cases, implementation of a Criticality Safety Program and standard practices are expected to keep the frequency of accidental nuclear criticalities as low as possible.

The proposed surplus plutonium disposition facilities are expected to meet or exceed the requirements of DOE Order 420.1B or 420.1C (as applicable), *Facility Safety* (DOE 2005b, 2012e), or the requirements of 10 CFR Part 70, *Domestic Licensing of Special Nuclear Material*, if the proposed facility is licensed by NRC. Because DOE and, if applicable, NRC design criteria require that new plutonium-processing buildings be of very robust, reinforced-concrete construction, very few events outside the building would have sufficient energy to threaten the building confinement. The principal concern would be the crash of a large commercial or military aircraft into the facility. Such an event, however, is highly unlikely. Only those crashes with a frequency greater than 1×10^{-7} per year are addressed in the *SPD EIS* and this *SPD Supplemental EIS*.

Although this background discussion concerns DOE facilities which are not subject to NRC licensing, NRC has similar requirements for NRC-licensed facilities, such as the MFFF. The analyses used in this appendix for the purposes of this *SPD Supplemental EIS* may differ in some respects from the analyses used to support license or license amendment applications submitted to the NRC in compliance with NRC licensing requirements.

Design-basis and beyond-design-basis natural-phenomenon-initiated accidents are also considered. Because of the robust nature of the construction of new plutonium facilities, the only design-basis natural-phenomenon-initiated accidents with the potential to affect the facility interior are seismic events. Similarly, seismic events also bound the consequences and risks posed by beyond-design-basis natural phenomena.

The suite of generic accidents in the *Storage and Disposition of Weapons-Usable Fissile Materials Final Programmatic Environmental Impact Statement* (*Storage and Disposition PEIS*) (DOE 1996) was considered in the analysis of accidents for the *SPD EIS*. However, the more-detailed design information in the surplus plutonium disposition data reports was the primary basis for the identification of accidents because it most accurately represents the expected facility configuration. The fire on the loading dock and the oxyacetylene explosion in a process cell were unsupported by this information, so they were not included in the *SPD EIS*.

Since publication of the *SPD EIS*, a number of the facilities that are evaluated in this *SPD Supplemental EIS* have had DSAs prepared. The purposes of the DSAs under the current DOE practices are well defined, but differ in fundamental ways from some of the past DOE safety analysis practices.

A central focus of the DSA process is to demonstrate that sufficient safety controls have been put in place, as opposed to quantifying an absolute value of risk. In general, DSAs do not attempt to establish best estimates of the probabilities or consequences of potential accidents. Consistent with their purpose, source terms and other assumptions used for bounding DSA frequency and consequence estimates are conservative. In other words, the DSA process accounts for the inherent uncertainties associated with quantifying risk by requiring that conservative assumptions are made to ensure that the final safety control set is comprehensive and adequate. In reality, the actual risk of the scenarios may be much lower than portrayed in DSAs.

This situation presents a challenge for the selection of accidents for this *SPD Supplemental EIS* and reporting their likelihood and consequences, because the goal of the accident analysis in this *SPD Supplemental EIS* is to present consistent estimates of accident risks between facilities so that fair comparisons can be made among alternatives. If, for example, the accident risks between facilities or alternatives are based on differing levels of conservatism, balanced comparisons are not possible. For the *SPD Supplemental EIS*, attempts were made to ensure consistent assumptions across facilities and sites such that whatever differences do exist in the analyses presented herein are not important.

The design-basis accidents descriptions and source terms that were reported in recent facility DSAs were based on unmitigated design-basis accidents. Each of the facilities has been designed and would be operated to reduce the likelihood of these accidents to the extent practicable. Design features and operating practices would also limit the extent of any accidents and mitigate the consequences for the workers, public, and environment if they occurred. As with all facilities, it is expected that the safety controls would be sufficient such that the likelihood of any of these accidents occurring would be "extremely unlikely," and if the accidents occurred, the likelihood of consequences of the magnitude reported in the draft DSA and this *SPD Supplemental EIS* are probably "beyond extremely unlikely" and, therefore, are not credible.

Accident frequencies are generally grouped into the bins of "anticipated," "unlikely," "extremely unlikely," and "beyond extremely unlikely," with estimated frequencies of greater than 1×10^{-2}, 1×10^{-2} to 1×10^{-4}, 1×10^{-4} to 1×10^{-6}, and less than 1×10^{-6} per year, respectively. The accidents evaluated represent a spectrum of accident frequencies and consequences ranging from low-frequency/high-consequence to high-frequency/low-consequence events. However, given the preliminary nature of some of the designs under consideration, it was not possible to quantitatively assess the frequency of occurrence of all the events addressed. The evaluation does not indicate the total risk of operating the facility, but does provide information on high-risk events that could be used to develop an accident risk ranking of the various alternatives.

D.1.3.3 Identification of Material at Risk

For each accident scenario, the MAR—generally plutonium—was identified. Plutonium has a wide range of chemical and isotopic forms. The sources of plutonium vary among the various candidate facilities and, for specific facilities, among various alternatives. The vulnerability of material generally depends on the form of that material, the degree and robustness of containment, and the energetics of the potential accident scenario (DOE 1999). For example, plutonium stored in strong, tight storage containers is not generally vulnerable to simple drops or spills, but may be vulnerable in a total collapse earthquake scenario. The isotopic composition of the MAR will vary, depending on the feed source. The assumed isotopic compositions used in the *SPD EIS* have been updated for this *SPD Supplemental EIS*, now that more-recent information is available on the potential feeds. For the K-Area facilities, including the immobilization capability, a worst-case composition for a DOE-STD-3013-2012 (DOE 2012a) container (also called a 3013 container or 3013 can) was assumed that is about 88 percent plutonium-239, 0.04 percent plutonium-238, and 6.25 percent americium-241 by weight (DOE/NNSA 2012). For HB-Line and H-Canyon, the same types of materials were assumed to be processed, so the same composition was used. For the Waste Solidification Building (WSB), the bounding composition from the *Waste Solidification Building Preliminary Documented Safety Analysis* (*WSB DSA*) (WSRC 2009) was used. For all others, compositions used in the *SPD EIS* (DOE 1999) were used.

At some of the facilities, highly enriched uranium (HEU) is also present. For these analyses, the weight fraction for uranium-234, uranium-235, uranium-236, and uranium-238 were assumed to be 0.01, 0.931, 0.005, and 0.054 (DOE/NNSA 2012). For the accidents considered in this *SPD Supplemental EIS*, the contribution to dose from HEU releases are negligible when released in conjunction with plutonium.

Tritium (hydrogen-3, a radioactive isotope of hydrogen) could also be present in some of these facilities. It would typically be stored on a “getter” bed that requires electrical heating to drive off the tritium. For these accident analyses, the tritium is assumed to be released as tritiated water vapor, which is more biologically important than tritium gas.

<u>Plutonium-239 dose equivalents:</u> For some facilities, the exact quantities for MAR, including plutonium, HEU, and tritium, as well as the isotopic composition of some forms of plutonium, are sensitive from a security perspective. The exact quantities and locations are typically classified for security reasons. Many safety analyses have adopted the strategy of using a convenient surrogate, plutonium-239 dose equivalents, for the actual quantities, forms, and isotopic composition of the materials. With this approach, the masses or activities of certain quantities of material, such as weapons-grade plutonium (or a mixture of various types of plutonium, HEU, and tritium), can be expressed in terms of the amount of plutonium-239 that would result in the same radiological dose upon inhalation.

For plutonium isotopes, the relative inhalation hazard is similar for plutonium-238, -239, -240, and -242. Plutonium-241 is less hazardous. Plutonium decays with time and americium-241 builds up. The relative inhalation hazard of americium-241 is higher than that of plutonium-239. As a result, the relative hazard of plutonium (and americium-241) materials is highly dependent on the composition of the plutonium isotopes, and more importantly, on the amount of americium-241 in the mixture. For example, the dose from inhalation of 1 gram of weapons-grade plutonium, such as the mixture assumed for the Pit Disassembly and Conversion Facility (PDCF) in F-Area (92.35 percent plutonium-239 and 1 percent americium-241), would have the same dose as inhalation of 2.086 grams (0.0736 ounces) of plutonium-239 (DOE/NNSA 2012). For K-Area Material Storage Area (MSA)/K-Area Interim Surveillance (KIS)-type plutonium (87.8 percent plutonium-239 and 6.25 percent americium-241), the effect of the much higher americium-241 is large, and inhalation of 1 gram (0.0353 ounces) of KIS plutonium would have the same dose as inhalation of 6.475 grams (0.228 ounces) of plutonium-239 (DOE/NNSA 2012). Quantities of other materials, such as HEU and tritium, can also be expressed in terms of plutonium-239 dose equivalents. For example, the dose from inhalation of 1 gram (0.0353 ounces) of HEU (of a particular enrichment) would have the same dose as inhalation of 0.000446 grams (1.57×10^{-5} ounces) of plutonium-239, and the inhalation (including skin adsorption) of 1 gram (0.0353 ounces) of tritium as tritiated water vapor would have the same dose as inhalation of 0.0486 grams (0.0017 ounces) of plutonium-239 (DOE/NNSA 2012).

Hazardous chemicals: On an industrial scale, the quantities of hazardous chemicals are generally small. The occupational risks are generally limited to material handling and are managed under a required Industrial Hygiene Program. While some facilities, such as H-Canyon, have larger tanks of materials such as nitric acid, these quantities are still small relative to quantities at most industrial facilities and only represent a local worker hazard. No substantial hazardous chemical releases are expected.

D.1.3.4 Identification of Material Potentially Released to the Environment

The amount and particle size distribution of material aerosolized in an accident generally depends on the form of that material, the degree and robustness of containment, and the energetics of the potential accident scenario. Once the material is aerosolized, it must still travel through building confinement and filtration systems or bypass the systems before being released to the environment.

A standard DOE formula was used to estimate the source term for each accident at each of the proposed surplus plutonium facilities:

$$\text{Source Term} = \text{MAR} \times \text{DR} \times \text{ARF} \times \text{RF} \times \text{LPF}$$

where:

MAR = material at risk (curies or grams)
DR = damage ratio
ARF = airborne release fraction
RF = respirable fraction[2]
LPF = leak path factor

The MAR is the amount of radionuclides (in curies of radioactivity or grams of each radionuclide) available for release when acted upon by a given physical stress or accident. The MAR is specific to a given process in the facility of interest. It is not necessarily the total quantity of material present; rather, it is that amount of material in the scenario of interest postulated to be available for release.

The damage ratio (DR) is the fraction of MAR exposed to the effects of the energy, force, or stress generated by the postulated event. For the accident scenarios discussed in this analysis, the value of the DR varies depending on the details of the accident scenario, but can range up to 1.0.

The airborne release fraction (ARF) is the fraction of material that becomes airborne due to the accident. The respirable fraction (RF) is the fraction of the material with a particulate aerodynamic diameter less than or equal to 10 microns (0.0004 inches) that could be retained in the respiratory system following inhalation. The value of each of these factors depends on the details of the specific accident scenario postulated. ARFs and RFs were estimated according to reference material in *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* (DOE 1994).

The leak path factor (LPF) accounts for the action of removal mechanisms (e.g., containment systems, filtration, and deposition) to reduce the amount of airborne radioactivity ultimately released to occupied spaces in the facility or the environment.

No accident scenarios were identified that would result in a substantial release of plutonium or other radionuclides via liquid pathways.

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[2] *Respirable fractions are not applied in the assessment of doses based on noninhalation pathways, such as criticality.*

D.1.4 Evaluation of Accident Consequences

D.1.4.1 Potential Receptors

For each potential accident, information is provided on accident consequences and frequencies for three types of receptors: (1) a noninvolved worker, (2) the maximally exposed member of the public, and (3) the offsite population. The first receptor, a noninvolved worker, is a hypothetical individual working on site, but not involved in the proposed activity. Consistent with the *SPD EIS*, the noninvolved worker at SRS was assumed to be downwind at a point 1,000 meters (3,280 feet) from the accident. Such a person outside of the area was assumed to be unaware of the accident, and so the emergency actions needed for protection, and to remain in the plume for the entire passage. Workers within the area would be trained to respond to an emergency and are expected to take proper actions to limit their exposure to a radioactive plume. If they failed to take proper actions, they could receive higher doses. For the accidents addressed in this *SPD Supplemental EIS*, accidental releases would be through medium-to-tall stacks for all design-basis accidents. Maximum doses within the area where the plume first touches down could be 1.4 to 2.9 times higher than the doses at 1,000 meters (3,280 feet). At LANL, because of differences in the geography of the area, the noninvolved worker was conservatively assumed to be exposed to the full release, without any protection, at the technical area boundaries, and within a distance of about 220 meters (about 720 feet) of Technical Area 55 (TA-55).

The second receptor, a maximally exposed member of the public, is a hypothetical individual assumed to be at a location along the site boundary where he or she would receive the largest dose. Exposures received by this individual are intended to represent the highest doses to a member of the public. The third receptor, the offsite population, comprises all members of the public within 50 miles (80 kilometers) of the accident location.

Consequences for workers directly involved in the processes under consideration are addressed generically, without attempt at a scenario-specific quantification of consequences. The uncertainties involved in quantifying accident consequences become overwhelming for most radiological accidents due to the high sensitivity of dose values to assumptions about the details of the release and the location and behavior of the affected worker. Consequences for potential receptors as a result of plume passage were determined without regard for emergency response measures and, thus, are more conservative than would be expected if evacuation, sheltering, or other measures to reduce or prevent impacts to the public were explicitly modeled. Instead, it was assumed that potential receptors would be fully exposed in fixed positions for the duration of plume passage, thereby maximizing their exposure to the plume. As discussed in Section D.1.4.2, a conservative estimate of total consequences was obtained by assuming that all released radionuclides contributed to the inhalation dose as opposed to removal of some of them from the plume by surface deposition; surface deposition is a less significant contributor to overall risk and is controllable through interdiction.

D.1.4.2 Modeling of Dispersion of Releases to the Environment

The MACCS2 computer code (version 1.13.1) was used to estimate the consequences of accidents for the proposed facilities. A detailed description of the MACCS2 model is available in NRC documents NUREG/CR-4691 (NRC 1990) and NUREG/CR-6613 (NRC 1998). Originally developed to model the radiological consequences of nuclear reactor accidents, this code has been used for the analysis of accidents in many EISs and other safety documentation and is considered applicable to the analysis of accidents associated with the disposition of plutonium.

MACCS2 models the offsite consequences of an accident that releases a plume of radioactive materials into the atmosphere; specifically, the degree of dispersion versus distance as a function of historical wind direction, speed, and atmospheric conditions. Were such an accidental release to occur, the radioactive gases and aerosols in the plume would be transported by the prevailing wind and dispersed in the atmosphere, and the population would be exposed to radiation. MACCS2 generates the distribution of downwind doses at specified distances, as well as the distribution of population doses out to 50 miles (80 kilometers).

For tritium releases, the tritium (as tritiated water vapor) inhalation dose conversion factor used in this *SPD Supplemental EIS* is 50 percent greater than the Federal Guidance Report 11 (EPA 1988) inhalation dose conversion factor used in MACCS2. This change incorporates the recommendation in the DOE MACCS2 guidance to account for the dose due to absorption of tritiated water vapor through the skin (DOE 2004a).

For other isotopes, the standard MACCS2 dose library was used. This library is based on Federal Guidance Report 11 (EPA 1988) inhalation dose conversion factors. For exposure to plutonium oxides and metal, the dominant pathway for exposure is inhalation of very small, respirable particles. Unlike tritiated water vapor, absorption through the skin is not a significant pathway for plutonium dose. For accidents involving release of plutonium, more-recent dose conversion factors, based on Federal Guidance Report 13 (EPA 1999), would result in estimated doses of about 15 to 43 percent of the values reported in this *SPD Supplemental EIS*, depending on the assumed form of the plutonium inhaled. Overall, the values reported in this *SPD Supplemental EIS* are both conservative and internally consistent. The uncertainties in the estimated source terms far outweigh the differences in the modeling and dose conversion factor models used in this *SPD Supplemental EIS*.

As implemented in this *SPD Supplemental EIS* for accidents at DOE facilities, the MACCS2 model evaluates doses due to inhalation of aerosols such as respirable plutonium, as well as exposure to the passing plume. This represents the major portion of the dose that a noninvolved worker or member of the public would receive as a result of a plutonium disposition facility accident. The longer-term effects of plutonium deposited on the ground and surface waters after the accident, including through resuspension and inhalation of plutonium and ingestion of contaminated crops, were not modeled for accidents involving DOE facilities in this *SPD Supplemental EIS*. These pathways have been studied and found not to contribute as significantly to dosage as inhalation, and they are controllable through interdiction. Instead, the deposition velocity of the radioactive material was set to zero, so that material that might otherwise be deposited on surfaces remains airborne and available for inhalation. This adds conservatism to inhalation doses that can become considerable at large distances (as much as two orders of magnitude of conservatism at the 50-mile [80-kilometer] limit). Thus, the method used in this *SPD Supplemental EIS* is conservative compared with the dose results that would be obtained if deposition and resuspension were taken into account.

Longer-term effects of fission products released during a nuclear criticality accident have been extensively studied. The principal concern is ingestion of iodine-131 via milk that becomes contaminated due to the ingestion of contaminated feed by milk cows. This pathway can be controlled and, in terms of the effects of an accidental criticality, doses from this pathway would be small.

The region around the facility is divided by a polar-coordinate grid centered on the facility itself. The user specifies the number of radial divisions and their endpoint distances. The angular divisions used to define the spatial grid correspond to the 16 directions of the compass.

Dose distributions were calculated in a probabilistic manner. Releases during each of the 8,760 hours of the year were simulated, resulting in a distribution of dose reflecting variations in weather conditions at the time of the postulated accidental release. The code outputs the conditional probability of exceeding an individual or population dose as a function of distance. The mean consequences are analyzed in this *SPD Supplemental EIS*.

Radiological consequences may vary somewhat as a result of variations in the duration of release. For longer releases, there is a greater chance of plume meander (i.e., variations in wind direction over the duration of release). MACCS2 models plume meander by increasing the lateral dispersion coefficient of the plume for longer release durations, thus lowering the dose. For perspective, doses from a homogenous 1-hour release would be 30 percent lower than those of a 10-minute release as a result of plume meander; doses from a 2-hour release would be 46 percent lower. The other effect of longer release durations is involvement of a greater variety of meteorological conditions in a given release, which reduces the variance of the resulting dose distributions. This would tend to lower high-percentile doses, raise low-percentile doses, and have no effect on the mean dose.

For this *SPD Supplemental EIS* accident analysis, a duration of 10 minutes was assumed for all SRS facility accident releases. This is consistent with the accident phenomenology expected for all scenarios, with the possible exception of fire. Depending on the circumstances, the time between fire ignition and extinction may be considerably longer, particularly for the larger beyond-design-basis fires. However, even in a fire of long duration, it is possible to release substantial fractions of the total radiological source term in fairly short periods as the fire consumes areas of high MAR concentrations. The assumption of a 10-minute release duration for fire is intended to generically account for this circumstance.

The approaches for dispersion and consequence analyses for the LANL site were similar to those used for the SRS site. The approaches and evaluation for the LANL accidents also follow the methods used in the recent *Final Supplemental Environmental Impact Statement for the Nuclear Facility Portion of the Chemistry and Metallurgy Research Building Replacement Project at Los Alamos National Laboratory, Los Alamos, New Mexico* (DOE 2011a) and the earlier *Final Site-Wide Environmental Impact Statement for Continued Operation of Los Alamos National Laboratory, Los Alamos, New Mexico (LANL SWEIS)*, DOE/EIS-0380 (DOE 2008b).

D.1.4.3 Modeling of Consequences of Releases to the Environment

The probability coefficients for determining the likelihood of fatal cancer, given a dose, are taken from the *1990 Recommendations of the International Commission on Radiological Protection* (ICRP 1991) and DOE guidance (DOE 2004b). For low doses or low dose rates, probability coefficients of 6.0×10^{-4} fatal cancers per rem and person-rem are applied for workers and the general public (DOE 2003). For cases where the individual dose would be equal to or greater than 20 rem, the LCF risk was doubled (NCRP 1993). Additional information about radiation and its effects on humans is provided in Appendix C.

D.1.5 Accident Scenarios for Surplus Plutonium Disposition Facilities

Bounding design-basis and beyond-design-basis accident scenarios have been developed from accident scenarios presented in the *SPD EIS*, previous NEPA analyses, data call responses from SRS and LANL, and current safety analyses for the facilities (DOE 1999; SRNS 2010, 2011a, 2011b, 2012a, 2012b; WSRC 2006, 2007a, 2007b, 2007c, 2007d, 2007e, 2007f, 2007g, 2008, 2009). These scenarios are discussed in detail in these documents, along with specific assumptions for each facility and site.

D.1.5.1 Accident Scenario Consistency

In preparing the accident analysis for this *SPD Supplemental EIS*, the primary objective was to ensure consistency between the data reports so that the results of the analyses for the proposed surplus plutonium disposition alternatives could be compared. In spite of efforts by all parties, some inconsistencies exist between the data reports. This does not imply technical inaccuracy in any analysis; it merely reflects the uncertainties and reliance on conventions that are generally inherent in accident analyses. To provide a consistent analytical basis, information in the data reports was modified or augmented as described in this section.

Aircraft crash. It was decided early in the process of developing accident scenarios for the original *SPD EIS* that aircraft crash scenarios would not be provided in the data reports, but would be developed, as appropriate, directly for the *SPD EIS*. This practice was continued for this *SPD Supplemental EIS*.

Frequencies of an aircraft crash into each facility evaluated in this *SPD Supplemental EIS* under each alternative were taken from individual facility safety basis documents. These frequency estimates were developed in accordance with the *Accident Analysis for Aircraft Crash into Hazardous Facilities* (DOE 2006b). Facility-specific safety analyses indicate that the frequency of crashes involving aircraft capable of penetrating the subject facility (assumed to be all aircraft except those in general aviation) would generally be below 1.0 × 10^{-7} per year for all facilities.

Of the variety of impact conditions accounted for in the above frequency values (e.g., impact angle, direction, lateral distance from building center, and speed), only a fraction would have the potential to produce consequences comparable to those reported in the *SPD EIS*, while other impacts (grazing impacts and impacts on office areas) would not result in significant radiological impacts.

For facilities for which an SAR or DSA was available, that information was used to determine whether an aircraft crash coupled with a release of material was credible. In most cases, the building would provide sufficient structural strength and shielding such that a release of radioactive material would not be likely.

Criticality. The source term for this criticality is based on a fission yield of 1.0 × 10^{19} fissions, which was used for all facilities. The source term was based on that given in DOE Handbook 3010-94 (DOE 1994). The estimated frequency of "extremely unlikely" (i.e., 1 × 10^{-6} to 1 × 10^{-4} per year) was also used because it is the bounding estimate.

Design-basis earthquake. Safety analyses for each facility present an analysis of a design-basis earthquake.

All the existing facilities that were considered in the *SPD EIS* have had seismic evaluations demonstrating that they meet the seismic evaluation requirements for a design-basis earthquake.

Beyond-design-basis earthquake. All of the proposed operations would be in either existing or new facilities that are expected to meet or exceed the applicable requirements of DOE Order 420.1B or 420.1C (as applicable), (DOE 2005b, 2012e) and DOE-STD-1020, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities* (DOE 2002a, 2012f), as applicable, for reducing the risks associated with natural phenomenon hazards. The proposed facilities would be characterized as Performance Category 3 (PC-3) facilities.[3] Such facilities would have to be designed or evaluated for a design-basis earthquake with a mean annual exceedance probability of 4 × 10^{-4}, corresponding to a return period of 2,500 years.

The numerical seismic design requirements detailed in DOE-STD-1020 are structured such that there is assurance that specific performance goals would be met. For PC-3 plutonium facilities, the performance goal is to ensure occupant safety, continued operation, and hazard confinement for earthquakes with an annual probability exceeding approximately 1 × 10^{-4}. There is sufficient conservatism in the design of the buildings and the structures, systems, and components that are important to safety that this goal should be met, given that they are designed to withstand earthquakes with an estimated mean annual probability of 4 × 10^{-4}.

By contrast, nonnuclear structures at these sites and the surrounding community would be constructed to the regional standards of the *Uniform Building Code* at the time of construction. These peak acceleration values are 50 to 82 percent of the peak acceleration design requirements for plutonium facilities in the same area and correspond approximately to DOE PC-1 facilities with 500-year return intervals. During major earthquakes, structures built to these *Uniform Building Code* requirements are expected to suffer significantly more damage than reinforced-concrete structures designed for plutonium operations. At sites far from tectonic plate boundaries, deterministic techniques such as those used by NRC in evaluating safe-shutdown earthquakes for the siting of nuclear reactors have also been used to determine the maximum seismic ground motion requirements for facility designs. These techniques involve estimating the ground acceleration at the proposed facility by either assuming the largest historical earthquake within

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[3] *Each structure, system, and component in a DOE facility is assigned to one of five performance categories, depending on its safety importance. PC-3 structures, systems, and components are those for which failure to perform their safety function could pose a potential hazard to public health, safety, and the environment from release of radioactive or toxic materials. Design considerations for this category are to limit facility damage as a result of design-basis natural phenomena events (for example, an earthquake) so that hazardous materials can be controlled and confined, occupants are protected, and the functioning of the facility is not interrupted (DOE 2002a).*

the tectonic province or by assessing the maximum earthquake potential of the appropriate tectonic structure or capable fault closest to the facility. For NRC-licensed reactors, this technique resulted in safe-shutdown earthquakes with estimated return periods in the 1,000- to 100,000-year range (DOE 2002a).

The magnitude of potential earthquakes with return periods greater than 10,000 years is highly uncertain. For purposes of the *SPD EIS,* it was assumed that, at all the candidate sites, earthquakes with return periods in the 100,000- to 10-million-year range might result in sufficient ground motion to cause major damage to even a modern, well-engineered, and well-constructed plutonium facility. Therefore, in the absence of convincing evidence otherwise, a total collapse of the plutonium facilities was assumed to be scientifically credible and within the rule of reason for return intervals in this range.

The frequency of all beyond-design-basis earthquakes for all facilities is reported in the *SPD EIS* as "extremely unlikely to beyond extremely unlikely" (the PDCF data report estimated a frequency of less than 1×10^{-6} per year). They are reported as such because the uncertainties inherent in associating damage levels with earthquake frequencies become overwhelming below frequencies of about 1.0×10^{-5} per year.

Filtration efficiency. In the *SPD EIS,* the exhaust from most facilities, including the MFFF, PDCF, and the immobilization facilities, was assumed to be directed through two stages of testable HEPA filters to a stack. A building LPF of 1.0×10^{-5} was used for particulate releases with HEPA filters unless otherwise noted (DOE 1999). Several of the existing facilities and some of the proposed facilities would use a stand-alone sand filter as the primary filter system for exhaust that leaves the main process area building. In most cases, exhaust air from a glovebox or process room would first be filtered by one or more sets of testable HEPA filters that would be designated Safety Significant or Safety Class and expected to continue functioning during and after design-basis accidents. The more recent *Plutonium Vitrification Facility Consolidated Hazard Analysis (U)* (WSRC 2007a) indicates that the heating, ventilating, and air conditioning (HVAC) exhaust would go through a duct to the sand filter and a new stack.

For facilities with sand filters, the recent SRS safety analyses have only taken credit for the sand filter with its stated efficiency of 99.51 percent (or a penetration factor of 4.9×10^{-3}). For facilities with sand filters as the final safety system, this *SPD Supplemental EIS* follows SRS practice and only takes credit for that filter for design-basis accidents unless otherwise noted. In most cases, multiple HEPA filters within the building would likely provide significant filtration of particulates released during an accident before they were transported through the exhaust system to the sand filter and stack.

For the hypothetical Beyond-Design-Basis Earthquake and Fire, a consistent LPF was assumed across the facilities evaluated. In the *SPD EIS*, the beyond-design-basis earthquake accidents are hypothetical, are not based on detailed analysis, and are postulated simply to show a bounding level of impacts should the safety design and operational controls fail. For NEPA purposes, the goal is to show the impacts of realistic, physically possible events even if it is believed their probability is extremely low.

For comparison purposes, it is postulated that:

- The hypothetical beyond-design-basis accident is assumed to be an earthquake that exceeds the design-basis earthquake (PC-3) by a sufficient margin that gloveboxes fail, fire suppression systems fail, power fails, and some building confinement is lost. It is further assumed that a room-wide fire or multiple local fires might occur. The overall probability of the event, considering the conditional probabilities of fires following a beyond-design-basis earthquake, is expected to be in the 1×10^{-6} to 1×10^{-7} per year range.
- For new facilities and significantly upgraded facilities, it is assumed that they would be designed to fail gracefully. A building LPF of 0.1 is assumed and expected to be conservative. This factor should adequately represent an LPF for cracks in the building or transport through rubble.
- For older, existing facilities that have not been or are not planned to be upgraded, it is not generally known how they might fail in a beyond-design-basis earthquake but an LPF of 1 is considered

unrealistic because even a rubble pile in a total building collapse offers some impediment to particulates being released to the environment. Therefore, this *SPD Supplemental EIS* assumes an LPF of 0.25 for these facilities even though the LPF could be several times lower than this.

- For all facilities, an LPF of 1.0 was assumed for tritium or gaseous releases.

D.1.5.2 Facility Accident Scenarios

D.1.5.2.1 Existing K-Area Material Storage Area/K-Area Interim Surveillance

The K-Area MSA and KIS area have materials and activities that are common to several of the facilities and, hence potential accidents that have some common characteristics. Each of the facilities handles containers of plutonium metal or oxide that protect the materials inside from a wide range of accidents.

K-Area MSA. The K-Area MSA is an area inside the decommissioned K-Area reactor building that was modified to store surplus plutonium. The K-Area MSA is within a robust structure and is designated a Hazard Category 2 Nuclear Facility. The area used for the K-Area MSA primarily consists of reinforced-concrete walls with solid concrete floor slabs. Plutonium is stored in the K-Area MSA in DOE-STD-3013-2012 or other approved containers nested inside DOE-certified Type B shipping packages. This robust packaging configuration serves as confinement against possible release of contamination. Within the K-Area MSA, the 3013 cans or other approved containers are required to remain in approved shipping containers at all times and, therefore, are not vulnerable to routine accidents. For example, a 9975 Type B shipping package consists of a stainless steel outer drum assembly, Celotex^{TM} insulation, lead shielding, a secondary containment vessel, and a primary containment vessel. Plutonium metal or oxide is stabilized and packaged according to DOE-STD-3013-2012. Type B shipping packages are designed to withstand fires with temperatures as high as 1,475 degrees Fahrenheit (°F) (800 degrees Celsius [°C]) for 30 minutes, as well as a wide spectrum of very severe transportation accidents. The environmental impacts of potential accidents associated with the K-Area MSA operations were discussed previously in the *Supplement Analysis for Storage of Surplus Plutonium Materials in the K-Area Material Storage Facility at the Savannah River Site* (DOE 2002b), as well as the *Supplement Analysis, Storage of Surplus Plutonium Materials at the Savannah River Site* (DOE 2007), and were found to be very small due to the robust packaging.

The *K-Area Complex Documented Safety Analysis* (*K-Area DSA*) (SRNS 2012b) evaluates the storage of surplus plutonium, as well as other materials, in the existing K-Area reactor building. A range of potential hazards and accidents was evaluated in the *K-Area DSA*. That evaluation indicates that, because all of the plutonium is stored in 3013 cans that are then stored in Type B shipping packages, none of the design-basis accidents would release plutonium from the confinement of the 3013 cans and the Type B shipping packages. The combination of the 3013 cans and the Type B shipping packages provides sufficient protection from a range of fires, explosions, overpressurizations, external events, and natural phenomenon-initiated events, such that any event that would potentially result in a release was designated “beyond extremely unlikely” and was not evaluated in detail. As a result, the K-Area MSA is not required to have criticality accident alarms or a building confinement system.

None of the credible accidents identified, including all of the design-basis accidents, threatened the integrity of the packages. The *K-Area DSA* (SRNS 2012b) did identify potential releases from a hypothetical, bounding, beyond-design-basis earthquake followed by a fire in the K-Area MSA. The likelihood of a beyond-design-basis earthquake that could collapse the K-Area Complex and release radioactive material from the drums stored in the MSA is estimated to be 5×10^{-7} per year or less (SRNS 2012b). The likelihood of subsequent fires of sufficient magnitude and duration to threaten 3013 containers within the shipping containers makes the likelihood of this accident even lower. The hypothetical event postulates collapse of the Actuator Tower through the roof of the building onto a storage array of Type B shipping packages. Debris from the collapse was assumed to crush the shipping packages, or some sharp object could penetrate them. The *K-Area DSA* assumed that as many as 190 shipping package drums could be damaged in this beyond-design-basis earthquake, with about

45 experiencing a direct release of plutonium due to the heavy impact of debris on the drum, and about 23 releasing plutonium material under high pressure when a secondary fire, caused by the earthquake, ignites Celotex™ in each drum and creates a severe localized fire. The worst-case release would be from impact stress on the shipping package, which could be modeled as a high-pressure (277.6 pounds per square inch) venting of plutonium oxide, and could release as much as 58 grams (2.0 ounces) of oxide per drum (SRNS 2012b). The releases due to secondary fires was modeled as a very high-pressure (1000 pounds per square inch) venting of plutonium oxide with a potential release of 142 grams (5 ounces) per drum. The total release from 45 drums experiencing high pressure releases due to direct impacts and 23 drums experiencing very high pressure releases due to subsequent fires would be 5,880 grams (207 ounces) [58 grams per drum × 45 drums + 142 grams per drum × 23 drums] (SRNS 2012b). This is a hypothetical, bounding scenario and more realistic assumptions would result in much lower releases.

The probability of an event of this magnitude with this large a release is extremely small, as it requires the initiating event, a significantly beyond-design-basis earthquake, to cause the collapse; a collapse at the right location, a collapse onto 190 shipping containers designed to withstand very severe transportation accidents; a crash onto shipping containers containing oxide instead of metal; and damage and pressurized release from containers. This scenario/release combination is not considered credible for analysis purposes in this *SPD Supplemental EIS*.

KIS. KIS became operational in 2007 and provides interim capability for nondestructive and destructive examination of plutonium materials. Nondestructive capabilities include weight verification, visual inspections, digital radiography, and prompt gamma analysis; destructive capabilities include can puncturing for headspace gas sampling and can cutting for oxide sampling. Repackaging capabilities are available at other facilities for safe storage of the material pending its eventual disposition. The K-Area Complex was modified to add equipment and tools to unload and reload DOE-STD-3013-2012 containers from DOE-certified Type B shipping packages; weigh and perform examinations of containers and shipping packages; and perform assays.

Potential accidents at KIS. The environmental impacts of potential accidents associated with KIS operations were discussed in the *Environmental Assessment for the Safeguards and Security Upgrades for Storage of Plutonium Materials at the Savannah River Site* (DOE 2005a), as well as the *Supplement Analysis, Storage of Surplus Plutonium Materials at the Savannah River Site* (DOE 2007), and were found to be very small due to the robust packaging and limited operations.

The environmental impacts of KIS operations have been evaluated in detail for KIS and the previously planned Container Surveillance and Storage Capability. These operations would be conducted in a glovebox and would involve one 3013 container at a time. Thus, the MAR for most operational accidents would be one container.

The *Environmental Assessment for the Safeguards and Security Upgrades for Storage of Plutonium Materials at the Savannah River Site* (DOE 2005a) states: "Implementing the surveillance program would require the loading and unloading of 9975 shipping packages, visual examination of a 3013 container, and the opening of 3013 containers. Opening the 3013 containers would be performed inside of a credited glovebox, which would protect the worker from exposure to the plutonium bearing materials. Although the processing of the plutonium introduces the possibility of different accidents, such as criticality, the scenario most likely to generate a significant release is still the design-basis fire. Safety features to prevent or mitigate this, and other credible accidents, include building design, engineered fire-suppression and detection systems, filtered ventilation systems, and procedural controls to preclude mishandling of the material." This environmental assessment also states: "As the authorization basis documentation for the proposed activity is in preliminary form, consequence analysis for the bounding event is estimated based on the mitigated release of five maximally loaded plutonium containers. The estimated mitigated dose to a maximally exposed individual at the Site boundary associated with a pressurized release of five plutonium containers is less than 1,000 millirem."

The consequences of radiological accidents in KIS and similar operations in the Container Surveillance and Storage Capability have subsequently been evaluated. The Washington Safety Management Solutions engineering calculation S-CLC-K-00208, from *The Consequences of Releases from Potential Accidents in the 105-K Slug Vault* (WSMS 2006), evaluates a range of potential accidents involving KIS operations, including fires involving transuranic (TRU) waste containers and pressurized releases from a single 3013 container containing less than 4.5 kilograms (9.9 pounds) of plutonium or 5.0 kilograms (11 pounds) of plutonium oxide with worst-case isotopic composition. This calculation was used for the accident analyses reported in the *KIS DSA Addendum* (WSRC 2006) to the *K-Area DSA* (SRNS 2012b). The *KIS DSA Addendum* (WSRC 2006) technical safety requirement mandates that at least one stage of HEPA filters should be functioning during design-basis accidents, with an efficiency of at least 99.5 percent, or a building LPF of 0.005.

Analysis of the 3013 container surveillance operations for KIS identified the following broad categories of accidents: design-basis fire, design-basis explosion, design-basis loss of containment/confinement, design-basis nuclear criticality, design-basis external hazard, and design-basis natural phenomena. Based on the *KIS DSA Addendum* (WSRC 2006) results of credible, mitigated accidents, several accidents were selected for presentation in this *SPD Supplemental EIS* to represent the bounding credible design-basis and beyond-design-basis accidents. Basic characteristics of each of these postulated accidents are described in this section. Additional discussion of scenario development based on consistency concerns was presented earlier in this appendix.

Fires. The bounding mitigated fire event is a postulated occurrence fire in the KIS vault that causes both a collapse of the KIS vault and pressurized release of 7 kilograms (15 pounds) of plutonium oxide at 1,000 pounds per square inch gauge (psig). The Fire Protection Program, fire-suppression system, fire doors, and structural design should limit any fire and prevent the fire from heating 3013 containers to the point that a pressurized release would occur. For a pressure of 1,000 psig, the expected ARF × RF is 0.0284, which corresponds to approximately 175 grams (6.2 ounces), and was indicated as released to the building exhaust system, where the building HEPA filters would reduce the amount released to the stack. A building LPF of 5.0×10^{-3} was assumed for one stage of HEPA filters. Therefore, the mitigated release to the environment through the stack would be approximately 0.88 grams (0.031 ounces) of plutonium. A release of this magnitude would fall into the "extremely unlikely to beyond extremely unlikely" category.

Explosions. The bounding mitigated explosion event is a postulated deflagration or detonation in the glovebox that occurs just as a 3013 container is being punctured for sampling purposes. The *KIS DSA Addendum* (WSRC 2006) indicates that the internal pressure should be within the 3013 container design rupture limit of 700 psig unless subjected to an external fire. For a pressure of 700 psig, the expected ARF × RF is 0.022, which corresponds to approximately 99 grams (3.5 ounces) from a drum containing 4,500 grams (160 ounces) of plutonium that is released to the building exhaust system, where the building HEPA filters would reduce the amount released to the stack. A building LPF of 5.0×10^{-3} was assumed for one stage of HEPA filters. Therefore, the mitigated release to the environment through the stack would be approximately 0.50 grams (0.018 ounces) of plutonium. A release of this magnitude would fall in the "extremely unlikely to beyond extremely unlikely" category.

Design-basis earthquake. The bounding design-basis earthquake was postulated to collapse the KIS vault and cause a fire that results in a pressurized release of 7 kilograms (15 pounds) of plutonium oxide to the room. Without a fire, no release is expected. Large, seismically induced fires that could start in the KIS vault or propagate into the KIS vault (PC-3, 3-hour-fire-rated barrier) from other areas are unlikely, even assuming an earthquake. A building LPF of 5.0×10^{-3} was assumed for one stage of HEPA filters. Therefore, the mitigated release to the environment through the stack would be approximately 0.031 grams (0.0011 ounces) of plutonium (WSRC 2006). A release of this magnitude would fall in the "unlikely" category, with the estimated return interval for a design-basis earthquake of 2,500 years. Realistically, the conditional probability of a fire with sufficient magnitude and duration to cause a release would make this scenario even less likely.

Beyond-design-basis fire. A beyond-design-basis fire has been postulated in the K-Area Complex that would involve an unmitigated transuranic waste drum fire on the loading dock that burns with sufficient intensity and duration that all of the material in the drum is consumed. The expected ARF × RF is 0.0005, which corresponds to approximately 0.2 grams (0.007 ounces) of plutonium from a drum containing 450 grams (16 ounces) of plutonium oxide. Because this fire is postulated to occur outside the building a LPF of 1 was assumed. This accident was conservatively estimated to have a total frequency of 1×10^{-6} per year or lower.

Beyond-design-basis earthquake with fire. The bounding seismic event is a postulated seismic event that causes a fire in the KIS vault that burns with sufficient intensity and duration that a very high (1,000 psig) pressurized release of 7 kilograms (15 pounds) of plutonium oxide occurs. This accident is expected to result in much-higher releases than any credible accident. Consistent with the general assumptions for beyond-design-basis accident LPFs presented in Section D.1.5.1 for an older existing facility, a building LPF of 0.25 was assumed, although a more realistic value is likely to be at least a factor of several lower. The safety documents also consider a large, seismically induced fire that could start in the KIS vault or propagate into the KIS vault (PC-3, 3-hour-fire-rated barrier) from other areas. This accident was conservatively estimated to have a total frequency of 7.2×10^{-7} per year or lower (WSRC 2006) and, hence, was not analyzed in the safety documents.

Table D–1 presents the postulated bounding accident scenarios. The unmitigated accidents were developed to determine the type of safety controls needed to prevent the accidents from happening and to reduce the potential consequences if the safety prevention systems failed. The postulated unmitigated accidents assumed bounding material inventories and bounding release mechanisms, with no credit taken for mitigation features such as building structure and filtration systems. With safety controls in place, the consequences of these bounding accidents would be substantially reduced by the building filtration systems, which would be designed to mitigate these accidents. Based on an LPF of 5.0×10^{-3} for a single HEPA filter, a stack release would reduce the quantities released to the environment with the exception of the beyond-design-basis accidents discussed above.

Table D–1 Accident Scenarios and Source Terms for the K-Area Material Storage Area/ K-Area Interim Surveillance Capability

Accident	*Frequency (per year)*	*MAR (grams)*	*DR*	*ARF×RF*	*LPF*	*Release (grams)*
Criticality	Not credible	–	–	–	–	–
Fire in KIS vault with 3013 can rupture at 1,000 psig	1×10^{-5} to 1×10^{-7} (extremely unlikely to beyond extremely unlikely)	6,173 Pu (7,000 PuO_2)	1	0.0284	0.005	0.88 Pu 5.7 PuE
Explosion (deflagration of 3013 can during puncturing; can assumed to be at 700 psig)	1×10^{-5} to 1×10^{-7} (extremely unlikely to beyond extremely unlikely)	4,500 Pu (5,000 PuO_2)	1	0.022	0.005	0.50 Pu 3.2 PuE
Design-basis earthquake	0.0004 (unlikely)	6,173 Pu (7,000 PuO_2)	1	0.001	0.005	0.031 Pu 0.20 PuE
Beyond-design-basis fire (unmitigated transuranic waste drum fire)	$< 1 \times 10^{-6}$ (beyond extremely unlikely)	396 Pu (450 PuO_2)	1	0.0005	1	0.20 Pu 1.3 PuE
Beyond-design-basis earthquake with fire (bounded by unmitigated pressurized 3013 can rupture due to an external fire and vault release [1,000 psig])	$< 1 \times 10^{-6}$ (beyond extremely unlikely)	6,173 Pu (7,000 PuO_2)	1	0.0284	0.25	44 Pu 280 PuE

ARF = airborne release fraction; DR = damage ratio; KIS = K-Area Interim Surveillance; LPF = leak path factor; MAR = material at risk; psig = pounds per square inch gauge; Pu = plutonium; PuE = plutonium-239 dose equivalent; PuO_2 = plutonium dioxide; RF = respirable fraction.

Note: To convert grams to ounces, multiply by 0.035274.

Source: SRNS 2012b; WSMS 2006; WSRC 2006.

Although both pit and non-pit plutonium could be handled in support of surplus plutonium disposition activities in K-Area, all of the plutonium involved is assumed to be non-pit plutonium. This is consistent with the safety analyses for these facilities and bounds the potential impacts of accidents. This material is assumed to have an americium-241 content of 6.25 percent. The relative inhalation hazard of this material is 6.47 times higher than plutonium-239 and about 3.1 times more hazardous than weapons-grade plutonium. The plutonium-239 dose equivalents for each source term are also included in Table D–1.

D.1.5.2.2 Pit Disassembly and Conversion Facility at F-Area

A wide range of potential accident scenarios was considered for PDCF. These scenarios are considered in detail in the *SPD EIS* (DOE 1999), as well as the ongoing safety analysis process as the facility is being designed, and are summarized for purposes of this *SPD Supplemental EIS* in the *NEPA Source Document for Pit Disassembly and Conversion Project (PDC NEPA Source Document)* (DOE/NNSA 2012). Under all of the alternatives being considered in this *SPD Supplemental EIS*, PDCF could process pits and other plutonium metal (see Appendix B, Section B.1.1.1). PDCF would be designed and built to withstand design-basis natural phenomenon hazards such as earthquakes, winds, tornadoes, and floods, such that no unfiltered releases are expected.

Analysis of the proposed process operations for PDCF identified the following broad categories of accidents: design-basis fire, design-basis explosion, design-basis loss of containment/confinement, design-basis nuclear criticality, design-basis external hazard, and design-basis natural phenomenon. Based on the review of the safety documents of credible, mitigated accidents, several accidents were selected for presentation in this *SPD Supplemental EIS* to represent the bounding credible design-basis and beyond-design-basis accidents. Basic characteristics of each of these postulated accidents are described in this section. Additional discussion of scenario development based on consistency concerns was presented earlier in this appendix.

Aircraft crash. A crash of a large, heavy commercial or military aircraft directly into a reinforced-concrete facility could damage the structure sufficiently to breach confinement and disperse material into the environment. A subsequent fuel-fed fire could provide energy to further damage structures and equipment, aerosolize material, and drive materials into the environment. Source terms are highly speculative, but could exceed those from the beyond-design-basis earthquake. The frequency of such a crash is below 1×10^{-7} per year and was not evaluated.

Criticality. This accident was identified as "unlikely" (with a frequency greater than or equal to 10^{-4} and less than 10^{-2}) without preventive controls. The scenario represents a metal criticality. The metal was postulated to soften, resulting in a 100 percent release of fission products generated in the criticality. However, no aerosolized, respirable metal fragments were predicted to be released. Engineered and administrative controls should be available to ensure that the double-contingency principles[4] are in place for all portions of the process. It was assumed that human error results in multiple failures, leading to an inadvertent nuclear criticality. The estimated frequency of this accident is in the range of 1×10^{-4} to 1×10^{-6} per year ("extremely unlikely"). A bounding source term resulting from 1×10^{19} fissions was assumed.

Explosion. The bounding radiological explosion is bounded by the postulated overpressurization of multiple oxide storage cans due to out-of-specification oxide product, as discussed below.

Fires. The safety analyses evaluated a range of fire scenarios, including glovebox fires, process fires, room fires, maintenance-related fires, dock fires, and fires associated with material transfer. The controls included in the facility design are expected to prevent or reduce the frequency of fires and to limit their severity. In most cases, when the planned controls are considered, the fire events identified in the hazards analysis have negligible risk.

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[4] *DOE criticality standards require that process designs incorporate sufficient factors of safety to require at least two unlikely, independent, and concurrent changes in process conditions before a criticality accident is possible. This is known as the double-contingency principle.*

Several fire scenarios were considered in more detail. The *PDC NEPA Source Document* (DOE/NNSA 2012) indicates that a fire in the product nondestructive assay module could release 3.4 grams (0.12 ounces) of plutonium-239 dose equivalents from the stack. A direct metal oxidation glovebox fire could release 2.4 grams (0.085 ounces) of plutonium-239 dose equivalents from the stack. A multi-room fire could release 15 grams (0.53 ounces) of plutonium-239 dose equivalents from the stack. This bounding fire event is marginally in the "extremely unlikely" frequency bin and approaches the "beyond extremely unlikely" frequency bin when planned controls are considered.

Leaks or spills of nuclear material. The safety analyses evaluate a range of loss of containment or confinement scenarios, including those due to loss of cooling, excessive moisture, helium atmosphere problems, operator error, material transfer failures, and container defects. Several types of events could potentially lead to overpressurization of containers and rupture. Other events might involve operator mishandling events that result in dropping or impacting containers. The rigorous controls imposed on containers should prevent or mitigate most of these types of events. The bounding loss of containment event involves the overpressurization of six 3013 cans due to out-of-specification oxide products that are outside of a glovebox confinement/ventilation (DOE/NNSA 2012). This accident assumes that moisture significantly in excess of specifications remains in the cans and the radioactive heating of the water overpressurizes the container to the point of rupture. For this accident, 30 kilograms (66 pounds) of plutonium oxide were assumed to be MAR and a DR of 1.0 was assumed. The ARF for a high-pressure burst associated with a 3013 can was estimated at 0.108, with an RF of 0.7. Thus, about 2.3 kilograms (5.1 pounds) of oxide would be released to the room. The release to the environment would be limited by the Safety Class processing building confinement structure and the HVAC confinement ventilation system. The release would be filtered by the sand filter and released through the stack. A bounding release of 9.8 grams (0.35 ounces) of plutonium, or 20 grams (0.71 ounces) of plutonium-239-dose-equivalent material, was postulated. This accident's frequency is categorized as "extremely unlikely to beyond extremely unlikely" because out-of-specification cans of oxide should not be present at PDCF and tests have demonstrated that the 3013 cans to be used at PDCF significantly exceed the performance requirements of DOE-STD-3013-2012 (DOE 2012a).

Tornado. The *PDC NEPA Source Document* (DOE/NNSA 2012) considers a tornado-initiated accident that results in a tornado-generated missile impacting two Type B shipping packages of plutonium oxide. This scenario would result in a release of 0.37 grams (0.013 ounces) of plutonium-239-dose-equivalent material to the environment. This event is considered "extremely unlikely." The risks from this event are bounded by the seismically induced fire, so it was not evaluated further.

Design-basis earthquake with fire. The *PDC NEPA Source Document* (DOE/NNSA 2012) also postulates a limited seismically induced fire in the Plutonium Processing Building, resulting in the release of all MAR inventory in the affected processing rooms. The fire was postulated to occur in the direct metal oxidation and canning areas. As specified in DOE-STD-1020 (DOE 2002a, 2012f), the mean probability of exceedance of a PC-3 design-basis earthquake is 1 in 2,500 years (4.0×10^{-4} per year). Furthermore, the conditional probability of a large, wide-scale full-facility fire threatening most of the material in a facility being induced by the design-basis earthquake was estimated as 8.67×10^{-3} in the fire risk analysis. The initiating frequency for a seismically induced facility fire is the product of these two frequencies, or 3.5×10^{-6} per year ($8.67 \times 10^{-3} \times 4.0 \times 10^{-4}$), resulting in the categorization of a seismically induced fire as an "extremely unlikely" event. Considering the conditional probability of a fire spreading beyond the direct metal oxidation and canning segments of the central processing area, the fire risk analysis concludes that a larger fire involving additional MAR is an "extremely unlikely to beyond extremely unlikely" event. This event was estimated to result in release of plutonium and tritium through the sand filter and stack, with the dose equivalent to 7.7 grams (0.27 ounces) of plutonium-239.

Beyond-design-basis earthquake with fire. The postulated beyond-design-basis earthquake was assumed to be of sufficient magnitude to initiate a facility-wide fire. This accident was postulated to result in loss of the PDCF fire-suppression system, as well as other controls, and to result in pressurizing the process building and releasing radioactive materials through the sand filter and the building confinement structure. As with the design-basis earthquake scenario, seismically induced glovebox failure was assumed to occur. Consistent with the general assumptions for beyond-design-basis accident LPFs presented in Section D.1.5.1 for a new facility, a LPF of 0.1 was assumed for the plutonium materials and 1 for tritium. These assumptions lead to the release of about 650 grams (23 ounces) of plutonium-239-dose-equivalent materials to the environment during the beyond-design-basis earthquake with fire. The estimated frequency of this accident is in the range of 1×10^{-5} to 1×10^{-7} per year or lower (“extremely unlikely to beyond extremely unlikely”).

Accident scenarios and source terms assumed for PDCF under all of the alternatives are presented in **Table D–2**.

Table D–2 Accident Scenarios and Source Terms for the Pit Disassembly and Conversion Facility at F-Area

Accident	*Frequency (per year)*	*MAR (grams)*	*DR*	*ARF*	*RF*	*LPF*	*Release (grams)*
Criticality	1×10^{-4} to 1×10^{-6} (extremely unlikely)	–	–	–	–	–	1×10^{19} fissions
Product NDA room fire	1×10^{-4} to 1×10^{-6} (extremely unlikely)	3.3×10^{5} PuE	Varies	0.108	0.7	0.0049	3.4 PuE
Multi-room fire	1×10^{-4} to 1×10^{-6} (extremely unlikely)	2.6×10^{5} PuE	Varies	Varies	Varies	0.0049 (particulates) 1 (tritium)	15 PuE
Fire in direct metal oxidation glovebox	1×10^{-4} to 1×10^{-6} (extremely unlikely)	39,000 PuE	Varies	Varies	Varies	0.0049 (particulates) 1 (tritium)	2.4 PuE
Overpressurization of oxide storage cans	1×10^{-4} to 1×10^{-6} (extremely unlikely)	30,000 Pu oxide 55,000 PuE	1	0.108	0.7	0.0049	20 PuE
Design-basis earthquake with fire (limited)	1×10^{-5} to 1×10^{-7} (extremely unlikely to beyond extremely unlikely)	2.8×10^{5} PuE	Varies	Varies	Varies	0.0049 (particulates) 1 (tritium)	7.7 PuE
Beyond-design-basis earthquake with fire	1×10^{-5} to 1×10^{-7} (extremely unlikely to beyond extremely unlikely)	1.6×10^{6} PuE	1	Varies	Varies	0.1 (particulates) 1 (tritium)	650 PuE

ARF = airborne release fraction; DR = damage ratio; LPF = leak path factor; MAR = material at risk; NDA = nondestructive assay; Pu = plutonium; PuE = plutonium-239 dose equivalent; RF = respirable fraction.
Note: To convert grams to ounces, multiply by 0.035274.
Source: DOE/NNSA 2012.

D.1.5.2.3 Pit Disassembly and Conversion Capability at K-Area

Under the mixed oxide (MOX) Fuel, H-Canyon/HB-Line to the Defense Waste Processing Facility (DWPF), and Waste Isolation Pilot Plant (WIPP) Alternatives, the K-Area Pit Disassembly and Conversion Project (PDC) could process pits and other plutonium metal (see Appendix B, Section B.1.2.2). PDC is at an early state of safety analysis. Potential accidents associated with PDC are expected to be similar to those identified for PDCF in Section D.1.5.2.2.

An early evaluation of potential accidents for PDC was developed based on facility-specific safety analyses, and representative accidents were selected for inclusion in this *SPD Supplemental EIS* (DOE/NNSA 2012). A wide range of potential accident scenarios was considered for PDC (DOE/NNSA 2012). The analyses assumed that the K-Area PDC would be designed and built to withstand design-basis natural phenomenon hazards such as earthquakes, winds, tornadoes, and floods, such that no unfiltered releases are expected.

Aircraft crash. A crash of a large, heavy commercial or military aircraft directly into a reinforced-concrete facility could damage the structure sufficiently to breach confinement and disperse material into the environment. A subsequent fuel-fed fire could provide energy to further damage structures and equipment, aerosolize material, and drive materials into the environment. Source terms are highly speculative, but could exceed those of the beyond-design-basis earthquake. The frequency of such a crash is below 1×10^{-7} per year and was not evaluated.

Criticality. This accident was identified as "unlikely" (with a frequency in the range of 1×10^{-2} to 1×10^{-4} per year) when unmitigated. The scenario represents a metal criticality. The metal was postulated to soften, resulting in a 100 percent release of fission products generated in the criticality. However, no aerosolized respirable metal fragments were predicted to be released. Engineered and administrative controls should be available to ensure that the double-contingency principles are in place for all portions of the process. It was assumed that human error results in multiple failures, leading to an inadvertent nuclear criticality. With the engineered and administrative controls, the estimated frequency of this accident is in the range of 1×10^{-4} to 1×10^{-6} per year ("extremely unlikely"). A bounding source term resulting from 1×10^{19} fissions was assumed.

Explosion. The bounding radiological explosion is bounded by the postulated overpressurization of multiple oxide storage cans due to out-of-specification oxide product, as discussed below.

Fires. The safety analyses evaluate a range of fire scenarios, including glovebox fires, process fires, room fires, maintenance-related fires, dock fires, and fires associated with material transfer. The controls included in the facility design are expected to prevent or reduce the frequency of fires and limit their severity. In most cases, when the planned controls are considered, the fire events identified in the hazards analysis have negligible risk.

Several fire scenarios were considered in more detail. The *PDC NEPA Source Document* (DOE/NNSA 2012) indicates that a fire in the product nondestructive assay module could release material with the plutonium-239 dose equivalent of 2.1 grams (0.074 ounces) if it involved pit plutonium from the stack. A multi-room fire could release 5.3 grams (0.19 ounces) of plutonium-239-dose-equivalent materials from the 150-foot (45.7-meter) stack. This bounding fire event is marginally in the "extremely unlikely" frequency bin and approaches the "beyond extremely unlikely" frequency bin when planned controls are considered.

In addition, a scenario involving fire in a direct metal oxidation glovebox was developed for this *SPD Supplemental EIS* (DOE/NNSA 2012). This scenario is a glovebox fire involving bounding quantities of plutonium oxide and tritium in the direct metal oxidation glovebox at risk. In this accident, a safety-class fire-suppression system would detect and extinguish an incipient fire, and no significant release is expected. A building LPF of 3.0×10^{-3} was assumed for the HEPA filter. Therefore, the mitigated release to the environment through the stack would be approximately 2.0 grams (0.071 ounces) of plutonium-239-dose-equivalent materials. For analysis purposes, this accident was assumed to fall in the "extremely unlikely" category; however, more realistically, a release of this magnitude would fall into the "extremely unlikely to beyond extremely unlikely" category.

Leaks or spills of nuclear material. The safety analyses evaluate a range of loss of containment or confinement scenarios, including those due to loss of cooling, excessive moisture, helium atmosphere problems, operator error, material transfer failures, and container defects. Several types of events could potentially lead to overpressurization of containers and rupture. Other events might involve operator mishandling events that result in dropping or impacting containers. The rigorous controls imposed on containers should prevent or mitigate most of these types of events. Fires were found to bound any leak or spill accident scenarios (DOE/NNSA 2012).

The bounding loss of containment event involves the overpressurization of six 3013 cans due to out-of-specification oxide products that are outside of glovebox confinement/ventilation (DOE/NNSA 2012). This accident assumes that moisture significantly in excess of specifications remains in the cans and the radioactive heating of the water overpressurizes the container to the point of rupture. For this accident, 30 kilograms (66 pounds) of plutonium oxide were assumed to be MAR, and a DR of 1.0 was assumed. The ARF for a high-pressure burst associated with a 3013 can was estimated at 0.108, with an RF of 0.7. Thus, about 2.3 kilograms (5.1 pounds) of oxide would be released to the room. The release to the environment would be limited by the Safety Class processing building confinement structure and the HVAC confinement ventilation system. The release would be filtered by the HEPA filter and released through the stack. A bounding release of 12 grams (0.42 ounces) of plutonium-239-dose-equivalent material was postulated. This accident's frequency is categorized as "extremely unlikely to beyond extremely unlikely" because out-of-specification cans of oxide should not be present at PDC and tests have demonstrated that the 3013 cans to be used at PDC significantly exceed the performance requirements of DOE-STD-3013-2012 (DOE 2012a).

Design-basis earthquake with fire. The *PDC NEPA Source Document* (DOE/NNSA 2012) also postulates a limited seismically induced fire resulting in the release of all MAR inventory in the affected processing rooms. The fire was postulated to involve the stabilization and packaging, canning, pit disassembly, and special recovery line areas. This event is categorized as an "extremely unlikely" event. Considering the conditional probability of a fire spreading beyond the direct metal oxidation and canning segments of the central processing area, it is reasonable to conclude that a larger fire involving additional MAR is an "extremely unlikely to beyond extremely unlikely" event. This event was estimated to release plutonium and tritium through the HEPA filters and stack, with the dose equivalent to 6.5 grams (0.23 ounces) of plutonium-239.

Tornado. The *PDC NEPA Source Document* (DOE/NNSA 2012) identifies a tornado-generated missile impacting two Type B shipping packages of plutonium oxide. This scenario would result in a release of 0.50 grams (0.018 ounces) of plutonium-239-dose-equivalent material to the environment. This event is considered "extremely unlikely." The risks from this event are bounded by the seismically induced fire, so it was not evaluated further.

Beyond-design-basis earthquake with fire. The postulated beyond-design-basis earthquake was assumed to be of sufficient magnitude to initiate a facility-wide fire. This accident was postulated to result in loss of the PDC fire-suppression system, as well as other controls, and to result in pressurizing the process building and releasing radioactive materials through pathways that bypass the HEPA filter and the building confinement structure. Similar to the design-basis earthquake scenario, seismically induced glovebox failure was assumed to occur. Consistent with the general assumptions for beyond-design-basis accident LPFs presented in Section D.1.5.1 for an existing facility that is significantly upgraded, a LPF of 0.1 was assumed for the plutonium materials and 1 for tritium. Based on these assumptions, materials equivalent to about 690 grams (24 ounces) of plutonium-239 would be released to the environment by the beyond-design-basis earthquake with fire. The estimated frequency of this accident is in the range of 1×10^{-5} to 1×10^{-7} per year or lower ("extremely unlikely to beyond extremely unlikely").

Accident scenarios and source terms for the PDC are presented in **Table D–3**.

Table D–3 Accident Scenarios and Source Terms for the Pit Disassembly and Conversion Project at K-Area

Accident	***Frequency (per year)***	***MAR (grams)***	***DR***	***ARF***	***RF***	***LPF***	***Release (grams)***
Criticality	1×10^{-4} to 1×10^{-6} (extremely unlikely)	–	–	–	–	–	1×10^{19} fissions
Product NDA room fire	1×10^{-4} to 1×10^{-6} (extremely unlikely)	310,000 PuE	Varies	0.108	0.7	0.003	2.1 PuE
Multi-room fire	1×10^{-4} to 1×10^{-6} (extremely unlikely)	260,000 PuE	Varies	Varies	Varies	0.003 (particulates) 1 (tritium)	5.3 PuE
Fire in direct metal oxidation glovebox	1×10^{-4} to 1×10^{-6} (extremely unlikely)	64,000 PuE	Varies	Varies	Varies	0.003 (particulates) 1 (tritium)	2.0 PuE
Overpressurization of oxide storage cans	1×10^{-4} to 1×10^{-6} (extremely unlikely)	30,000 Pu oxide 55,000 PuE	1	0.108	0.7	0.003	12 PuE
Design-basis earthquake with fire	1×10^{-4} to 1×10^{-6} (extremely unlikely)	4.1×10^{5} PuE	Varies	Varies	Varies	0.003 (particulates) 1 (tritium)	6.5 PuE
Beyond-design-basis earthquake with fire	1×10^{-5} to 1×10^{-7} (extremely unlikely to beyond extremely unlikely)	2.2×10^{6} PuE	Varies	Varies	Varies	0.1 (particulates) 1 tritium	690 PuE

ARF = airborne release fraction; DR = damage ratio; LPF = leak path factor; MAR = material at risk; NDA = nondestructive assay; Pu = plutonium; PuE = plutonium-239 dose equivalent; RF = respirable fraction.
Note: To convert grams to ounces, multiply by 0.035274.
Source: DOE/NNSA 2012.

D.1.5.2.4 Pit Disassembly Capability in a K-Area Complex Glovebox

Under the Immobilization to WIPP, MOX Fuel, H-Canyon/HB-Line to DWPF, and WIPP Alternatives, pits could be disassembled, resized, and packaged in a K-Area Complex glovebox, with subsequent plutonium processing at H-Canyon/HB-Line (see Appendix B, Section B.1.2.5).

At this early stage of planning, it is assumed that the disassembly operations would occur either in the existing KIS glovebox or a similar existing or new glovebox in the K-Area Complex and that existing infrastructure and building confinement would be used. It is further assumed that the pits to be disassembled could be mechanically disassembled within a K-Area glovebox and that none of the disassembled components would contain tritium. It is also assumed that the disassembled pieces would be placed in transfer containers similar to those proposed for interim lag storage of similar components in PDC and then shipped to H-Area in accordance with SRS procedures. It is assumed that only one pit would be disassembled at a time within the glovebox. It is assumed that one or more pits would be in temporary storage awaiting disassembly, but if stored outside of a vault, they would be in an approved shipping container. As this activity is at an early stage of design, the amount of plutonium and uranium outside of the shipping container and considered MAR is expected to be a fraction of that identified in the K-Area PDC safety analyses. For analysis purposes, the material in interim storage that is at risk is assumed to be proportional to the processing rate at KIS, compared with PDC, or about 20 percent of that identified for PDC.

The accident scenarios for these limited operations would be a subset of those identified for the PDC operations in K-Area or PDCF in F-Area. As the final product from the K-Area disassembly would be metal pieces, no substantial inventory of oxide would be produced other than small amounts associated with TRU waste generated during the handling and disassembly operations. When compared with the conversion operations, there would be limited opportunities for release of materials from the glovebox other than through fires and a criticality. The following discussion identifies the potential changes and source terms associated with the limited pit disassembly operations proposed under this option.

Criticality. A criticality accident for pit disassembly operations similar to that identified for the K-Area PDC was postulated. This accident was identified as unlikely (with a frequency greater than or equal to 10^{-4} and less than 10^{-2}) when unmitigated. The scenario represents a metal criticality. The metal was postulated to soften, resulting in a 100 percent release of fission products generated in the criticality. However, no aerosolized respirable metal fragments were predicted to be released. Engineered and administrative controls should be available to ensure that the double-contingency principles are in place for all portions of the process. It was assumed that human error results in multiple failures, leading to an inadvertent nuclear criticality. The estimated frequency of this accident is in the range of 1×10^{-4} to 1×10^{-6} per year ("extremely unlikely"). A bounding source term resulting from 1×10^{19} fissions was assumed.

Explosion. No events were identified in the pit disassembly operations that would result in an explosion or release (DOE/NNSA 2012). A bounding explosion from a postulated overpressurization of multiple oxide storage cans due to out-of-specification oxide product was not considered credible for the materials under consideration.

Fires. The safety analyses evaluate a range of fire scenarios, including glovebox fires, process fires, room fires, maintenance-related fires, dock fires, and fires associated with material transfer. The controls included in the facility design are expected to prevent or reduce the frequency of fires and limit their severity. In most cases, when the planned controls are considered, the fire events identified in the hazards analysis have negligible risk.

Several fire scenarios were considered in more detail. The *PDC NEPA Source Document* (DOE/NNSA 2012) indicates that the source term associated with metal is generally a few percent of the source term associated with oxide releases. A bounding multi-room fire with a MAR of 8 kilograms (18 pounds) of metal pieces was assumed. It was conservatively assumed that 25 percent of the plutonium metal MAR is involved in a fire. No tritium was assumed to be at risk. A building LPF of 5.0×10^{-3} was assumed for a single existing HEPA filter with the existing 50-foot (15.2-meter) KIS stack. Therefore, the mitigated release to the environment from the stack would be 0.0025 grams (8.82×10^{-5} ounces) of pit plutonium, or 0.0052 grams (0.00018 ounces) of plutonium-239 dose equivalents. For analysis purposes, this accident was assumed to fall in the "extremely unlikely" category; however, more realistically, a release of this magnitude would fall into the "extremely unlikely to beyond extremely unlikely" category.

Leaks or spills of nuclear material. No events were identified in the pit disassembly operations that would result in a leak or spill release.

Design-basis earthquake with fire. The *PDC NEPA Source Document* (DOE/NNSA 2012) also postulates a limited seismically induced fire resulting in the release of all MAR inventory in the affected processing rooms. The fire was postulated to involve transfer containers containing plutonium metal pieces from the pit disassembly operations. A bounding estimate of the plutonium metal at risk is 16.4 kilograms (36.2 pounds), or 20 percent of the 82 kilograms (181 pounds) assumed to be at risk for the similar accident scenario for the K-Area PDC, although the actual MAR may be smaller with the limited disassembly operations postulated. This event is categorized as an "extremely unlikely" event. Considering the conditional probability of a fire spreading beyond the disassembly glovebox, it is reasonable to conclude that a larger fire involving additional MAR is an "extremely unlikely to beyond extremely unlikely" event. This event was estimated to release 0.0051 grams (0.000181 ounces) of plutonium, or 0.011 grams (0.00039 ounces) of plutonium-239 dose equivalents, through the HEPA filter and stack.

Tornado. The *PDC NEPA Source Document* (DOE/NNSA 2012) identifies a tornado-generated missile impacting two Type B shipping packages. With the pit disassembly operations at KIS, no substantial quantities of oxide would be generated and the releases from shipping packages with metal pieces would be negligible. The risks from this event are therefore bounded by the seismically induced fire, so it was not evaluated further.

Beyond-design-basis earthquake with fire. The postulated beyond-design-basis earthquake was assumed to be of sufficient magnitude to initiate a facility-wide fire. This accident was postulated to result in loss of the pit disassembly area fire-suppression system, as well as other controls, including building confinement. Similar to the design-basis earthquake scenario, seismically induced glovebox failure was assumed to occur. The fire was postulated to involve transfer containers containing plutonium metal pieces from the pit disassembly operations. A bounding estimate of the plutonium metal at risk is 26.8 kilograms (59.1 pounds), or 20 percent of the 134 kilograms (295 pounds) assumed to be at risk, and 32 kilograms (70.5 pounds) of HEU, or 25 percent of the HEU metal (160 kilograms or 353 pounds) in transfer containers assumed to be at risk for the similar accident scenario for the K-Area PDC, although the actual MAR may be much smaller with the limited disassembly operations postulated. Based on this release scenario, about 1.7 grams (0.060 ounces) of weapons-grade plutonium and 8.0 grams (0.282 ounces) of HEU were assumed to be released to the room for the beyond-design-basis earthquake. Consistent with the general assumptions for beyond-design-basis accident LPFs presented in Section D.1.5.1 for older existing facilities, a building LPF of 0.25 was assumed, although a more realistic value is likely to be at least a factor of several lower. A release of plutonium and HEU of this magnitude would be equivalent to releasing 0.88 grams (0.031 ounces) of plutonium-239. The estimated frequency of this accident is in the range of 1×10^{-5} to 1×10^{-7} per year or lower ("extremely unlikely to beyond extremely unlikely").

Accident scenarios and source terms for the K-Area Complex pit disassembly capability are presented in **Table D–4**.

Table D–4 Accident Scenarios and Source Terms for the Pit Disassembly Capability in a K-Area Complex Glovebox

Accident	*Frequency (per year)*	*MAR (grams)*	*DR*	*ARF*	*RF*	*LPF*	*Release (grams)*
Criticality	1×10^{-4} to 1×10^{-6} (extremely unlikely)	–	–	–	–	–	1×10^{19} fissions
Multi-room fire	1×10^{-4} to 1×10^{-6} (extremely unlikely)	8,000 WG Pu metal	0.25	0.0005	0.5	0.005	0.0025 Pu or 0.0052 PuE
Design-basis earthquake with fire (limited)	1×10^{-4} to 1×10^{-6} (extremely unlikely)	16,400 WG Pu metal	0.25	0.0005	0.5	0.005	0.0051 Pu or 0.011 PuE
Beyond-design-basis earthquake with fire	1×10^{-5} to 1×10^{-7} (extremely unlikely to beyond extremely unlikely)	26,800 WG Pu metal 32,000 HEU metal	0.25 0.25	0.0005 0.001	0.5 1	0.25 0.25	0.42 Pu, 2.0 HEU or 0.88 PuE

ARF = airborne release fraction; DR = damage ratio; HEU = highly enriched uranium; LPF = leak path factor; MAR = material at risk; Pu = plutonium; PuE = plutonium-239 dose equivalent; RF = respirable fraction; WG = weapons-grade.

Note: To convert grams to ounces, multiply by 0.035274.

Source: DOE/NNSA 2012.

D.1.5.2.5 Immobilization Capability at K-Area

Under the Immobilization to DWPF Alternative, an immobilization capability would be installed in K-Area which would convert surplus plutonium to an oxide and then immobilize the oxide within a glass matrix (see Appendix B, Section B.1.2.1). A wide range of potential accident scenarios are reflected in the immobilization facility data reports developed for the *SPD EIS* (DOE 1999) and the more recent *Plutonium Vitrification Facility Consolidated Hazard Analysis* (WSRC 2007a) and *K-Area Complex Plutonium Vitrification Nuclear Criticality Safety Design Guidance Document* (WSRC 2007b). The analyses assumed that the immobilization capability is located in a new or upgraded existing building designed to withstand design-basis natural phenomenon hazards such as earthquakes, winds, tornadoes, and floods, such that no unfiltered releases are expected. Additional discussion of scenario development based on consistency concerns can be found in Section D.1.5.1.

A DSA has not been performed for the proposed immobilization capability. The latest safety-related documents include the *Plutonium Vitrification Facility Consolidated Hazard Analysis* (WSRC 2007a), the *K-Area Complex Plutonium Vitrification Nuclear Criticality Safety Design Guidance Document* (WSRC 2007b), the *Conceptual Safety Design Report for Plutonium Vitrification Project in K-Area* (WSRC 2007c), and the *PDC NEPA Source Document* (DOE/NNSA 2012). These documents identify the basic process steps, material flows and inventories, and potential unmitigated hazards. The hazards analysis identifies the potential hazards or accidents and makes a preliminary selection of controls to reduce or eliminate these risks. If this alternative were selected, a detailed evaluation of the bounding accidents with release fractions and source terms would not be available until the DSA is performed.

This *SPD Supplemental EIS* presents a selection of bounding accidents that were identified in the *SPD EIS* for a generic immobilization facility, but with modifications to those scenarios to reflect the current proposed location and design as described in the hazards analysis. Thus, this *SPD Supplemental EIS* reflects, to the extent practicable, the immobilization capability design changes that have occurred since the *SPD EIS* was prepared in 1999. The design changes include changes in the process operations, building design, and safety controls. As a result, some of the bounding accident scenarios identified in the *SPD EIS* are no longer applicable. For example, the plutonium conversion process has changed from the "HYDOX" [hydride/oxidation] process, which required heating of the plutonium metal and hydrogen, to a metal oxidation process that does not use hydrogen and keeps the plutonium metal below the melting temperature. In addition, the current design is intended to reduce the likelihood and consequences of all of the accidents that have been identified.

In the *SPD EIS*, the exhaust from the immobilization facility was assumed to be directed through two stages of testable HEPA filters to a stack. The more recent *Plutonium Vitrification Facility Consolidated Hazard Analysis* (WSRC 2007a) indicates that the HVAC exhaust would go through a duct to the sand filter and a new stack. Thus, for the purposes of this *SPD Supplemental EIS*, the building exhaust was assumed to be filtered through a sand filter.

Analysis of the proposed process operations identified specific scenarios for the conversion process and the canister-handling portion of the process. Design-basis and beyond-design-basis earthquakes were identified for the overall facility in the *SPD EIS* (DOE 1999). Identified accidents specific to the plutonium conversion processes are similar to those identified for the metal oxidation processes in PDCF and include a criticality, an explosion in a direct metal oxidation furnace, and a direct metal oxidation furnace glovebox fire. Identified accidents in the immobilization area include a melter eruption and a melter spill. All of the scenarios identified with the canister-handling phase at DWPF were negligible compared with the conversion and immobilization scenarios.

Plutonium Conversion Operations

Criticality. Review of the possibility of accidents attributable to plutonium conversion operations indicated that the principal processes of concern include the direct metal oxidation furnace and the sorting/unpacking glovebox. Engineered and administrative controls should be available to ensure that double-contingency principles are in place for all portions of the process. It was assumed that human error could result in multiple failures leading to an inadvertent nuclear criticality. The estimated frequency of this accident is in the range of 1×10^{-4} to 1×10^{-6} per year ("extremely unlikely"). A bounding source term resulting from 1×10^{19} fissions was assumed.

Explosion in the direct metal oxidation furnace. The bounding radiological explosion for direct metal oxidation is expected to be a steam explosion due to a cooling water leak into the furnace. As with the PDCF steam explosion, cooling water was assumed to leak into the furnace and make contact with heated plutonium. The maximum MAR of 4.4 kilograms (9.7 pounds) of plutonium metal, which is the criticality safety limit within a single furnace, was assumed (WSRC 2007b). The water leak was assumed to enter the furnace at the worst possible time, when the material is near-molten. The DR was conservatively assumed to be 1.0. The initial plutonium present in the furnace was assumed to be molten metal. If the explosion event is treated as a liquid metal/steam explosion, the ARF can be conservatively assumed to be 1.0 with an RF of 0.5. The explosive energy would be sufficient to damage glovebox windows, but insufficient to threaten the building confinement or the HVAC filter system. Both the confinement structure and the HVAC confinement system would be designated as Safety Class and are expected to function as designed throughout this event. A building LPF of 4.9×10^{-3} was assumed for the sand filter. Therefore, the mitigated release to the environment through the sand filter stack would be approximately 10.8 grams (0.38 ounces) of plutonium. Because the direct metal oxidation furnace and cooling water system designs would be designated as "safety significant," and the metal temperatures normally would be far below those required to melt the plutonium. This accident is not expected to occur in the life of the plant, and the initiating event frequency is "extremely unlikely to beyond extremely unlikely."

Furnace-initiated glovebox fire (direct metal oxidation furnace). It was assumed that a fault in the direct metal oxidation furnace results in the ignition of any combustibles (e.g., bags) left inside the glovebox. The fire would be self-limiting, but could cause suspension of the radioactive material. It was also assumed that the glovebox (including the window) maintains its structural integrity, but the internal glovebox HEPA filter fails. All of the loose surface contamination within the glovebox, assumed to be 10 percent of the daily inventory of 4.5 kilograms (9.9 pounds) of plutonium in the direct metal oxidation furnace, was assumed to be involved. Based on an ARF of 6×10^{-3}, an RF of 0.01, and an LPF of 4.9×10^{-3} for the sand filter, a stack release of 1.3×10^{-4} grams (4.6×10^{-6} ounces) of plutonium was postulated. The estimated frequency of this accident is in the range of 1×10^{-4} to 1×10^{-6} per year ("extremely unlikely").

Immobilization Activities

Melter eruption. A melter eruption could result from the buildup of impurities in or addition of impurities to the glass frit or melt. Impurities range from water, which could cause a steam eruption, to chemical contaminants, which could react at elevated temperatures to produce a highly exothermic reaction (eruption or deflagration). The resulting sudden pressure increase could propel the fissile-material-bearing melt liquid into the processing glovebox structure. However, the energy release would likely be insufficient to challenge the glovebox structure. It was assumed that the entire contents of the melter, about 1.4 kilograms (3.1 pounds) of plutonium, are ejected into the glovebox. Based on an ARF of 4×10^{-4}, an RF of 1, and an LPF of 4.9×10^{-3} for the sand filter, a stack release of 2.7×10^{-3} grams (9.5×10^{-5} ounces) of plutonium was postulated. The estimated frequency of this accident is approximately 2.5×10^{-3} per year, which is in the "unlikely" range.

Melter spill. A melter spill into the glovebox could occur due to improper alignment of the product glass cans during pouring operations. The melter glovebox enclosure and the offgas exhaust ventilation system would confine radioactive material released in the spill. The glovebox structure and its associated filtered exhaust ventilation system would not be affected by this event. It was assumed that the entire contents of the melter, about 1.4 kilograms (3.1 pounds) of plutonium, are spilled into the glovebox. On the basis of an ARF of 2.4×10^{-4}, an RF of 1, and an LPF of 4.9×10^{-3} for the sand filter, a stack release of 1.7×10^{-3} grams (6.0×10^{-5} ounces) of plutonium was postulated. The estimated frequency of this accident is approximately 3×10^{-3} per year, in the "unlikely" range.

Design-basis earthquake. The principal design-basis natural phenomenon event that could release material to the environment is the design-basis earthquake. While the major safety systems, including building confinement and the building HEPA filtration system, should continue to function, the vibratory motion is expected to suspend loose plutonium powder within gloveboxes and cause some minor spills. Particulates would be picked up by the ventilation system and filtered by the HEPA filters before release from the building. Most material storage containers were assumed to be engineered to withstand design-basis earthquakes without failing. For plutonium conversion, it was assumed that, at the time of the event, the entire day's inventory (25 kilograms [55 pounds]) of plutonium is present in the form of oxide powder. For the glass immobilization portion, this includes oxide inventories from the rotary splitter, oxide grinding, blend melter, and feed storage. Although the source term is highly uncertain, an assessment of the MAR, ARF, and RF for each of the process areas indicated a potential for the release of 33 grams (1.2 ounces) of plutonium to the still-functioning building ventilation system and 1.7×10^{-1} grams (6.0×10^{-3} ounces) from the stack. The nominal frequency estimate for a design-basis earthquake affecting new DOE plutonium facilities is 4×10^{-3} per year, which is in the "unlikely" range.

Beyond-design-basis earthquake. The postulated beyond-design-basis earthquake was assumed to be of sufficient magnitude to cause total collapse of the process equipment, building walls, roof, and floors, as well as loss of the containment function of the building. The material in the building was assumed to be driven airborne by the seismic vibrations, free fall during the collapse, and impact. Material in storage containers in vault storage would be adequately protected from the scenario energetics. Consistent with the general assumptions for beyond-design-basis accident LPFs presented in Section D.1.5.1 for a significantly upgraded facility, a LPF of 0.1 was assumed for the plutonium materials with the release at ground level. Although the source term is highly uncertain, an assessment of the MAR, ARF, and RF for each of the process areas indicated a potential for the release of 17 grams (0.6 ounces) of plutonium to the facility with 1.7 grams (0.06 ounces) being released to the environment. The estimated frequency of this accident is in the range of 1×10^{-5} to 1×10^{-7} per year or lower ("extremely unlikely to beyond extremely unlikely").

Can-in-Canister Operations at the Immobilization Capability

Can-handling accident (before shipment to DWPF). A can-handling accident would involve a can containing a vitrified glass log of plutonium material. Studies supporting DWPF (DOE 1999) indicate that the source term resulting from dropping or tipping a log of vitrified waste, even without credit for the steel canister, would be negligible. The surplus plutonium immobilization technology results in a form with a durability that is comparable to that of the DWPF vitrified waste form. Consequently, no postulated can-handling event would result in a radioactive release to the environment.

Accident scenarios and source terms for the Immobilization to DWPF Alternative are presented in **Table D–5**. The immobilization capability could be used for pit or non-pit plutonium. For purposes of ensuring a conservative accident analysis, the plutonium is assumed to be non-pit plutonium. This material is assumed to have an americium-241 content of 6.25 percent. The relative inhalation hazard of this material is 6.47 times higher than plutonium-239 and about 3.1 times more hazardous than weapons-grade plutonium. The plutonium-239 dose equivalents for each source term are also included in Table D–5. If the accidents involved pit plutonium instead of non-pit plutonium, the plutonium-239-dose-equivalent MAR, doses, and risks would be about a factor of 3.1 lower.

Table D–5 Accident Scenarios and Source Terms for the Immobilization Capability Under the Immobilization to DWPF Alternative

Accident	*Frequency (per year)*	*MAR (grams)*	*DR*	*ARF*	*RF*	*LPF* [a]	*Release (grams)*
Criticality	1×10^{-4} to 1×10^{-6} (extremely unlikely)	–	–	–	–	–	1×10^{19} fissions
Explosion in the direct metal oxidation furnace	1×10^{-5} to 1×10^{-7} (extremely unlikely to beyond extremely unlikely)	4,400 Pu	1	1	0.5	0.0049	10.8 Pu 70 PuE
Glovebox fire (direct metal oxidation furnace)	1×10^{-4} to 1×10^{-6} (extremely unlikely)	450 Pu	1	0.006	0.01	0.0049	0.00013 Pu 0.00084 PuE
Melter eruption	0.0025 (unlikely)	1,400 Pu	1	0.0004	1	0.0049	0.0027 Pu 0.018 PuE
Melter spill	0.003 (unlikely)	1,400 Pu	1	0.00024	1	0.0049	0.0016 Pu 0.011 PuE
Design-basis earthquake	0.0004 (unlikely)	Varies	Varies	Varies	Varies	0.0049	0.17 Pu 1.1 PuE
Beyond-design-basis earthquake	1×10^{-5} to 1×10^{-7} (extremely unlikely to beyond extremely unlikely)	Varies	Varies	Varies	Varies	0.1	1.7 Pu 11 PuE (ground level)

ARF = airborne release fraction; DR = damage ratio; DWPF = Defense Waste Processing Facility; LPF = leak path factor; MAR = material at risk; Pu = plutonium; PuE = plutonium-239 dose equivalent; RF = respirable fraction.
Note: To convert grams to ounces, multiply by 0.035274.
Source: DOE 1999.

D.1.5.2.6 Mixed Oxide Fuel Fabrication Facility

Under all of the alternatives considered in this *SPD Supplemental EIS*, the MFFF being constructed in F-Area would take feed material from the various facilities that may be involved with pit disassembly and conversion and use this material to produce MOX fuel for use in commercial light water reactors (see Appendix B, Section B.1.1.2). A wide range of potential accident scenarios was considered in the analysis reflected in the *SPD EIS* (DOE 1999) and supporting analyses, including the *Environmental Impact Statement on the Construction and Operation of a Proposed Mixed Oxide Fuel Fabrication Facility at the Savannah River Site, South Carolina (MFFF EIS)* (NRC 2005). The MFFF is located in a new building designed to withstand design-basis natural phenomenon hazards such as earthquakes, winds, tornadoes, and floods, such that no unfiltered releases are expected. That facility is under construction, must be licensed by the NRC, and must meet all NRC safety requirements.

Analysis of the proposed process operations for MFFF identified the following broad categories of accidents: aircraft crash, criticality, design-basis earthquake, beyond-design-basis earthquake, explosion in sintering furnace, fire, and beyond-design-basis fire. Basic characteristics of each of these postulated accidents are described in this section. Additional discussion of scenario development based on consistency concerns can be found in Section D.1.5.1.

Aircraft crash. A crash of a large, heavy commercial or military aircraft directly into a reinforced-concrete facility could damage the structure sufficiently to breach confinement and disperse material into the environment. A subsequent fuel-fed fire could provide energy to further damage structures and equipment, aerosolize material, and drive materials into the environment. Source terms are highly speculative, but could exceed those of the beyond-design-basis earthquake. The frequency of such a crash is below 1×10^{-7} per year ("beyond extremely unlikely") and was not evaluated.

Criticality. Review of the possibility of accidents at MFFF indicated no undue criticality risk associated with the proposed operations. Engineered and administrative controls would be available to ensure that double-contingency principles are in place for all portions of the process. It was assumed that human error could result in multiple failures, leading to an inadvertent nuclear criticality. The estimated frequency of this accident is in the range of 1×10^{-4} to 1×10^{-6} per year ("extremely unlikely"). A bounding source term resulting from 1×10^{19} fissions in solution was assumed.

Explosion in sintering furnace. The several furnaces proposed for the MOX fuel fabrication process all use nonexplosive mixtures of 5 percent hydrogen and 95 percent argon. Given the physical controls on the piping for nonexplosive and explosive gas mixtures, operating procedures, and other engineered safety controls, accidental use of an explosive gas is "extremely unlikely," though not impossible. A bounding explosion or deflagration was postulated to occur in one of the two sintering furnaces in MFFF. Multiple equipment failures and operator errors would be required to lead to a buildup of hydrogen and an inflow of oxygen into the inert furnace atmosphere. As much as 5.6 kilograms (12.3 pounds) of plutonium in the form of MOX powder would be at risk, and a bounding ARF of 0.01 and RF of 1.0 were assumed. Based on an LPF of 1.0×10^{-5} for two HEPA filters, a stack release of 5.6×10^{-4} grams (2.0×10^{-5} ounces) of plutonium (in the form of MOX powder) was postulated. It was estimated that the frequency of this accident is in the range of 1×10^{-4} to 1×10^{-6} per year ("extremely unlikely").

Fire. It was assumed that the liquid organic solvent containing the maximum plutonium concentration leaks as a spray into the glovebox, builds to a flammable concentration, and is contacted by an ignition source. The combined ARF and RF value for this scenario is 1.0×10^{-2} for quiescent burning to self-extinguishment. Based on an LPF of 1.0×10^{-5} for two HEPA filters, a stack release of 4.0×10^{-6} grams (1.41×10^{-7} ounces) of plutonium was postulated. The frequency of this accident is in the "unlikely" range (1×10^{-2} to 1×10^{-4} per year).

Spill. Leakage of liquids from process equipment must be considered as an anticipated event. However, with multiple containment barriers, a release from the process room would be "extremely unlikely" (1×10^{-4} to 1×10^{-6} per year). A bounding scenario involves a liquid spill of concentrated aqueous plutonium solution, with 13.2 gallons (50 liters) accumulating before the leak is stopped. The ARF and RF values used for this scenario are 2.0×10^{-4} and 0.5, respectively. Based on an LPF of 1.0×10^{-5} for two HEPA filters, a stack release of 5.0×10^{-6} grams (1.76×10^{-7} ounces) of plutonium was postulated.

Design-basis earthquake. The principal design-basis natural phenomenon event that could release material to the environment is the design-basis earthquake. While the major safety systems, including building confinement and the building HEPA filtration system, should continue to function, the vibratory motion is expected to resuspend loose plutonium powder within gloveboxes and cause some minor spills. Particulates would be picked up by the ventilation system and filtered by the HEPA filters before release from the building. Material storage containers, including cans, hoppers, and bulk storage vessels, were assumed to be engineered to withstand design-basis earthquakes without failing. Although the source term is highly uncertain, an assessment of the MAR, ARF, and RF for each of the process areas indicated a potential for the release of 7.9 grams (0.28 ounces) of plutonium (in the form of MOX powder) to the still-functioning building ventilation system and 7.9×10^{-5} grams (2.8×10^{-6} ounces) from the stack. The nominal frequency estimate for a design-basis earthquake for new DOE plutonium facilities is 4×10^{-4} per year, which is in the "unlikely" range.

Beyond-design-basis fire. MFFF would be built and operated such that there would be insufficient combustible materials to support a large fire. To bound the possible consequences of a major fire, a large quantity of combustible materials was assumed to be introduced into the process area near the blending area, which contains a fairly large amount of plutonium. A major fire was assumed to occur that causes the building ventilation and filtration systems to fail, possibly due to clogged HEPA filters. A total of 11 kilograms (24 pounds) of plutonium in the form of MOX powder was assumed to be at risk. Based on an ARF of 6×10^{-3}, an RF of 0.01, and an LPF of 0.1 for two damaged, clogged HEPA filters, a ground-level release of 6.0×10^{-2} grams (2.1×10^{-3} ounces) of plutonium (in the form of MOX powder) was postulated. It was estimated that the frequency of this accident is less than 1×10^{-6} per year, which is in the "beyond extremely unlikely" range.

Beyond-design-basis earthquake. The postulated beyond-design-basis earthquake was assumed to be of sufficient magnitude to cause loss of the containment function of the building. Although the source term is highly uncertain, an assessment of the MAR, ARF, and RF for each of the process areas indicated a potential for the release of 95 grams (3.4 ounces) of plutonium (in the form of MOX powder) to the room is predicted. Consistent with the general assumptions for beyond-design-basis accident LPFs presented in Section D.1.5.1 for new facilities, a LPF of 0.1 was assumed for the plutonium materials with the release at ground level. The estimated frequency of this accident is in the range of 1×10^{-5} to 1×10^{-7} per year or lower ("extremely unlikely to beyond extremely unlikely").

<u>Plutonium metal oxidation capability at MFFF</u>. In addition to the previously evaluated mission activities, under some options, MFFF would receive plutonium metal from pit disassembly operations and convert it to oxide. Plutonium metal oxidation technology and associated systems and equipment would be installed in MFFF to convert metal to oxide suitable for subsequent processing. The equipment, operations, and throughput were assumed to be similar to the operation evaluated for PDCF. For purposes of this analysis, it is assumed that plutonium metal oxidation is accomplished using direct metal oxidation furnaces. Under this option, the accident scenarios associated with PDCF plutonium metal oxidation operations would be added to the MFFF scenarios. It is expected that the overall inventories within MFFF outside of the metal oxidation technology would not change significantly, as metal oxidation just adds another source of feed for the other MFFF processes. The source term for the beyond-design-basis fire would be increased if the fire heated the cans and equipment within the metal oxidation capability.

The principal accident scenario associated with the metal oxidation operations is a severe fire in a metal oxidation glovebox. Based on the *PDC NEPA Source Document* (DOE/NNSA 2012), it was assumed that a direct metal oxidation glovebox fire could have about 15 kilograms (33 pounds) of plutonium as oxide in cans at risk under a fire scenario, as well as 6 kilograms (13 pounds) of plutonium as oxide within equipment. A DR of 0.25 was assumed for all. The cans of oxide were assumed to become moderately pressurized and to release oxide to the confinement system with an ARF of 0.1 and an RF of 0.7. For the oxide assumed to be within the equipment, an ARF of 0.005 and an RF of 0.4 were assumed. The overall release from the direct metal oxidation glovebox to the confinement would be about 266 grams (9.38 ounces) of plutonium. Based on an LPF of 1.0×10^{-5} for two HEPA filters, a stack release of 0.00266 grams (9.38×10^{-5} ounces) of plutonium was postulated. It was estimated that the frequency of this accident is in the range of 1×10^{-4} to 1×10^{-6} per year ("extremely unlikely").

Beyond-Design-Basis Fire – Direct Metal Oxidation Addition. It was assumed that a beyond-design-basis fire would also encompass the direct metal oxidation glovebox and result in a release similar to that postulated for that event. Again assuming that a major fire might cause the building ventilation and filtration systems to fail, possibly due to clogged HEPA filters, an LPF of 0.1 for two damaged, clogged HEPA filters was assumed. Therefore, a ground-level release of 26.3 grams (0.928 ounces) of plutonium was postulated. It was estimated that the frequency of this accident is less than 1×10^{-6} per year, which is in the "beyond extremely unlikely" range.

Accident scenarios and source terms for MFFF under all *SPD Supplemental EIS* alternatives are presented in **Table D–6**. The additional accident scenarios associated with conversion of plutonium metal to oxide in the optional direct metal oxidation furnaces are also noted. For this facility, all of the plutonium involved was assumed to be plutonium suitable for use in MOX fuel and to have an americium-241 content of 1 percent, which is expected to bound the hazards associated with such plutonium. The relative inhalation hazard of this material is 2.086 times higher than pure plutonium-239. The plutonium-239 dose equivalents for each source term are also included in Table D–6.

Table D–6 Accident Scenarios and Source Terms for the Mixed Oxide Fuel Fabrication Facility Under All Alternatives

Accident	*Frequency (per year)*	*MAR (grams)*	*DR*	*ARF*	*RF*	*LPF*	*Release (grams)*
Criticality	1×10^{-4} to 1×10^{-6} (extremely unlikely)	–	–	–	–	–	1×10^{19} fissions
Explosion in sintering furnace	1×10^{-4} to 1×10^{-6} (extremely unlikely)	5,600 Pu	1	0.01	1	0.00001	0.00056 Pu 0.0012 PuE
Fire	1×10^{-2} to 1×10^{-4} (unlikely)	–	–	–	–	0.00001	4.0×10^{-6} Pu 8.3×10^{-6} PuE
Spill	1×10^{-4} to 1×10^{-6} (extremely unlikely)	50 liters	–	0.0002	0.5	0.00001	5.0×10^{-6} Pu 1.0×10^{-5} PuE
Metal oxidation capability only: Fire in direct metal oxidation glovebox causing pressurized release of oxide from cans and equipment [a]	1×10^{-4} to 1×10^{-6} (extremely unlikely)	15,000 Pu as oxide in cans 6,000 Pu as oxide in equipment	0.25 0.25	0.1 cans 0.005 equip.	0.7 cans 0.4 equip.	0.00001 0.00001	0.00263 Pu 3.0×10^{-5} Pu Total: 0.0056 PuE
Design-basis earthquake	0.0004 (unlikely)	–	–	–	–	0.00001	0.000079 Pu 0.00017 PuE
Beyond-design-basis fire	$< 1 \times 10^{-6}$ (beyond extremely unlikely)	11,000 mixed oxide fuel powder	1	0.006	0.01	0.1	0.06 Pu 0.13 PuE
Beyond-design-basis fire – additional metal oxidation contribution	$< 1 \times 10^{-6}$ (beyond extremely unlikely)	Additional 15,000 Pu as oxide in cans and 6,000 Pu as oxide in equipment	0.25 0.25	0.1 cans 0.005 equip.	0.7 cans 0.4 equip.	0.1 0.1	26 Pu 0.30 Pu Total: 55 PuE
Beyond-design-basis earthquake (MFFF only)	1×10^{-5} to 1×10^{-7} (extremely unlikely to beyond extremely unlikely)	Varies	Varies	Varies	Varies	0.1	9.5 Pu 20 PuE (ground level)

ARF = airborne release fraction; DR = damage ratio; equip. = equipment; LPF = leak path factor; MAR = material at risk; MFFF = Mixed Oxide Fuel Fabrication Facility; Pu = plutonium; PuE = plutonium-239 dose equivalent; RF = respirable fraction.

[a] Scenario parameters for the metal oxidation capability are from DOE/NNSA 2012.

Note: To convert grams to ounces, multiply by 0.035274.

Source: DOE 1999, NRC 2005, DOE/NNSA 2012.

D.1.5.2.7 Waste Solidification Building

Under all of the alternatives considered in this *SPD Supplemental EIS*, the WSB being constructed in F-Area would process liquid radioactive waste in support of surplus plutonium disposition activities at SRS (see Appendix B, Section B.1.1.3). A wide range of potential accident scenarios were considered for the initial design of WSB in the *Environmental Report for MFFF* (DCS 2002) and the *MFFF EIS* (NRC 2005). The *WSB DSA* (WSRC 2009) confirms that the initial accident scenarios, source terms, and impacts are bounding. The analyses demonstrate that WSB can withstand design-basis natural phenomenon hazards such as earthquakes, winds, tornadoes, and floods, such that no unfiltered releases are expected.

Analysis of the proposed process operations for the plutonium dissolution operations in WSB identified the following broad categories of accidents: aircraft crash, criticality, design-basis earthquake, beyond-design-basis earthquake, explosion, fire, and leaks or spills. Basic characteristics of each of these postulated accidents are described in this section. Additional discussion of scenario development based on consistency concerns can be found in Section D.1.5.1.

WSB processes high-activity waste and low-activity waste from MFFF and PDCF. The dominant radionuclide hazard in WSB is americium-241 in the high-activity waste. In the high-activity waste and total building inventory, americium-241 would represent over 99.9 percent of the alpha activity and radionuclide hazard if released to the environment. Therefore, the WSB inventory is normalized to americium-241 for identification of the MAR and source terms.

The following design-basis accident descriptions and source terms were based on the unmitigated design-basis accidents analyzed in the current *WSB DSA*. WSB has been designed and would be operated to reduce the likelihood of these accidents to the extent practicable. The design features and operating practices would also limit the extent of any accident and mitigate the consequences for the workers, public, and environment if an accident occurred. As with all new SRS facilities, it is expected that the safety controls would be sufficient, such that the likelihood of any of these accidents happening is "extremely unlikely" or lower and that, if an accident were initiated, the source term and consequences reported in the facility DSAs and this *SPD Supplemental EIS* would be conservative.

Criticality. A criticality is not considered credible at WSB (WSRC 2009).

High-Activity Waste Process Room fire. It was postulated that a small fire starts within the High-Activity Waste Process Room or propagates from another location in the high-activity waste area. The fire propagates through the High-Activity Waste Process Room and heats high-activity waste solution in the high-activity waste tanks. The process solutions in the tanks are heated to boiling. The boiling action entrains radiological material, which is swept into the process vessel vent system and ultimately out the WSB stack. In this bounding scenario, no credit is taken for in-line process vessel vent system demisters or other design features that should reduce the severity of the accident. Further, because the process tanks are only separated by partitions extending halfway to the ceiling, it was conservatively assumed that all high-activity waste vessels may be involved as the fire progresses. Without safety controls, the release mechanism in this accident could be vigorous boiling in the high-activity waste tanks, which would entrain radiological material in the tanks.

The MAR for this scenario is the dose equivalent of 18.3 kilograms (40 pounds) of americium-241. The DR was assumed to be 1, so all of the MAR was assumed to be involved. A bounding ARF of 2.0×10^{-3} and an RF of 1 were applied for a boiling solution (DOE 1994) to determine the unmitigated source term, assuming fire mitigation controls fail. Therefore, the unmitigated source term is 18,300 grams $\times 2 \times 10^{-3} = 36.3$ grams (1.28 ounces) of americium-241 dose equivalent. With the proposed controls including fire-suppression and low-combustion design, there should be insufficient heat to cause vigorous boiling. If there were insufficient heat to vigorously boil the vessel contents, the ARF × RF value could be as low as 3.0×10^{-5}, resulting in a much lower source term and consequences (WSRC 2009). Because this is considered a design-basis accident in the *WSB DSA*, it is appropriate to assume these fire-limiting controls function in order to develop a realistic source term. Therefore, the mitigated source term is 18,300 grams $\times 3 \times 10^{-5} = 0.55$ grams (0.019 ounces) of americium-241 dose equivalent.

This scenario would be mitigated by design features that should limit the spread of the fire, such as the in-line process vessel vent system demisters (for which no credit is taken), HEPA filters, and elevated release from the stack. With a conservative HEPA filter penetration factor of 1×10^{-5}, the amount released from the stack is conservatively bounded by 5.5×10^{-6} grams (1.9×10^{-7} ounces) of americium-241 dose equivalent.

High-activity waste process vessel hydrogen explosion. The high-activity waste tanks contain high concentrations of TRU radionuclides dissolved in an aqueous nitric acid solution. Hydrogen is abundantly produced through radiolytic decomposition of hydrogenous material (i.e., water) within the high-activity waste process vessels and removed through the process vessel vent system. With a loss of flow through the process vessel vent system, hydrogen can reach the lower flammable limit within a few hours, conservatively ignoring nitrates. The loss of exhaust flow in the process vessel vent system could be caused by loss of power, operator error, mechanical failure of the fans, line breaks, vent path plugging, or natural phenomenon hazard events. Once above the lower flammability limit, an ignition source from either static or electrical shorts could ignite the flammable gas.

The unmitigated source term (WSRC 2009) was derived using the method described in the DOE Handbook, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* (DOE 1994), for a vapor explosion in an enclosed space above the solution, equating the mass of respirable solution made airborne to the energy released and expressed in terms of equivalent mass of TNT [trinitrotoluene]. That analysis concluded that, with a stoichiometric hydrogen/air mixture of 10,000 liters (350 cubic feet), a vapor explosion would result in an airborne release of 13.8 grams (0.487 ounces) of americium-241 through the process vessel vent systems to demisters, HEPA filters, and the stack.

This scenario would be mitigated by design features that should maintain flow through the process vessel vent system. In addition, there should be sufficient time to take corrective actions before the hydrogen levels reach the lower flammable limit. With no credit taken for the in-line process vessel vent system demisters and a conservative HEPA filter penetration factor of 1×10^{-5}, the amount released from the stack is conservatively bounded by 1.38×10^{-4} grams (4.87×10^{-6} ounces) of americium-241 dose equivalent.

Red oil explosion. A "red oil" explosion was included in the *WSB DSA* and the engineered controls associated with this process would be sufficient to realistically prevent this accident (WSRC 2009). The accident is included in this *SPD Supplemental EIS* as a bounding, beyond-design-basis accident because of public interest in the accident and its potential consequences.

The designs of PDCF and MFFF indicate that organic compounds that would be required to initiate a red oil explosion would only be present in the WSB feed in trace amounts. Because the red oil explosion is only possible at higher organic concentrations, this scenario was not considered as part of the WSB design-basis accident analysis, but is included as a beyond-design-basis accident (WSRC 2009).

If high concentrations of organics were present in the WSB feed, an explosion could potentially occur in the high-activity waste evaporator. A red oil explosion is the product of a chemical reaction between nitric acid and tributyl phosphate at high temperatures in the presence of heavy metal solutions, producing pressure and explosive gases. Tributyl phosphate is used in the solvent extraction process in MFFF, which is the source of the waste streams to WSB. Such an explosion would result in the release of the contents of the evaporator to the High-Activity Waste Process Room.

The high-activity waste evaporator was assumed to hold 6.0 kilograms (13 pounds) of americium-241, as well as other radionuclides, and all were assumed to be released to the High-Activity Waste Process Room. A bounding ARF of 0.1 and an RF of 0.7 for superheated liquid (DOE 1994) were assumed to determine the unmitigated amount released to the room. Therefore, the unmitigated source term for a high-pressure release to the room is $6{,}000$ grams $\times 7 \times 10^{-2} = 420$ grams (15 ounces) of americium-241 dose equivalent (WSRC 2009).

This scenario would be made "beyond extremely unlikely" by design features in PDCF and MFFF that should ensure the WSB feed contains only very low concentrations of organics. The engineered controls associated with this process would be sufficient to prevent this accident (WSRC 2009). The impacts of a red oil explosion would be mitigated by the HEPA filters and elevated release from the stack. With a conservative HEPA filter penetration factor of 1×10^{-5}, the amount released from the stack is conservatively bounded by 4.2×10^{-3} grams (1.5×10^{-4} ounces) of americium-241 dose equivalent.

Leaks/spills from high-activity waste process vessels and piping. A high-activity waste process vessel could leak due to loss of integrity due to corrosion, poor maintenance, or an operational error such as overfilling. The bounding MAR for any single leak or spill was assumed to be the entire inventory of the worst-case high-activity waste vessel, equivalent to 6.0 kilograms (13 pounds) of americium-241. Splashing and entrainment of process liquid were considered. The bounding ARF (3×10^{-3}) and RF (0.4) were derived from the DOE Handbook (DOE 1994), assuming a free fall spill of aqueous solutions with a 9.1-meter (30-foot) fall distance. Therefore, the unmitigated source term from the spill is $6{,}000$ grams $\times 3 \times 10^{-3} \times 0.4 = 7.2$ grams (0.25 ounces) of americium-241 dose equivalent.

This scenario is considered to be in the "unlikely" category, but would fall into the "extremely unlikely" category with consideration of design features and operating practices that should limit the amount of material leaked or spilled. The impacts of a leak or spill would be mitigated by the HEPA filters and elevated release from the stack. Assuming a conservative HEPA filter penetration factor of 1×10^{-5}, the amount released from the stack is conservatively bounded by 6.0×10^{-6} grams (2.1×10^{-7} ounces) of americium-241 dose equivalent.

Aircraft crash. The *WSB DSA* evaluates an aircraft crash as an unmitigated event in which an aircraft operating in the vicinity of WSB loses control and crashes into the building. The aircraft does not crash directly into the high-activity waste process area. The safety analysis (WSRC 2009) concluded that it was not credible for an aircraft to directly affect the reduced area of concern associated with the high-activity waste process area. Rather, the aircraft was assumed to impact another portion of the building and break apart upon impact, resulting in fuel spills, missiles, and burning debris.

The *WSB DSA* did not credit the structure of the building or fire barriers between the high-activity waste process area and the rest of the building. Multiple fires were assumed to occur as a result of the fuel spill, resulting in a large propagating fire. This fire would eventually involve the high-activity waste process vessels and vigorously boil the liquid in the tanks. The major contributor to the dose would be the high-activity waste liquid inventory in the High-Activity Waste Process Room. Lesser contributors would include the high-activity waste liquid in the Cementation Area, the low-activity waste inventory, and the F/H Area Laboratory inventory.

The MAR involved in this scenario is 18.3 kilograms (40 pounds) of americium-241 and other associated radionuclides. The DR was assumed to be 1. A bounding ARF of 2.0×10^{-3} and an RF of 1 were applied for a boiling solution in the fire following the event to determine the unmitigated source term associated with thermal stress on liquids. The LPF was set equal to 1; therefore, the unmitigated source term is 18,300 grams × 2×10^{-3} = 36.6 grams (1.29 ounces) of americium-241 dose equivalent (WSRC 2009).

If credit were taken for the building structure and fire barriers between the high-activity waste process area and the rest of the building, a fire of this magnitude could not occur and the source term and probability would be much lower. If there were insufficient heat to vigorously boil the vessel contents, the ARF × RF value could be as low as 3.0×10^{-5}, resulting in much less severe consequences (WSRC 2009). Because this is considered a design-basis accident in the *WSB DSA*, it is appropriate to assume these fire-limiting controls function in order to develop a realistic source term. Therefore, the mitigated source term is 18,300 grams × 3×10^{-5} = 0.55 grams (0.019 ounces) of americium-241 dose equivalent.

Because the frequency of a small aircraft crash into the building is extremely low, the probability of an aircraft crash followed by a fire of this magnitude is probably in the "beyond extremely unlikely" frequency category.

Design-basis earthquake. In this scenario, it was postulated that, during a seismic event, power to WSB is lost. Support systems such as electrical systems, electrical power to the facility, and building ventilation systems may fail to function either during or after a seismic event. It was assumed that, upon a loss of power and/or damage incurred from the seismic event, the process vessel vent system fails. This would allow hydrogen generated by radiolytic decomposition of the aqueous solution in the high-activity waste process solution tanks to begin to accumulate. Under worst-case conditions, the hydrogen level in a high-activity waste vessel could exceed the lower flammability limit in a few hours, conservatively ignoring nitrates. Additionally, a fire was assumed to start in either a maintenance area or laboratory area due to the presence of flammable materials and a relatively high combustible loading.

The WSB structure, process vessels, and pipes are designed to Natural Phenomena Hazard PC-3+ (seismic) criteria; therefore, the building structure, process tanks, and piping would remain intact during and after the design-basis seismic event.

The high-activity waste area is not routinely accessed, is designed with a low combustible loading, and is isolated by a seismically rated fire barrier. Though the possibility of electrical sparking and incipient fires cannot be ruled out in the high-activity waste area, a fire of sufficient intensity to release material from the high-activity waste area was not postulated. The potential for large post-seismic event fires in areas designed with low combustible loads and isolated by seismically qualified fire barriers is addressed in the beyond-design-basis earthquake evaluation.

A seismic event was assumed to disable the process vessel vent system and initiate a propagating fire in a laboratory or maintenance area. Hydrogen would accumulate in a high-activity waste process tank above the lower flammability limit. Hydrogen was conservatively assumed to accumulate in a 10,000-liter (350-cubic-foot) volume above the americium-241 solution. Conservatively ignoring nitrates in the americium-241 solution, a tank containing a maximum of 6 kilograms (13 pounds) of americium-241 would require almost 14 days to accumulate to a stoichiometric hydrogen/air mixture in this volume. If this mixture ignited, a vapor explosion in the headspace of the tank could occur, similar to that evaluated for the hydrogen explosion accident scenario.

Concurrently with this event, a fire was postulated to start in a laboratory or maintenance area and involve the radiological inventory outside the High-Activity Waste Process Room. This inventory is very small relative to the high-activity waste and represents a negligible dose potential to the MEI.

The source term for this event is similar to the source term developed for the bounding hydrogen explosion in a high-activity waste process tank. The mass of respirable solution made airborne due to the energy released by the vapor explosion was conservatively assumed to be equivalent to the mass released that would result from the same amount of energy produced by detonation of an equivalent mass of TNT.

The unmitigated source term was derived (WSRC 2009) using the method described in the DOE Handbook (DOE 1994) for a vapor explosion in an enclosed space above the solution, equating the mass of respirable solution made airborne to the energy released, expressed in terms of equivalent mass of TNT. That analysis concluded that, with a stoichiometric hydrogen/air mixture of 10,000 liters (350 cubic feet), a vapor explosion would result in an airborne release of 13.8 grams (0.487 ounces) of americium-241 through the process vessel vent system to demisters, HEPA filters, and the stack.

This scenario would be mitigated by design features that should maintain flow through the process vessel vent system. In addition, there should be sufficient time to take corrective actions before the hydrogen levels reach the lower flammable limit. Assuming no credit for the in-line process vessel vent system demisters and a conservative HEPA filter penetration factor of 1×10^{-5}, the amount released from the stack is conservatively bounded by 1.38×10^{-4} grams (4.87×10^{-6} ounces) of americium-241 dose equivalent.

Beyond-design-basis earthquake. WSB structural components, including process vessels and pipes, are qualified to Natural Phenomena Hazard PC-3+ (seismic) criteria. However, a more energetic seismic event could fail key WSB safety controls, such as high-activity waste vessels and fire walls, and initiate propagating fires.

In this accident scenario, a severe seismic event was postulated to occur in the immediate vicinity of WSB. The ground acceleration would be more severe than the natural phenomenon hazard PC-3+ (seismic) site criteria established for the facility. The resultant force would result in significant damage to load-bearing walls, including the 18-inch (46-centimeter) fire wall surrounding the High-Activity Waste Process Room. Further, the structural supports for high-activity waste tanks and piping would fail, resulting in a large spill of high-activity waste solution. For a seismically initiated fire to occur inside the process room with sufficient intensity to result in a significant release of high-activity waste solution, an ignition source must be present and sufficient combustibles must be available to fuel a large and intense fire that could boil the high-activity waste solution. The High-Activity Waste Process Room is designed with a low combustible loading, limited ignition sources, and no flammable gases or liquids that are typical potential initiators for post-seismic event fires. Therefore, for purposes of this *SPD Supplemental EIS*, a widespread post-seismic event fire is not considered credible.

For purposes of this *SPD Supplemental EIS*, the entire high-activity waste inventory was assumed to spill. The high-activity waste process MAR was assumed to be the maximum facility inventory, which is 18.3 kilograms (40 pounds) of americium-241 and other associated radionuclides. The DR was assumed to be 1. A bounding ARF of 2×10^{-4} and RF of 0.5 were applied to impact (spill) stresses. Consistent with the general assumptions for beyond-design-basis accident LPFs presented in Section D.1.5.1 for new facilities, a LPF of 0.1 was assumed. Therefore, the unmitigated source term is 18,300 grams × 2×10^{-4} × 0.5 × 0.1 = 0.183 grams (0.0065 ounces) americium-241 dose equivalent.

Accident scenarios and source terms for WSB under the No Action, Immobilization to DWPF, MOX Fuel, H-Canyon/HB-Line to DWPF, and WIPP Alternatives are presented in **Table D–7**.

No new substantial accident risks from the proposed new activities in this *SPD Supplemental EIS* have been identified (WSRC 2008).

Table D–7 Accident Scenarios and Source Terms for the Waste Solidification Building

Accident	*Frequency (per year)*	*MAR (grams americium-241 dose equivalent)*	*DR*	*ARF*	*RF*	*LPF*	*Release (grams americium-241 dose equivalent)*
Criticality	Not credible	–	–	–	–	–	–
High-activity waste process vessel hydrogen explosion	1×10^{-4} to 1×10^{-6} (extremely unlikely)	13.8	1	–	–	0.00001	0.00014
High-Activity Waste Process Room fire	1×10^{-4} to 1×10^{-6} (extremely unlikely)	18,300	1	0.00003		0.00001	5.5×10^{-6}
Leak or spill	Unlikely	6,000	1	0.003	0.4	0.00001	7.2×10^{-5}
Design-basis earthquake	0.0004 (unlikely)	13.8	1	–	–	0.00001	0.00014
Aircraft crash	$< 1 \times 10^{-7}$ (beyond extremely unlikely)	18,300	1	0.00003		1	0.55
Beyond-design-basis red oil explosion	$< 1 \times 10^{-6}$ (beyond extremely unlikely)	6,000	1	0.1	0.7	0.00001	0.0042
Beyond-design-basis earthquake	1×10^{-5} to 1×10^{-7} (extremely unlikely to beyond extremely unlikely)	18,300	1	0.0002	0.5	0.1	0.18

ARF = airborne release fraction; DR = damage ratio; LPF = leak path factor; MAR = material at risk; RF = respirable fraction.
Note: To convert grams to ounces, multiply by 0.035274.
Source: WSRC 2009.

D.1.5.2.8 H-Canyon/HB-Line

Under the Immobilization to DWPF, MOX Fuel, H-Canyon/HB-Line to DWPF, and WIPP Alternatives considered in this *SPD Supplemental EIS*, H-Canyon/HB-Line could be used to support various surplus plutonium disposition activities (see Appendix B, Section B.1.3). As a result, a wide range of potential accident scenarios were considered for H-Canyon/HB-Line. These scenarios are considered in detail in the safety analyses and NEPA analyses for H-Canyon/HB-Line. The analyses demonstrate that H-Canyon/HB-Line can withstand design-basis natural phenomenon hazards such as earthquakes, winds, tornadoes, and floods, such that no unfiltered releases are expected.

Three options would use the H-Canyon/HB-Line processing capabilities to convert plutonium metal and oxides into a form suitable for oxide feed at MFFF, a blended oxide suitable for onsite shipment to E-Area and then on to WIPP, or a nitrate solution for vitrification with high-level radioactive waste in DWPF. The types of operations are similar to either ongoing or recent operations in the H-Canyon/HB-Line complex and would not introduce any new types of accidents into the facilities or substantially change the frequencies for the accidents analyzed. The operations proposed under the three options are well within H-Canyon/HB-Line capabilities, and existing safety systems would ensure the operations would be conducted safely. Because all of the operations involve dissolving metal and oxides and then handling and processing similar quantities of dispersible plutonium oxides, the bounding accidents, such as failure of cans of oxide and large fires, would be similar. The three options identified for use of H-Canyon/HB-Line are as follows:

Process plutonium for MFFF feed. Under this option, H-Canyon and HB-Line would be utilized in the following ways:

- H-Canyon would dissolve plutonium sent to it for processing.
- H-Canyon would store dissolved plutonium solution and provide it as feed to HB-Line.
- HB-Line would convert dissolved plutonium to plutonium oxide in the Phase II portion of the HB-Line[5] for MFFF feed.
- H-Canyon would process HB-Line column raffinate and precipitator filtrate waste to recover plutonium for recycle or disposition at the Liquid Waste Tank Farm.

The surplus plutonium disposition-related MAR in HB-Line would be up to 50 kilograms (110 pounds) of plutonium oxide. The H-Canyon surplus plutonium disposition-related MAR would include the dissolved plutonium inventory, which should be bounded by an inventory of 1,000 kilograms (2,200 pounds) of plutonium-239 in an aqueous nitrate solution spread over several tanks.

Process non-pit plutonium for DWPF. Under this option, H-Canyon and HB-Line would dissolve surplus non-pit plutonium metal and oxide for subsequent vitrification with high-level radioactive waste in DWPF. Dissolution of the majority of the material in oxide form would occur in HB-Line, while the dissolution of most of the metals would occur in H-Canyon. The dissolved solutions would then be transferred to the separations process, during which any uranium present in the material would be recovered. The plutonium solutions would be transferred primarily to the DWPF sludge feed tank in the liquid radioactive waste tank farm pending vitrification at DWPF.

Process non-pit plutonium for WIPP. Under this option, plutonium would be processed utilizing the existing H-Canyon and HB-Line facilities to prepare the plutonium for subsequent disposition at WIPP. HB-Line would install new equipment in existing gloveboxes to open DOE-STD-3013 containers, remove the plutonium contents, blend the plutonium with materials to terminate safeguards, and package the result in Pipe Overpack Containers (POCs). H-Canyon would support HB-Line by providing temporary or interim storage of loaded POCs prior to their shipment to E-Area, if required. Once the POCs are loaded and ready for shipping, they would be transported to E-Area for storage, characterization, and shipment to WIPP. The addition of a muffle furnace to one of the glovebox lines would also be required to convert some metal to oxide prior to blending with termination-of-safeguards material.

If unirradiated Fast Flux Test Facility (FFTF) fuel cannot be dispositioned by direct disposal at WIPP, then the unirradiated FFTF fuel would have to be disassembled and could be disposed of at WIPP through processing at H-Canyon/HB-Line. Existing gloveboxes in HB-Line would be used to perform the operations to crush the pellets into a powder, load the powder into suitable containers, mix/blend the powder with inert material, assay the resulting material, package the loaded containers into POCs, and transfer the POCs to E-Area.

Because processing the oxides would occur primarily in HB-Line and would be a dry activity, the associated accident scenarios would primarily involve HB-Line operations. No changes would be expected in liquid process waste generation from either H-Canyon or HB-Line as a result of performing this mission. H-Canyon would provide support to HB-Line by providing temporary or interim storage of loaded POCs prior to shipment to E-Area if required. Thus, the potential accidents associated with

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[5] *Phase II is the production line for plutonium and neptunium oxides.*

ongoing H-Canyon operations would dominate any additional accident risks associated with this surplus plutonium disposition option.

Bounding accidents. The material processing and throughputs associated with any of the options for H-Canyon and HB-Line are not expected to add any new accident types. Accident scenarios and source terms are not expected to change. With longer periods of operation, the accident risks would continue for a longer period.

Analysis of the proposed process operations for plutonium dissolution operations in H-Canyon/HB-Line identified the following broad categories of accidents: aircraft crash, criticality, design-basis earthquake, beyond-design-basis earthquake, explosion, fire, and leaks or spills. Because H-Canyon and HB-Line are very robust structures and provide a high degree of inherent confinement, releases from almost all accidents would be confined within the structure and would be filtered through the sand filter prior to release to the environment. Of all of the accidents considered in the safety documents, accidents that result in room-wide fires present the greatest risks. The basic characteristics of each of these postulated accidents are described in this section. Additional discussion of scenario development based on consistency concerns can be found in Section D.1.5.1.

The potential for accidents and the potential accident consequences for workers and the environment from processing of the proposed surplus plutonium disposition materials is well within the scope of the accident scenarios, MARs, and consequences evaluated in the existing safety documents for H-Canyon (SRNS 2011a) and HB-Line (SRNS 2011b). These existing and prior safety documents have evaluated processing of both plutonium-239 and plutonium-238 materials; the latter material has a curie content of about a factor of 100 greater than that proposed for the Surplus Plutonium Disposition Program.

Both the H-Canyon and the HB-Line safety documents identify a range of accidents, including nuclear criticalities, spills, fires, explosions, natural phenomena such as earthquakes, and external events such as potential bounding accidents. For HB-Line, the dominant operational scenarios include explosions associated with the dissolvers in Phase I portion of the HB-Line,[6] localized or widespread fires, and criticalities.

The HB-Line safety documents evaluate the consequences for a range of accidents using the actual inventories associated with ongoing processing campaigns at the time of the safety document preparation, which included dissolution of low-assay plutonium in Phase I dissolvers. The safety documents also evaluated a range of fires involving legacy materials in the old HB-Line, which would not be used for surplus plutonium disposition materials.

Although the current safety analysis for HB-Line (SRNS 2011b) is for somewhat different processing operations than those projected for the surplus plutonium disposition mission, the current safety basis, including accident scenarios and building MAR limits (SRNS 2011b, Table 5.5.7-1), would support the proposed surplus plutonium disposition operations.

Based on the current safety documents for HB-Line (SRNS 2011b), the most severe accidents include rupture of a 3013 container due to impact, a fifth- or sixth-level facility fire, and an earthquake with subsequent fire and post-seismic event hydrogen explosions in the process vessels. In each of these accidents, the HB-Line structure and containment system, including the sand filters, are expected to continue to function.

Both the H-Canyon and HB-Line safety analyses evaluated the potential for an inadvertent nuclear criticality, particularly in the dissolvers, and identified appropriate controls.

The H-Canyon safety analyses also evaluated a potential explosion–hydrogen deflagration due to radiolysis in the dissolvers and identified the controls necessary to dissolve plutonium materials. The

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[6] *Phase I is the Scrap Recovery Line, which is used to dissolve and dispose of legacy plutonium materials.*

potential accident risks for this type of accident are much less than the postulated hydrogen deflagration uncontrolled reaction and the tributyl phosphate/nitric acid explosions evaluated for other portions of the H-Canyon processes that are not associated with surplus plutonium disposition operations. The bounding explosion in the H-Canyon safety documents is a hydrogen explosion involving high-activity waste derived primarily from the processing of used nuclear fuel. This accident bounds any of the accidents associated with plutonium metal dissolution.

Because the dissolvers do not contain solvents, a fire would not be likely in that area. Fire events considered included a pyrophoric fire occurring in the crane vestibule or the H-Canyon material area, which could result from spontaneous ignition of plutonium metal, dropped dissolvable containers, defective can crimp seals, or operator error. This fire could involve the DOE-STD-3013-2012 limit of 4,400 grams (160 ounces) of plutonium. Based on an ARF of 6×10^{-3}, an RF of 0.01 and an LPF of 4.9×10^{-3} for the sand filter system, a stack release of 1.3×10^{-3} grams (4.6×10^{-5} ounces) of plutonium was postulated. The estimated frequency of this accident is in the range of 1×10^{-4} to 1×10^{-6} per year ("extremely unlikely"). Fires that result in a pressurized release of oxide would bound these metal fires.

Aircraft crash. A crash of a large, heavy commercial or military aircraft directly into a reinforced-concrete facility could damage the structure sufficiently to breach confinement and disperse material into the environment. A subsequent fuel-fed fire could provide energy to further damage structures and equipment, aerosolize material, and drive materials into the environment. Source terms are highly speculative, but could exceed those of the beyond-design-basis earthquake. At all SRS sites, the frequency of such a crash is below 1×10^{-7} per year, and so was not evaluated.

Criticality. Engineered and administrative controls should be available to ensure that the double-contingency principles are in place for all portions of the process. It was assumed that human error results in multiple failures, leading to an inadvertent nuclear criticality. The estimated frequency of this accident is in the range of 1×10^{-4} to 1×10^{-6} per year ("extremely unlikely"). A bounding source term resulting from 1×10^{19} fissions was assumed.

Explosions. The bounding explosion associated with surplus plutonium disposition material was assumed to be a hydrogen deflagration in a process vessel with plutonium liquid. A bounding quantity of 150,000 grams (5,300 ounces) of plutonium in solution was assumed to be at risk. Based on an ARF of 6×10^{-3}, an RF of 0.01, and an LPF of 4.9×10^{-3} for the sand filter system, a stack release of 0.044 grams (0.0016 ounces) of plutonium was postulated. The estimated frequency of this accident is in the range of 1×10^{-4} to 1×10^{-6} per year ("extremely unlikely").

Within the portion of HB-Line that would be used for surplus plutonium disposition material dissolution and processing, the bounding explosion is a hydrogen explosion in a dissolver. A similar MAR or smaller is expected. The impacts of an explosion in HB-Line would be bounded by the H-Canyon explosion.

Fire. The bounding fire in H-Canyon involving surplus plutonium disposition plutonium metal was assumed to be a pyrophoric fire. This fire could involve the MAR limit of 4,400 grams (160 ounces) in a single 3013 container. The analysis also assumed an ARF of 5.0×10^{-4} and an RF of 0.5. Based on an LPF of 4.9×10^{-3} for the sand filter system, a stack release of 5.4×10^{-3} grams (1.9×10^{-4} ounces) was postulated. The estimated frequency of this accident is in the range of 1×10^{-2} to 1×10^{-4} per year ("unlikely"). This event is bounded by fires involving oxides and TRU waste in HB-Line.

A bounding fire event for HB-Line is described in the current safety analyses (SRNS 2011b). A large-scale fire, although unlikely, would have the potential to result in high-pressure releases of oxides from 3013 cans and lower-pressure releases of oxides from other, less robust containers or gloveboxes. Current safety analyses for HB-Line (SRNS 2011b) evaluate this accident with the current and legacy inventory of materials within the HB-Line rooms. Although the current analysis addressed somewhat different processing operations than those projected for the surplus plutonium disposition mission, the accident scenarios and building MAR limits (SRNS 2011b, Table 5.5.7-1) would support the proposed surplus plutonium disposition operations.

With the proposed surplus plutonium disposition operations in HB-Line, the bounding MAR for a level-wide fire in HB-Line would be 4,400 grams (160 ounces) of plutonium oxide in a single 3013 container, 50,000 grams (1,800 ounces) of non-pit plutonium as oxide in process (including WIPP material), 100,000 grams (3,500 ounces) of plutonium in solution in process, and 10,000 grams (350 ounces) of plutonium-239 dose equivalent as TRU waste.

Using the assumptions for response to these materials in a bounding fire event identified in the *Savannah River Site, H-Canyon & Outside Facilities, H-Area, Documented Safety Analysis (HB-Line DSA)* (SRNS 2011b, Table 3.4-1), including a bounding DR of 1 for most materials, the total release to the building would be as follows:

- Heating and overpressurization of 3013 container – Assuming a release at 1,000 psig due to overpressurization of a 3013 container with 4,400 grams (160 ounces) of plutonium resulting from a surrounding fire, a DR of 1, and an ARF × RF of 0.113, about 500 grams (18 ounces) would be released to the building.
- Heating oxide in process – Assuming a less than 25 psig release due to thermal stress of 50,000 grams (1,800 ounces) of plutonium as oxide, a DR of 1, and an ARF × RF of 0.002, 100 grams (3.5 ounces) of plutonium would be released to the building.
- Heating solution in process – Assuming boiling due to thermal stress of 100,000 grams (3,500 ounces) of plutonium in solution in process, a DR of 1, and an ARF × RF of 0.002, 200 grams (7.1 ounces) of plutonium would be released to the building.
- Burning TRU waste – Assuming that 20 percent of the 10,000 grams (350 ounces) is unconfined and subject to open burning with an ARF × RF of 0.01, 20 grams (0.71 ounces) of plutonium-239 dose equivalent would be released to the building. Assuming the remaining 80 percent is confined and subject to confined burning with an ARF × RF of 0.0005, 4 grams (0.14 ounces) of plutonium-239 dose equivalent would be released to the building.

Thus, for the bounding fire event, approximately 800 grams (28 ounces) of plutonium and 24 grams (0.85 ounces) of plutonium-239 dose equivalent could be released to the building. The building structure and confinement are expected to continue to function during this design-basis event so the release would be filtered through the sand filter system. Based on an LPF of 4.9×10^{-3} for the sand filter system, a stack release of 3.9 grams (0.14 ounces) of plutonium plus 0.12 grams (0.0042 ounces) of plutonium-239 dose equivalent was postulated. The nominal frequency estimate for the combination of a severe fire following a design-basis earthquake would be in the range of 1×10^{-4} to 1×10^{-6} per year ("extremely unlikely").

Leaks or spills of nuclear material. The bounding spill was assumed to be a breach of a dissolvable container. It was assumed that 2.0 kilograms (4.4 pounds) of plutonium-239 dose equivalent were MAR. Because the material would be in metal form, no substantial release is expected.

Once the plutonium is dissolved, a spill of the solution is possible and would bound any oxide spills. The spill or transfer error of plutonium solution was analyzed in the *H-Canyon DSA* (SRNS 2011a). Concerning the proposed surplus plutonium disposition operations in H-Canyon and HB-Line, the bounding MAR would be a spill of 320,000 grams (11,000 ounces) of plutonium as solution from the largest storage tank. Based on an ARF of 2×10^{-4}, an RF of 0.5, and an LPF of 4.9×10^{-3} for the sand filter system, a stack release of 0.16 grams (5.6×10^{-3} ounces) of plutonium was postulated. This accident has an estimated frequency in the range of 1×10^{-2} to 1×10^{-4} per year ("unlikely").

Design-basis earthquake with fire. The design-basis event that presents the highest potential for release of material to the environment is a design-basis earthquake followed by a major fire. While the major safety systems, including building confinement and the building sand filter system, should continue to function, the vibratory motion is expected to result in spills of solution or low-energy spills of oxide and perhaps a pyrophoric fire, as described earlier.

H-Canyon. With the proposed surplus plutonium disposition operations in H-Canyon, the bounding MAR for an earthquake and fire in H-Canyon would be 8,800 grams (310 ounces) of plutonium as metal and 50,000 grams (1,800 ounces) of plutonium as oxide stored in Pipe Overpack Containers (Type B-like shipping containers). The *H-Canyon DSA* (SRNS 2011a, Section 3.4.2.1) shows no credible scenarios for solutions subject to fires. The plutonium metal would be subject to burning if it were uncontained and exposed to transient fires associated with the seismic event and subsequent fires. A bounding DR of 1 with an ARF of 0.0005 and RF of 0.5 was assumed (SRNS 2011a, Table 3.4-10). Thus, a release of 2.2 grams (0.078 ounces) to the building was postulated.

The oxide stored in Type B-like shipping containers that are expected to survive severe transportation accidents is not expected to be vulnerable to the postulated fires and no release is expected.

Based on an LPF of 4.9×10^{-3} for the sand filter system, a stack release of 0.011 grams (0.00039 ounces) was postulated. The nominal frequency estimate for the combination of a severe fire following a design-basis earthquake would be in the range of 1×10^{-4} to 1×10^{-6} per year ("extremely unlikely").

HB-Line. A subsequent large-scale fire, although unlikely, would have the potential to result in high-pressure releases of oxides from 3013 cans and lower-pressure releases of oxides from other, less robust containers or gloveboxes. Current safety analyses for HB-Line (SRNS 2011b) evaluate this accident with the current and legacy inventory of materials within the HB-Line rooms. That analysis (SRNS 2011b, Tables 3.4-15 and 3.4-16) indicates that the subsequent fire would be the dominant contributor to the overall source term and the release, which would be due to the seismic vibration and impacts only, would contribute about 1 percent to the overall source term. Thus, for purposes of this *SPD Supplemental EIS*, the vibration, impacts, and spill contribution would be negligible.

Although the current analysis is for somewhat different processing operations than those projected for the surplus plutonium disposition mission, the accident scenarios and building MAR limits (SRNS 2011b, Table 5.5.7-1) would support the proposed surplus plutonium disposition operations.

Concerning the proposed surplus plutonium disposition operations in HB-Line, the bounding MAR for a level-wide fire in HB-Line would be 4,400 grams (160 ounces) of plutonium oxide in a single 3013 container; 50,000 grams (1,800 ounces) of plutonium as oxide in process (including WIPP material); 100,000 grams (3,500 ounces) of plutonium in solution in process; and 10,000 grams (350 ounces) of plutonium equivalent as TRU waste. This is the same MAR identified for the bounding fire event. Because the releases due to the seismic motion, spills, and subsequent impacts can be neglected, the total release due to the seismic release and subsequent fire can be approximated by the bounding level-wide fire in HB-Line evaluated earlier. Thus, the total fire contribution would be about 800 grams (28 ounces) of plutonium and 24 grams (0.85 ounces) of plutonium-239 dose equivalent released to the building.

The building structure and confinement are expected to continue to function during this design-basis event, so the release would be filtered through the sand filter system. Based on an LPF of 4.9×10^{-3} for the sand filter system, a stack release of 3.9 grams (0.14 ounces) of non-pit plutonium plus 0.12 grams (0.0042 ounces) of plutonium-239 dose equivalent was postulated. The nominal frequency estimate for the combination of a severe fire following a design-basis earthquake would be in the range of 1×10^{-4} to 1×10^{-6} per year ("extremely unlikely").

Beyond-design-basis earthquake with fire. The postulated beyond-design-basis earthquake was assumed to be of sufficient magnitude to cause collapse of the process equipment, initiation of widespread fires, and loss of the containment function of the building. For purposes of this *SPD Supplemental EIS*, the Surplus Plutonium Disposition Program materials released are expected to be bounded by the postulated source terms associated with the design basis earthquake with fire for H-Canyon and HB-Line. As indicated for those accidents, the dominant contribution would come from the postulated fires in HB-Line that could overpressurize 3013 containers and heat oxides and solutions. For the bounding fire events, the release to the building due to proposed surplus plutonium activities was estimated at 2.2 grams (0.078 ounces) for H-Canyon and 800 grams (28 ounces) of plutonium plus 24 grams (0.85 ounces) of plutonium-239 dose equivalent from HB-Line activities. Concerning the beyond-design-basis event, the building confinement was assumed to have failed and releases were postulated at ground level. Consistent with the general assumptions for beyond-design-basis accident LPFs presented in Section D.1.5.1 for older facilities, a building LPF of 0.25 was assumed, although a more realistic value is likely to be at least a factor of several lower. The estimated frequency of this accident is in the range of 1×10^{-5} to 1×10^{-7} per year or lower ("extremely unlikely to beyond extremely unlikely").

Accident scenarios and source terms for H-Canyon/HB-Line under the disposition alternatives are presented in **Table D–8**. These scenarios indicate that, for any of the surplus plutonium disposition options for use of H-Canyon/HB-Line, the accident releases are dominated by fires that result in the high-pressure rupture of 3013 cans of oxide or lower-pressure venting of other containers of oxide. Plutonium metal dissolution activities in H-Canyon present a much smaller accident risk than past used fuel dissolution involving large quantities of fission products and would not result in a significant radiological dose to the public. For purposes of analysis for this facility, all of the plutonium involved is assumed to be non-pit plutonium, with an assumed americium-241 content of 6.25 percent. The relative inhalation hazard of this material is 6.47 times higher than plutonium-239 and about 3.1 times more hazardous than weapons-grade plutonium. The plutonium-239 equivalents for each source term are also included in Table D–8. If the accidents involved pit plutonium instead of non-pit plutonium, the plutonium-239-dose-equivalent MAR, doses, and risks would be about a factor of 3.1 lower.

D.1.5.2.9 Defense Waste Processing Facility

Under the Immobilization to DWPF and H-Canyon/HB-Line to DWPF Alternatives considered in this *SPD Supplemental EIS*, DWPF in S-Area could be used to support various surplus plutonium disposition activities (see Appendix B, Section B.1.4.1).

Defense Waste Processing Facility Can-in-Canister Operations

Can-handling accidents and DWPF accidents were considered in the *SPD EIS* (DOE 1999), and no releases to the environment were predicted for vitrified plutonium canisters. The following accidents were considered:

Can-handling accident (before shipment to DWPF). A can-handling accident would involve a framework loaded with small cans containing vitrified plutonium material. Studies supporting the DWPF safety analyses indicate that the source term resulting from dropping vitrified waste, even without credit for the steel canister, would be negligible. The surplus plutonium immobilization technology would produce a waste form with a durability comparable to that of the DWPF vitrified waste form. Consequently, no postulated can-handling event would result in a radioactive release to the environment.

Melter spill (melt pour at DWPF). Analysis of a spill of melt material was included in studies performed in support of the DWPF safety analyses. According to that analysis, the source term resulting from dropping or tipping a log of vitrified waste, even without credit for the steel canister, would be negligible. Both surplus plutonium immobilization technologies (ceramic and glass) would produce a waste form with a durability comparable to that of the DWPF vitrified waste form. Consequently, it was postulated that no melter spill event would result in a radioactive release to the environment.

Table D–8 Accident Scenarios and Source Terms for the H-Canyon/HB-Line Under All Alternatives

Accident [a]	*Frequency (per year)*	*MAR (grams)*	*DR*	*ARF*	*RF*	*LPF*	*Release* [a] *(grams)*
Criticality	1×10^{-4} to 1×10^{-6} (extremely unlikely)	–	–	–	–	–	1×10^{19} fissions
Hydrogen explosion in H-Canyon dissolver	1×10^{-4} to 1×10^{-6} (extremely unlikely)	150,000 Pu in solution	1	0.006	0.01	0.0049	0.044 Pu 0.29 PuE
Fire (level-wide in HB-Line)	1×10^{-4} to 1×10^{-6} (extremely unlikely)	4,400 Pu in 3013	1	0.113		0.0049	2.4 Pu
		50,000 Non-pit Pu as oxide in process	1	0.002		0.0049	0.49 Pu
		100,000 Pu in solution in process	1	0.002		0.0049	0.98 Pu
		10,000 PuE as TRU waste	0.2 0.8	0.01 0.0005		0.0049 0.0049	0.098 PuE 0.020 PuE
		Total	–	–	–	–	3.9 Pu + 0.12 PuE or Total: 26 PuE
Leaks/spills of nuclear material (H-Canyon)	1×10^{-2} to 1×10^{-4} (unlikely)	320,000 Pu as solution	1	0.0002	0.5	0.0049	0.16 Pu 1.0 PuE
Design-basis earthquake with fire (H-Canyon)	1×10^{-4} to 1×10^{-6} (extremely unlikely)	8,800 Pu metal	1	0.0005	0.5	0.0049	0.011 Pu
		50,000 Pu in shipping containers	0	-	-	0.0049	0
Design-basis earthquake with fire (HB-Line)	1×10^{-4} to 1×10^{-6} (extremely unlikely)	4,400 Pu in 3013	1	0.113		0.0049	2.4 Pu
		50,000 Non-pit Pu as oxide in process	1	0.002		0.0049	0.49 Pu
		100,000 Pu in solution in process	1	0.002		0.0049	0.98 Pu
		10,000 PuE TRU waste	0.2 0.8	0.01 0.0005		0.0049 0.0049	0.098 PuE 0.020 PuE
		Total	–	–	–	–	3.9 Pu + 0.12 PuE or 26 PuE
Beyond-design-basis earthquake with fire	1×10^{-5} to 1×10^{-7} (extremely unlikely to beyond extremely unlikely)	8,800 Pu metal	1	0.0005	0.5	0.25	0.55 Pu
		4,400 Pu in 3013	1	0.113		0.25	124 Pu
		50,000 Non-pit Pu as oxide in process	1	0.002		0.25	25 Pu
		100,000 Pu in solution in process	1	0.002		0.25	50 Pu
		10,000 PuE TRU waste	0.2 0.8	0.01 0.0005		0.25 0.25	5.0 PuE 1.0 PuE
		Total	–	–	–	–	200 Pu + 6.0 PuE or 1,300 PuE

ARF = airborne release fraction; DR = damage ratio; LPF = leak path factor; MAR = material at risk; Pu = plutonium; PuE = plutonium-239 dose equivalent; RF = respirable fraction; TRU=transuranic.

[a] These scenarios and source terms were developed for surplus plutonium processing activities only and do not reflect other H-Canyon and HB-Line activities, including plutonium-238 activities and legacy contamination activities.

Note: To convert grams to ounces, multiply by 0.035274.

Source: SRNS 2011a, 2011b.

Canister-handling accident (after melt pour at DWPF). Analysis of events involving the handling and storage of vitrified waste canisters was included in studies performed in support of the DWPF safety analyses. Results of that analysis indicate that the source term resulting from the dropping or tipping of a log of vitrified waste, even without credit for the steel canister, would be negligible. The surplus plutonium immobilization technology would produce a waste form with a durability comparable to that of the DWPF vitrified waste form. Consequently, it was postulated that no canister-handling event would result in a radioactive release to the environment.

No new substantial accident risks from the proposed new activities in this *SPD Supplemental EIS* have been identified (WSRC 2008).

D.1.5.2.10 Glass Waste Storage Buildings

Under the Immobilization to DWPF and H-Canyon/HB-Line to DWPF Alternatives considered in this *SPD Supplemental EIS*, Glass Waste Storage Buildings in S-Area could be used to store vitrified waste containing surplus plutonium (see Appendix B, Section B.1.4.2). Vitrified waste canister-handling accidents at the Glass Waste Storage Buildings were considered in the *SPD EIS* (DOE 1999), and no releases to the environment were predicted for canister-handling accidents. The following accident was considered:

Canister-handling accident (after melt pour at DWPF). Analysis of events involving the handling and storage of vitrified waste canisters was included in studies performed in support of the DWPF SAR. Results of that analysis indicate that the source term resulting from the dropping or tipping of a log of vitrified waste, even without credit for the steel canister, would be negligible. The surplus plutonium immobilization technology would produce a waste form with a durability comparable to that of the DWPF vitrified waste form. Consequently, it was postulated that no canister-handling event would result in a radioactive release to the environment.

D.1.5.2.11 Los Alamos National Laboratory Plutonium Facility

Under all alternatives, the LANL Plutonium Facility (PF-4) would process pits and other plutonium metal (see Appendix B, Section B.2.1). Accident analyses of PF-4 for this *SPD Supplemental EIS* were based on recent safety documents for TA-55, as summarized in the data report prepared to support this *SPD Supplemental EIS* (LANL 2013). Approaches to evaluation of these accidents follow the methods used in the *Final Supplemental Environmental Impact Statement for the Nuclear Facility Portion of the Chemistry and Metallurgy Research Building Replacement Project at Los Alamos National Laboratory, Los Alamos, New Mexico* (DOE 2011a) and the earlier *LANL SWEIS* (DOE 2008b).

DOE has committed to seismic upgrades to PF-4 that would result in an updated safety-basis estimate for a seismically induced fire. Proposed future improvements that will be incorporated into PF-4 include fire-rated containers, seismically qualified fire-suppression systems, and seismically qualified portions of the confinement ventilation system. This *SPD Supplemental EIS* takes into consideration these improvements and incorporates information from the LANL safety-basis documents in force as of March 2013.

The TA-55 safety-basis documents use a hazards analysis process based on guidance provided by DOE Standard 3009-2006 (DOE 2006a). This process ranks the risk of each hazard based on the estimated frequency of occurrence and potential consequences to screen out low-risk hazards. Based on this process, a spectrum of accidents was selected. The selection process included, but was not limited to: (1) consideration of the impacts on the public and workers of high-frequency/small-consequence accidents and low-frequency/large-consequence accidents; (2) selection of the highest-impact accident in each accident category to envelope the impacts of all potential accidents; and (3) consideration of reasonably foreseeable accidents. The hazards and accident analyses considered the potential for accidents initiated by external events (e.g., aircraft crash, explosions in collocated facilities) and natural phenomena (e.g., wildfires, external flooding, earthquake, extreme winds with wind-blown projectiles).

Accident scenarios initiated by human error were also evaluated. The safety-basis documents also include evaluation of low-frequency/large-consequence accidents that are considered to be beyond-design-basis accidents.

One purpose of the TA-55 safety-basis documents is to demonstrate that, under design-basis accident conditions, the safety of the public can be assured, even with the building ventilation in a "passive" state. Thus, the safety-basis documents do not take credit in the unmitigated analysis for the building ventilation system, including multiple stages of HEPA filters, continuing to function during these design-basis accidents. Furthermore, the safety-basis documents assume that exit doors and key internal doors are open, a wind blows through the building, and 5 percent of the material made airborne from spills and 18 percent made airborne in fires is transported from the rooms within the building to the outside atmosphere. Demonstrating that the public is protected, even under these extreme conditions, provides a wide margin of safety, but does not provide a realistic estimate of how small the public consequences would be, should these accidents occur.

Over the last several years, the independent Defense Nuclear Facilities Safety Board (DNFSB) has expressed concerns to DOE related to the vulnerabilities of the PF-4 structure and components in a severe earthquake (DNFSB 2009, 2012a, 2012b, 2013a, 2013b, 2013d). The DNFSB has recently indicated in its *Twenty-Third Annual Report to Congress* that "the risk posed by the Plutonium Facility (PF-4) at Los Alamos National Laboratory remains among the Board's greatest concerns. An earthquake resulting in collapse of the facility would likely result in very high radiological doses to the public in nearby towns. The Board continues to urge senior leaders at DOE to take meaningful, near-term action to mitigate this risk" (DNFSB 2013b). This *SPD Supplemental SEIS* discusses the DNFSB concerns and DOE responses related to a seismic event affecting PF-4 as reflected in official correspondence as of August 2014.

The accident analyses for PF-4 included in this *SPD Supplemental EIS* are based on the most recent DOE-approved safety basis, which reflects ongoing safety upgrades. The 2011 DOE-approved safety basis addressed safety concerns that were identified by DNFSB prior to 2012 (DNFSB 2009; DOE 2011b, 2012b). These include improvements in the fire-suppression systems and the ability of the facility structure and confinement system to withstand design-basis earthquakes.

Defense Nuclear Facilities Safety Board (DNFSB) Concerns

In response to DNFSB concerns, the U.S. Department of Energy (DOE) provided a report on its assessment of the current state of public and worker protection for Plutonium Facility (PF-4) seismic accident scenarios and the risk reduction measures to be applied to mitigate near-term seismic risks (DOE 2013a). Consistent with DOE's requirements, a re-evaluation of seismic data, assumptions, and modeling was performed. This re-evaluation determined that PF-4 could undergo a collapse in a severe earthquake (one with peak ground motion that could occur on the order of once in ten thousand years).

Actions taken to date have both reduced the potential for collapse of PF-4 and reduced the magnitude of release that may occur. Currently, the analysis shows that the building provides its intended confinement safety function for an earthquake of an annual probability of exceedance of 1.2×10^{-4}. This is within the DOE Standard 1020 allowance provided for existing facilities (i.e., 2×10^{-4}).

DOE is taking the following near-term measures to further reduce risk at PF-4: 1) Reduce the first floor plutonium inventory limit; 2) Reduce the vault plutonium inventory limit; 3) Implement a new safety-class container for heat source plutonium, which is predominantly plutonium-238; and 4) Remove one kilogram of heat-source plutonium from the PF-4 first floor. Additionally, conceptual designs have been developed for two structural modifications that will further reduce the probability of collapse and will be installed during the next 2 to 3 years.

Based on current seismic analysis showing that PF-4 can provide its confinement safety function and on near-term risk reduction measures that reduce potential consequences, DOE determined that PF-4 can continue to operate safely while longer-term structural modifications are completed (DOE 2013a). Responding to DNFSB concerns with the current seismic analysis, an alternate analysis is being performed. DOE believes this alternate analysis will be helpful in understanding further the seismic integrity of the PF-4 facility and providing assurance that all of its structural elements that require updating are identified (DOE 2013c).

In response to DNFSB concerns regarding criticality safety at Los Alamos National Laboratory (LANL) (DNFSB 2013c, 2014), DOE responded with information on corrective actions, commitments to complete causal analysis, and needed improvements to the criticality safety program; as a precautionary measure, the LANL Director paused PF-4 programmatic operations (DOE 2013b; 2013d). Subsequent LANL actions included revision of program management plans to improve performance in Conduct of Operations and Nuclear Criticality Safety. DOE is taking a deliberate approach to resuming operations, requiring high-risk operations to undergo a Federal readiness assessment. These assessments validate that criticality safety controls are identified and implemented to ensure safety in operations.

DNFSB subsequently sent letters to DOE on June 18 and July 18, 2012 addressing additional concerns related to seismic safety at PF-4 (DNFSB 2012a, 2012b). The first letter concerned the adequacy of certain aspects of the 2011 safety-basis analysis of a seismically induced fire accident in PF-4. In particular, the letter indicated a concern with non-conservative deficiencies in DOE analysis and concluded that DNFSB's estimate of the seismically induced fire accident dose consequence was in excess of 100 rem (compared to an Evaluation Guideline of 25 rem [DOE 2006a]). The second letter requested technical information regarding the modeling being performed to characterize the PF-4 structural response to large earthquake ground motions.

DOE responded to each of the concerns raised by DNFSB in letters on September 28 and November 5, 2012 (DOE 2012c, 2012d). The DOE letter on September 28, 2012 provided information about the technical approach to the structural analysis, including key assumption and parameters. In response to DNFSB's concern that the post-seismic fire could result in mitigated dose consequences to the public exceeding 100 rem total effective dose equivalent (DNFSB 2012a), thereby requiring additional safety controls, DOE's November 5, 2012 letter discussed the conservatisms built into the approved 2011 DSA.

In responding to DNFSB's concern that the post-seismic fire analysis was deficient, DOE indicated that it considered the post-seismic fire accident analysis in the 2011 DSA reasonably conservative for the following reasons (DOE 2012d, Enclosure 1):

- PF-4 has extensive safety controls that reduce the probability and consequences of this accident scenario. These include, but are not limited to, passive confinement, robust plutonium storage systems, reduced MAR limits, and seismic switches that would isolate non-vital laboratory electrical loads, thereby eliminating key fire ignition sources. PF-4 has also dramatically reduced combustibles since 2009; implemented stringent combustible controls, ignition source controls, and fire barrier upgrades and maintenance; and made other relevant improvements.
- Previous seismic evaluations indicated laboratory rooms would maintain the configuration assumed in the DSA following a major earthquake. The PF-4 structure is being re-evaluated to consider recent seismic upgrades. Results show that, if the interior laboratory walls of PF-4 failed after a seismic event and a fire started, a lower temperature fire would result than if the walls were intact. Thus, assuming that the interior laboratory walls remain standing is both conservative and consistent with these walls meeting PC-3 seismic criteria.
- The 2011 DSA made conservative assumptions regarding internal and external door openings, fire heat release rates, and the assumed forces that would propel plutonium out of the building main floor following an earthquake.
- The 2011 DSA assumed that several fires would be ignited following an earthquake and would occur in the worst possible locations in the building.
- While the bounding LPF is derived by considering fire in only a few rooms, it is applied to all MAR in all of the rooms on the main floor for the fire portion of the source term. The analysis also assumes that all gloveboxes topple, breach, and spill plutonium.
- The 2011 DSA assumes bounding ARFs and RFs.

DOE also indicated that in its approval of the 2011 DSA, it had directed a number of further improvements to be made by September 2014. Those improvements include, but are not limited to, the following (DOE 2012d, Enclosure 1):

- Improved process descriptions to improve hazard identification;
- Improved safety system descriptions, including relevant information to improve system operability determinations;
- Re-evaluated process hazard analyses to ensure that a comprehensive accident spectrum is evaluated, the hazards identified, and appropriate safety controls are selected;

- Re-evaluated selection of bounding, representative, and unique accidents to ensure appropriate accident scenarios are selected for detailed analysis;
- Improved safety control selection process to ensure that preferences for the hierarchy of controls described in DOE-STD-3009, *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Safety Analysis Reports* (DOE 2006a), have been applied and appropriate safety controls are traceable to the hazard analysis;
- Closure of comments in the fire hazard analysis; and
- A periodically updated project management mechanism to track the status of and ensure priority for planned nuclear safety facility improvements.

On January 3, 2013, the DNFSB sent a letter to DOE expressing its concern over the vulnerability of PF-4 to a collapse pending completion of seismic upgrades and the potential for very high offsite dose consequences (DNFSB 2013a). In particular, the DNFSB observed that recent analysis performed by LANL demonstrates that the PF-4 is vulnerable to structural collapse following a large, rare earthquake (i.e., once in 8,300 years); the large plutonium inventory, coupled with the facility's proximity to the public, creates the potential for very high consequences if the building were to collapse; and structural upgrades are currently projected to take several years to complete. The DNFSB urged DOE to take near-term actions to reduce the potential consequences of a seismically induced collapse until the acknowledged seismic problems are fixed.

DOE responded to the January 3, 2013 DNFSB letter on March 27, 2013 (DOE 2013a). Secretary Chu indicated that DOE has taken significant actions to reduce PF-4 seismic-related risk including installing significant structural upgrades, removing combustible material, and repackaging and disposing of hundreds of kilograms of plutonium (DOE 2013a). Secretary Chu also indicated that DOE is continuing to take further actions to reduce the amount of plutonium at PF-4 and to improve the facility's seismic capabilities. Since PF-4 can provide its confinement safety function based on DOE's current seismic analysis and the identified near-term risk reduction measures will further reduce potential consequences, Secretary Chu concluded that PF-4 can continue to operate safely while longer-term structural modifications are completed (DOE 2013a).

On July 17, 2013, the DNFSB responded to former Secretary Chu's March 27, 2013 letter assessing public and worker protection for a seismic collapse scenario at PF-4 and indicated that the Board did not agree with the methodology used by the LANL contractor for seismic analysis upon which Secretary Chu based his conclusions (DNFSB 2013d). The letter also indicated that the Board did not agree with the DOE conclusion that the modeling demonstrated compliance with DOE standards for confinement integrity following a design-basis earthquake. The Board indicated that it was encouraged that DOE was performing an "alternate" seismic analysis.

On September 3, 2013, DOE responded and provided the DNFSB a status update on the alternate seismic analysis and a schedule for its completion (DOE 2013c). DOE indicated that the alternate analysis would be helpful in understanding further the seismic integrity of the PF-4 facility and providing assurance that all of its structural elements that require updating are identified.

Modifications currently in design are anticipated to increase the facility's seismic safety margin to collapse. Both the Draft and this *Final SPD Supplemental EIS* consider scenarios that result in significant damage to the building and evaluate the potential consequences of the event.

In order to better understand the potential impacts if a large, rare earthquake occurred, LANL prepared an addendum to the current DSA. The analyses in the addendum assume an earthquake would cause major structural damage to PF-4, including collapse of the roof onto the first floor and collapse of the first floor into the basement. The analyses assume that radioactive materials within PF-4 are subjected to spills, impacts from falling structural materials, and a subsequent major fire. The analyses evaluate two cases: 1) the hypothetical, bounding case in which it is assumed everything is damaged by spills, impacts, and fires (that is, a DR of 1); the maximum amount of damaged materials is made airborne in a respirable size (that is, a bounding ARF × RF); and that all respirable material released within the building is transported through the debris to the atmosphere (that is, an LPF of 1); and 2) a more realistic case that is still expected to bound the potential impacts but relies on more reasonable assumptions regarding the amounts of materials that could be damaged in spills, impacts, and fires; the amount of that damaged materials that might be made airborne in a respirable size; and the fraction that could be transported through the debris to the atmosphere. The results of the analyses in the addendum and their application to the surplus plutonium disposition activities at PF-4 are evaluated in this *SPD Supplemental EIS* and the *Revised Final Report, Data Call to Support the Surplus Plutonium Disposition Supplemental Environmental Impact Statement* (LANL 2013).

The DSA addendum was prepared specifically to address circumstances that could occur after a seismic collapse of PF-4 and a post-seismic fire. The 2011 DSA included an earthquake plus fire accident scenario with a bounding consequence of 23 rem (LANL 2013). The 2011 DSA assumed the facility remained standing and provided its credited safety containment, but it also assumed highly conservative ARF × RF values and 95th percentile meteorology. Consequences of structural collapse calculated in the DSA addendum range from less than a fourth of the bounding DSA design-basis earthquake with spill plus fire impacts for the more realistic case (which assumed mean values for ARF × RF and 50th percentile meteorology) to a factor of 40 higher for the hypothetical extreme bounding case (LANL 2013).

In response to these analyses, DOE has adopted several near-term measures to increase the margin of PF-4 safety. Two of the measures are structural modifications that would reduce the probability of collapse and are projected to be completed by early 2016. The third measure is to reduce the source term by lowering MAR to further reduce the risk at PF-4 (DOE 2013a). Three near-term measures are scheduled to be completed 30 days after the DSA Addendum has been approved: reducing the first floor plutonium inventory limit (from 2,600 kilograms [5,700 pounds] to 1,800 kilograms [4,000 pounds]); lowering vault MAR; and implementing a new safety-class container for heat-source plutonium which is primarily plutonium-238 (DOE 2013a, LANL 2013). In addition, removal of 1 kilogram of heat-source plutonium from the PF-4 first floor is scheduled to be completed in calendar year 2013 (DOE 2013a). The estimated reduction of the bounding dose consequence as a result of such MAR reductions is 30 to 60 percent (LANL 2013).

The DNFSB staff performed a review of the Criticality Safety Program at LANL in May 2013 and identified specific non-compliances with applicable DOE requirements and industry standards in the implementation of the program. In addition, the review identified criticality safety concerns stemming from weaknesses in conduct of operations at PF-4 and noted that some of the deficiencies were long standing and indicate flaws in Federal oversight and contractor assurance systems (DNFSB 2013c).

On August 15, 2013, DOE responded, indicating the corrective actions being taken at LANL to incorporate criticality safety controls into procedures and to improve procedures, procedure use, criticality safety postings, and criticality safety support of operations (DOE 2013b). In addition, DOE committed to determining the root causes of the problems and making improvements in Federal oversight and contractor assurance systems to improve criticality safety at LANL in general and PF-4 in particular. In a December 6, 2013, letter to the DNFSB, DOE described the process for and status of resuming PF-4 programmatic operations; the conclusions of an external review and causal analysis review chartered by the Director; two improvement plans addressing the outcomes of these reviews and prior assessments; and the nexus of the improvement plans with the LANL contractor assurance system (DOE 2013d). The improvement efforts resulted in revision of the LANL program management plans for improved performance in Nuclear Criticality Safety and Conduct of Operations.

The LANL Director paused PF-4 programmatic operations as a precautionary measure. Addressing DNFSB concerns (DNFSB 2014), DOE is employing a deliberate approach to authorize resumption of operations. Federal readiness assessments are required prior to restarting high-risk operations at PF-4. These assessments will validate that criticality safety controls are identified and implemented to ensure operations are conducted safely.

In addition to the safety basis analyses prepared for PF-4, which are conservative and provide a basis for establishing safety controls, this *SPD Supplemental EIS* also evaluates the key accident scenarios using more-realistic accident assumptions that are consistent with those used for other facilities where surplus plutonium disposition activities are being considered.

Accident Scenario Selection

The safety basis for PF-4 starts with hazard evaluations that systematically consider a wide range of potential hazards and identifies the controls needed to prevent the accidents from occurring or to mitigate the potential consequences should an accident occur. Accidents that could result in larger consequences or higher accident risks are further evaluated to identify the potential radiological consequences if the accident were to occur, as well as to identify controls to reduce the likelihood of the accident occurring and the potential radiological consequences to the extent practicable.

For facilities like PF-4, the general safety strategy requires the following:

- Plutonium materials must be contained in a glovebox (if in use) or in a container at all times, with multiple layers of confinement that prevent the materials from reaching the environment.
- Energy sources that are large enough to disperse the plutonium and threaten confinement must be minimized.

This basic strategy means that operational accidents, including spills, impacts, fires, and operator errors, never have sufficient energy to threaten the multiple levels of confinement that are always present within a plutonium facility. For PF-4, the final layer of confinement is the reinforced-concrete structure and the system of barriers, controls, and multiple stages of HEPA filters that limit the amount of material that could be released to the environment even in the case of severe internal events.

The operational events that present the greatest threats to confinement are large-scale internal fires, which, if they did occur, could present heat and smoke loads that threaten the building's ventilation system and HEPA filters. For modern plutonium facilities, the safety strategy is to prevent large internal fires by limiting the energy sources, such as flammable gases and other combustible materials, to the point that a wide-scale, propagating fire is not physically possible and to defeat smaller internal fires with safety-class or safety-significant fire-suppression systems.

Plutonium facilities, such as PF-4, are designed and operated such that the estimated frequency of any large fire within the facility would fall into the "extremely unlikely" category and would require multiple violations of safety procedures to introduce sufficient flammable materials into the facility to support such a fire. Any postulated large-scale fire in a plutonium facility such as PF-4 would be categorized as a "beyond-design-basis" event and is not expected to occur during the life of the facility.

Earthquakes present the greatest design challenges for these facilities due to the requirement to prevent substantial releases of radioactive materials to the environment during and after a severe earthquake. For safety analysis purposes, it is often assumed that after a very severe earthquake that exceeds the design loading levels of the facility equipment, enclosures, and building structure and confinement, a substantial release of radioactive material occurs within the facility. This allows designers and safety analysts to determine which additional design features may be needed to ensure greater containment and confinement of the radioactive MAR, even in a severe earthquake that could result in major damage to a reinforced-concrete facility. In these safety analyses, it is often assumed that major safety systems are not in place (unmitigated analyses) to enable estimation of the mitigation effectiveness of each of the individual safety systems or controls (mitigated analyses).

The accident scenarios selected for inclusion in this *SPD Supplemental EIS* are the ones that would present the greatest risk of radiological exposure to members of the public. Because PF-4 is a reinforced concrete facility, most of these scenarios would require substantial amounts of additional energy, either from a widespread internal fire or through a severe natural disaster such as an earthquake so severe that building safety system design limits are exceeded and confinement of the plutonium materials within the building is lost. Thus, any of the accidents presented in this *SPD Supplemental EIS* with frequencies of 1 in 10,000 per year or less would fall into the "beyond-design-basis" category and have probabilities that would fall into the "extremely unlikely" or "beyond extremely unlikely" category. None of these postulated events is expected to occur during the life of the facility.

Because the specific isotopic composition of some of the nuclear materials are classified, the MAR inventories for the accident scenarios have been converted to dose-equivalent amounts of plutonium, that is, a particular, defined mixture of plutonium and americium isotopes as used in the safety-basis analyses for PF-4. When the source terms are calculated, the plutonium equivalent releases have been converted to a dose-equivalent amount of plutonium-239 (plutonium-239 equivalent). The conversions are on a constant-consequence basis, so that the consequences calculated in the accident analyses are equivalent to what they would be if actual material inventories were used.

The following sections describe the selected accident scenarios and corresponding source terms for the alternatives.

For the selected accident scenarios, two sets of source terms are presented. First, the conservative, bounding source term estimates developed in the safety-basis process at LANL for the purpose of identifying the controls necessary to protect the public are presented. These are referred to as "Safety-Basis Scenarios"[7] in the following descriptions and analyses. In general, these source term estimates take little, if any, credit for the integrity of containers or building confinement under severe accident conditions and assume a DR of 1, meaning that all containers and material at risk would be subjected to near-worst-case conditions. The LPF accounts for the action of removal mechanisms (e.g., containment systems, filtration, and deposition) to reduce the amount of airborne radioactivity ultimately released to occupied spaces in the facility or to the environment. LPFs are assigned in accident scenarios involving a major failure of confinement barriers. The safety-basis evaluations generally assume an LPF of 1 for the unmitigated case, meaning that all of the material that is made airborne and respirable within the building or process enclosure is released to the environment. For the mitigated case, the LANL safety-basis analyses only take credit for the PF-4 building operating in a passive mode, with the doors open and the building confinement system and HEPA filters not functioning, and assumes a lower LPF, generally 0.05.

For the purposes of this *SPD Supplemental EIS*, a second set of accident source terms was developed that attempts to present more-realistic, but still conservative, estimates of source terms. These source term estimates take into account a range of responses of facility features and materials containers and typical operating practices employed at DOE's plutonium facilities. For design-basis-type accidents, a DR of 1 would not normally be realistic if the required safety systems function as expected during the accident and operational procedures are followed. Similarly, the building confinement, including HEPA filters, is expected to continue functioning, although perhaps at a degraded level, during and after the accident. This *SPD Supplemental EIS* uses the term "SEIS Scenario" to identify these accident scenarios. The SEIS Scenarios use conservative, but more realistic assumptions regarding the potential release of radioactive material to the environment compared to those used in the Safety-Basis Scenarios; for example, they take limited credit for some containers surviving an accident and for some airborne material being captured by an air filtration system. Both the Safety-Basis and the SEIS Scenarios use conservative ARFs and RFs from DOE Handbook 3010, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities* (DOE 1994).

These SEIS Scenario source terms are developed in a manner consistent with those for the SRS facilities being considered for surplus plutonium disposition activities to help facilitate the comparison of the

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[7] *This* SPD Supplemental EIS *uses the term "Safety-Basis Scenario" to identify accident scenarios that use conservative assumptions regarding the potential release of radioactive material to the environment. For example, no credit is taken for some containers surviving an accident or for some airborne material being captured by an air filtration system even though this would likely be the case. The safety-basis process is used to identify the controls needed to mitigate the impacts of accidents to meet established guidelines for protection of the public and workers.*

potential radiological impacts of severe design-basis and beyond-design-basis accidents among the various surplus plutonium disposition pit disassembly and conversion options.

The accident scenarios associated with the proposed surplus plutonium disposition activities at LANL's PF-4 include the following:

Criticality. The potential for a criticality exists whenever there is a sufficient quantity of special nuclear material in an unsafe configuration. Although a criticality could affect the public, its effects would be primarily associated with workers near the accident. The Safety-Basis and SEIS Scenarios are identical for a criticality accident.

This accident is identified as "unlikely" (with a frequency in the range of 1×10^{-2} to 1×10^{-4}) without preventive controls. The bounding criticality accident was assumed to occur in a plutonium solution. The process representing the criticality accident scenario was considered to occur in a glovebox that also contains a deep well that has a sufficiently large volume to support a realistic and credible accident scenario. Engineered and administrative controls would be available to ensure that the double-contingency principles are in place for all portions of the process. It was assumed that human error results in multiple failures, leading to an inadvertent nuclear criticality. With these engineered and administrative controls, the estimated frequency of this accident is in the range of 1×10^{-4} to 1×10^{-6} per year ("extremely unlikely"). A bounding source term resulting from 1×10^{19} fissions was assumed.

Spills. Spills of radioactive and/or chemical materials could be initiated by failure of process equipment and/or human error, natural phenomena, or external events. Radioactive and chemical material spills typically involve laboratory room quantities of materials that are relatively small compared to releases caused by fires and explosions. Laboratory room spills could affect members of the public, but represent a more serious risk to the laboratory room workers. Larger spills involving vault-size quantities are also possible.

Safety-Basis Spill Scenario. The surplus plutonium disposition operations at PF-4 would use the Advanced Recovery and Integrated Extraction System (ARIES) facilities within PF-4. Accidents identified in the safety-basis documents include spills of oxide, with a MAR of 4,500 grams (159 ounces) of plutonium, in the ARIES canning module, the ARIES nondestructive assay area, or the ARIES integrated packaging system. For these spills, a DR of 1, an ARF of 0.002, and an RF of 0.3 were estimated, resulting in a release of 2.7 grams (0.0952 ounces) to the building. LANL safety-basis documents conservatively assign an LPF of 0.05 to account for the potential for open doors during evacuation of the building. Using this LPF would result in a release of 0.14 grams (0.0049 ounces) of plutonium to the environment.

SEIS Spill Scenario. As with the Safety-Basis Scenario, a spill of oxide in the ARIES facilities within PF-4 was postulated. The SEIS Spill Scenario would be the same as the Safety-Basis Scenario, with the exception that such a spill would not be expected to threaten the integrity of the building confinement system or the HEPA filters; for the SEIS Scenario, an LPF of 0.005 was estimated. Using this LPF would result in a release of 0.014 grams (0.00049 ounces) of plutonium to the environment.

A spill of molten metal that then rapidly oxidizes or burns within the ARIES metal oxidation glovebox was also postulated as an SEIS Spill Scenario. For this accident, a MAR of 4,500 grams (159 ounces) plutonium, a DR of 1, an ARF of 0.0005, and an RF of 0.5 were estimated, which would result in a release of 1.1 grams (0.039 ounces) to the building. This spill would not be expected to threaten the integrity of the building confinement system or the HEPA filters, so an LPF of 0.005 was estimated. Using this LPF would result in a release of 0.0055 grams (0.00019 ounces) of plutonium to the environment. The impacts of this accident would be bounded by a spill of a container of oxide, as discussed above.

Fires. Fires that occur in the facility could lead to the release of radioactive materials with potential impacts on workers and the public. Initiating events may include internal process and human error events; natural phenomena, such as an earthquake; or external events, such as an airplane crash into the facility. Combustibles near an ignition source could be ignited in a laboratory room containing the largest amounts of radioactive material. The fire may be confined to the laboratory room, propagate uncontrolled and without suppression to adjacent laboratory areas, or lead to a major fire. A fire or deflagration in a HEPA filter could also occur due to an exothermic reaction involving reactive salts and other materials. External fires (i.e., wildfires) were also considered. Though unlikely, a wildfire could directly affect the facility, in which case the scenario would be similar to fires initiated by the other means discussed above. A wildfire could also affect the infrastructure in the vicinity of LANL. Wildfires are discussed in more detail below.

Safety-Basis Fire Scenarios. The bounding glovebox fire identified in safety-basis documents that would directly involve surplus plutonium disposition operations is a glovebox fire in the pyrochemical metal preparation area (LANL 2013). For this accident, a MAR of 9,000 grams (317 ounces) of plutonium in salt form was assumed. For the fire with plutonium in a salt form, a DR of 1, an ARF of 0.0005, and an RF of 0.5 were estimated, which would result in a release of 2.25 grams (0.0794 ounces) to the building. LANL safety-basis documents conservatively assign an LPF of 0.1 to account for the potential for an open door from the laboratory room to the corridor and open exit doors during evacuation of the building (although the doors have automatic closers that are specifically credited as part of the confinement system). Using this LPF would result in a release of 0.22 grams (0.0078 ounces) of plutonium to the environment.

The bounding fire for the facility identified in the safety-basis documents is a large fire within the TA-55 vault (LANL 2013). For this accident to occur and progress to a large fire, the combustible limits for the vault (2.3 kilograms [5 pounds]) must be greatly exceeded and the sprinkler system must fail to extinguish the fire. For this accident, a MAR of 1,500 kilograms (3,310 pounds) of plutonium as metal or oxide was assumed. For the fire with burning plutonium metal, a DR of 1, an ARF of 0.0005, and an RF of 0.5 were estimated, resulting in a release of 375 grams (13 ounces) to the building. An LPF of 0.05 was assigned, which conservatively assumes that multiple sets of interior doors (from the vault, in basement hallways, to stairwells, and in upstairs hallways) remain open and exit doors are open during evacuation (although the doors have automatic closers that are specifically credited as part of the confinement system). Using this LPF would result in a release of 19 grams (0.67 ounces) of plutonium to the environment.

SEIS Fire Scenarios. As with the Safety-Basis Scenario, the bounding glovebox fire scenario is a glovebox fire in the pyrochemical metal preparation area involving plutonium salt (LANL 2013). The SEIS Scenario parameters for a glovebox fire would be the same as those for the Safety-Basis Scenario, with the exception that this accident would not be expected to threaten the integrity of the building confinement system or the HEPA filters, so an LPF of 0.005 was estimated. Using this LPF would result in a release of 0.011 grams (0.00039 ounces) of plutonium to the environment.

A spill of molten metal that then rapidly oxidizes or burns within the ARIES metal oxidation glovebox was also postulated. Such an accident has a lower MAR and proportionally lower impacts that would be bounded by the impacts of the above glovebox fire.

As with the Safety-Basis Scenario, the bounding fire for the facility is a large fire within the TA-55 vault (LANL 2013). For this accident to occur and progress to a large fire, the combustible limits for the vault (2.3 kilograms [5 pounds]) must be greatly exceeded and the sprinkler system must fail to extinguish the fire. For this accident scenario, a MAR of 1,500 kilograms (3,310 pounds) of plutonium metal was assumed. Because this material is generally double-contained in metal containers, a reasonably conservative DR of 0.1 was assumed, although realistically it would be even lower. For the fire with burning plutonium metal, an ARF of 0.0005 and an RF of 0.5 were estimated, resulting in a release of 37.5 grams (1.32 ounces) to the building. The corresponding values for oxide powder, if it was assumed that oxide was present instead of metal, are given as an ARF of 0.006 and an RF of 0.01, resulting in a release of 9 grams (0.32 ounces) to the building. Because the respirable release fraction (ARF × RF) for the metal is higher, it was conservatively assumed that all material in the vault is metal. This design-basis accident is not expected to seriously threaten the integrity of the building confinement system or the HEPA filters, which are designed to continue to provide their safety function throughout such an accident. Therefore, an LPF of 0.005 was assumed. Using these factors would result in a release of 0.19 grams (0.0067 ounces) of plutonium to the environment for a fire involving plutonium metal and a release of 0.045 grams (0.0016 ounces) for a fire involving plutonium oxide. Realistically, a lower LPF would be expected. The PF-4 structure, filter plenums, HEPA filters, and ductwork for the plenums are designated as safety-class and would be expected to function during and after such a fire. In addition, the sprinkler system should be highly effective in limiting the fire.

Explosion. Explosions that could occur in the facility could lead to the release of radioactive materials, with potential impacts on workers and the public. Initiating events may include internal process and human error events; natural phenomena, such as an earthquake; or external events, such as an explosive gas transportation accident. Explosions could both disperse nuclear material and initiate fires that could propagate throughout the facility. An explosion of methane gas followed by a fire in a laboratory area could potentially propagate to other laboratory areas and affect the entire facility.

Safety-Basis Explosion Scenario. The bounding explosion identified in the safety-basis documents is a hydrogen deflagration resulting from the dissolution of plutonium metal (LANL 2013). For this accident, the MAR is 1,040 grams (36.7 ounces) of plutonium as a salt or oxide. For the deflagration with plutonium in a salt form, a DR of 1, an ARF of 0.2, and an RF of 1.0 were estimated, which would result in a release of 208 grams (7.34 ounces) to the building. For the deflagration with plutonium in an oxide form, a DR of 1, an ARF of 0.005, and an RF of 0.3 were estimated, which would result in a release of 1.6 grams (0.055 ounces) to the building. LANL safety-basis documents assign an LPF of 0.05, which is considered conservative and bounding (the calculated LPF value is 0.012) taking into account the potential for open doors during evacuation of the building, even though the doors have automatic closers that are specifically credited as a safety system (LANL 2013). Using this LPF would result in a release of about 10 grams (0.37 ounces) of plutonium to the environment for plutonium in a salt form and 0.078 grams (0.0028 ounces) for plutonium in an oxide form.

SEIS Explosion Scenario. The SEIS Explosion Scenario would be the same as the Safety-Basis Scenario, with the exception that this accident would not be expected to threaten the integrity of the building confinement system or the HEPA filters, so an LPF of 0.005 was estimated. Using this LPF would result in a release of 1.0 gram (0.035 ounces) of plutonium to the environment for plutonium in a salt form and 0.0078 grams (0.00028 ounces) for plutonium in an oxide form.

Natural Phenomena. The potential accidents associated with natural phenomena include wildfires, earthquakes, high winds, flooding, and similar naturally occurring events. For PF-4, a severe earthquake could lead to the release of radioactive materials and exposure of workers and the public, as well as cause the partial collapse of facility structures, falling debris, and failure of gloveboxes and nuclear materials storage facilities. An earthquake could also initiate a fire that propagates throughout the facility and results in an unfiltered release of radioactive material to the environment. In addition to the potential exposure of workers and the public to radioactive and chemical materials, an accident could cause human injuries and fatalities from the force of the event, such as falling debris during an earthquake or the thermal effects of a fire.

Design-Basis Earthquake with Spill. The analysis of impacts of a severe, design-basis earthquake have been revised in the current safety-basis documents for PF-4 in an attempt to provide a more realistic, yet conservative, estimate of the potential impacts. These analyses have established limits for the MAR within the facility that ensure that, in all design-basis events, including a seismically induced spill plus fire, the impacts on the maximally exposed offsite individual would be below the 25-rem safety goal in the DOE Evaluation Guideline described in the *Preparation Guide for U.S. Department of Energy Nonreactor Nuclear Facility Documented Safety Analyses* (DOE Standard 3009) (DOE 2006a). In conjunction with engineered controls, keeping the MAR below the facility limit is effected by administrative controls and technical safety requirements. According to current safety-basis documents, the MAR limit for the first floor of PF-4, which contains the main laboratory areas, is 2,600 kilograms (5,730 pounds) of plutonium. All of this material was assumed to be at risk during the design-basis seismic event, and a DR of 1.0 was assigned in the LANL safety-basis documents for this event. This is quite conservative in that spillage outside of the confinement of a glovebox is not expected in a design-basis earthquake because the gloveboxes are expected to survive such an earthquake.

Other material stored in the PF-4 basement in robust containers, shipping containers, and in vaults is expected to survive extreme conditions, including the design-basis seismic event. Whereas this material might be affected in a beyond-design-basis accident initiated by an earthquake, it is not considered to be at risk in a design-basis event and would not be expected to contribute to the overall dose. Therefore, this material was excluded from the calculations. As discussed below, these materials are considered at risk in a beyond-design-basis accident initiated by an earthquake that results in a building collapse.

Under the proposed expansion of surplus plutonium disposition operations, the mix of MAR is expected to change to accommodate the new activities. The MAR associated with the proposed higher throughput for the surplus plutonium disposition mission includes bulk plutonium dioxide powder, bulk metal, molten metal in casting furnaces, and tritium in getters[8] (LANL 2013). Other ongoing work within the facility, including work with plutonium-238 heat-source material, would continue with typical or illustrative forms and quantities provided in the current safety-basis documents. However, while the makeup of the plutonium could change, the MAR limit of 2,600 kilograms (5,730 pounds) of plutonium material on the first floor would not change. The mix of MAR within this limit would be managed to meet the DOE Evaluation Guide dose due to an accident of 25 rem at the nearest offsite location in accordance with DOE Standard 3009. Accordingly, some of the material now on the floor and in gloveboxes may have to be moved to robust storage to accommodate the expanded surplus plutonium disposition glovebox activities.[9]

<u>Safety-Basis Design-Basis Earthquake with Spill Scenario.</u> The LANL safety-basis documents assume that, for the design-basis earthquake with a spill, all of the surplus plutonium in various forms would be at risk, and a DR of 1.0 is assigned. This means that all of the MAR would be available for dispersal, even though a large portion of the MAR would be in robust containers that have been demonstrated via challenging engineering tests to be leak-tight under such accident conditions (DOE 2012b). This is judged to be quite conservative because spills outside of glovebox confinement are not expected. Standard bounding ARFs and RFs for spills were applied to each material type (DOE 1994).

The LANL safety-basis documents indicate that the predicted LPF for the design-basis spill could vary depending on the location within the building, but a general LPF of 0.05 was found to be bounding, even with key doors open and the building ventilation system off. This value was used in safety-basis analyses for all releases except for the seismically induced fire. More realistically, the building confinement system should still work, including fans and HEPA filters, and the LPF would be much lower (LANL 2013). Using an LPF of 0.05 would result in a release to the environment of 82 grams (2.9 ounces) of plutonium-239 equivalent under the lower PF-4 throughput case and 121 grams

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[8] *A tritium getter is a material that absorbs free tritium and chemically binds it within its own structure.*

[9] *At the time this* SPD Supplemental EIS *was prepared, the safety-basis documents for PF-4 had an established MAR limit of 2,600 kilograms of plutonium. As discussed earlier in the introduction to this section of this appendix, DOE has proposed several near-term measures to increase the margin of PF-4 safety; one of these measures is to reduce the MAR on the first floor of PF-4 to 1,800 kilograms.*

(4.3 ounces) under the higher PF-4 throughput case.[10] Approximately 50 percent of the overall release would be due to surplus plutonium disposition materials under the lower throughput case and 74 percent under the higher throughput case.

SEIS Design-Basis Earthquake with Spill Scenario. For the Safety-Basis design-basis earthquake with a spill, all of the surplus plutonium in various forms was assumed to be at risk of damage. For the purposes of this *SPD Supplemental EIS* analysis, a DR of 0.25 was assumed because some of the MAR would be in robust containers and would not be damaged by an earthquake. This is still considered to be quite conservative because spills outside of glovebox confinement would not be expected. No changes to the Safety-Basis Scenario ARFs and RRFs for spills of each material type were assumed for the SEIS Design-Basis Earthquake with Spill Scenario. The building confinement system should still work after a design-basis accident, including fans and HEPA filters, because these are considered safety systems and are seismically qualified. Therefore, for the SEIS Scenario, an LPF of 0.005 was assumed. Using these factors would result in a release to the environment of 2.0 grams (0.071 ounces) of plutonium-239 equivalent under the lower throughput case and 3.0 grams (0.11 ounces) under the higher throughput case. Approximately 50 percent of the overall release would be due to surplus plutonium disposition materials under the lower throughput case and 74 percent under the higher throughput case.

Design-Basis Earthquake with Spill plus Fire. The safety analyses for PF-4 also address the potential impacts of a design-basis earthquake followed by a fire. The spill-only scenario is described above. The fire scenario includes the initiation of a fire that contributes to the potential release of nuclear material from the facility. Although a seismic event is not expected to start a fire because of the very low combustible loading in the facility, the potential for a fire is considered a credible scenario, given that ignition sources are present as part of normal operations. Therefore, the impact of a seismically induced fire was evaluated, along with a spill release caused by a seismic event. For the purposes of determining the impacts of this bounding seismic event, the spill was assumed to occur first and to contribute to the fire scenario source term.

Safety-Basis Design-Basis Earthquake with Spill plus Fire Scenario. The safety-basis documents make conservative assumptions about internal and external door openings, fire heat release rates, and the assumed forces that would propel radioactive material out of the building main floor following an earthquake. The forces that would propel radioactive material out of the building were assumed to have the following two key components:

- Fires in laboratory rooms would cause air to flow out of the laboratories into the main corridors; the laboratory doors are assumed to be open for the duration of the event. That air flow would entrain airborne materials and increase pressure in the corridors. The increased pressure causes plutonium contaminated air to flow out of the building exits at the ends of the two main corridors.

- The main floor exit doors (five doors per corridor) were all assumed to be open for the first five minutes of the accident. The analysis assumed a 2-meter-per-second wind flows down the corridor, further propelling contaminated air from PF-4; the wind speed was based on a computational fluid dynamics analysis that considered 48 combinations of outside wind speeds and directions and ignored adjacent buildings. In particular, the effectiveness of the adjacent building (PF-3) at blocking this air flow was ignored (DOE 2012d, Enclosure 1:6).

The LANL safety-basis documents assumed that, for the design-basis earthquake with a spill plus fire, all of the LANL plutonium in various forms is at risk and assigned a DR of 1.0, even though a large portion of the MAR would be in robust containers. The MAR due to surplus plutonium disposition operations

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[10] *The lower PF-4 throughput case corresponds to the disassembly and conversion of 2 metric tons (2.2 tons) of pit plutonium over a 7-year period; the higher PF-4 throughput case corresponds to the disassembly and conversion of 35 metric tons (38.6 tons) of pit plutonium over a 22-year period.*

and other ongoing activities was assumed to be similar to that of the Safety-Basis Design-Basis Earthquake with Spill Scenario, with the same amounts and types of MAR and DRs. The ARFs and RFs for the fire event would be different than those for spills and were assumed to be the bounding values from DOE Handbook 3010 (DOE 1994). The safety-basis documents indicate that the predicted LPF for a fire following a design-basis earthquake could vary, depending on the location within the building, but a general LPF of 0.18 was found to be bounding. Using an LPF of 0.18 would result in a release to the environment of 169 grams (6.0 ounces) of plutonium-239 equivalent under the lower throughput case and 306 grams (11 ounces) under the higher throughput case for the fire contribution.

Together, the spill contribution plus the fire contribution would result in a release to the building. Using an LPF of 0.05 for the spill and 0.18 for the fire would result in a combined spill plus fire release to the environment of 250 grams (8.8 ounces) of plutonium-239 equivalent under the lower throughput case and 427 grams (15 ounces) under the higher throughput case. Approximately 47 percent of the overall release would be due to surplus plutonium disposition materials under the lower throughput case and 72 percent under the higher throughput case.

<u>SEIS Design-Basis Earthquake with Spill plus Fire Scenario.</u> For this *SPD Supplemental EIS*, a DR of 0.25 was assumed because much of the MAR would be in robust containers and not damaged by the fires. This is still considered to be conservative because fires are expected to be very localized, such that most of the material in containers or spilled would not be subjected to the direct fire effects of heat and air movement that might aerosolize additional material in excess of that volatilized as a direct result of the spills.

DOE has indicated to the DNFSB that:

> PF-4 has extensive safety controls that reduce the probability and consequences for this accident scenario. These include, but are not limited to, passive confinement; robust plutonium storage systems; reduced material-at-risk limits; and seismic switches that would isolate non-vital laboratory electrical loads, thereby eliminating key fire ignition sources. PF-4 has also dramatically reduced combustibles since 2009, and implemented stringent combustible controls, ignition source controls, fire barrier upgrades and maintenance, and other relevant improvements (DOE 2012d, Enclosure 1:6).

Collectively, these features, which are not credited in the safety-basis documents, reduce the likelihood of post-seismic fires, the potential magnitude of those fires, and the amount of material that might be released. The SEIS seismic scenario assumes an LPF associated with the fire contribution of 0.005, consistent with the degraded but continued functioning of the building confinement system and HEPA filters.

For the SEIS Scenario seismically-initiated fire, a DR of 0.25 is assumed and the Safety-Basis Scenario bounding ARFs and RFs for fires were applied to each material type. Recognizing that the LPF varies for different materials and locations, that the fire hazard analysis indicates that only a few rooms are susceptible to a fire, that the exterior doors would be closed (except during evacuation), and that the building confinement and ventilation systems, though degraded, would continue to function, an LPF of 0.005 was assumed. Using an LPF of 0.005 for the SEIS Scenario would result in a release to the environment of 1.8 grams (0.063 ounces) of plutonium-239 equivalent under the lower throughput case and 3.0 grams (0.11 ounces) of plutonium-239 equivalent under the higher throughput case for the fire contribution from the design-basis earthquake accident. The spill contribution would be the same as presented in the SEIS Design-Basis Earthquake with Spill Scenario above.

Together, the spill contribution plus the fire contribution would result in a bounding source term for the SEIS Design-Basis Earthquake Spill plus Fire Scenario. Using an LPF of 0.005 for the spill and an overall LPF of 0.005 for the fire would result in a combined spill plus fire release to the environment of 3.8 grams (0.13 ounces) of plutonium-239 equivalent under the lower throughput case and 6.0 grams

(0.21 ounces) under the higher throughput case. Approximately 44 percent of the overall release would be due to surplus plutonium disposition materials under the lower throughput case and 68 percent under the higher throughput case.

The frequency of the accident, an earthquake coupled with a seismically induced fire, was estimated to be on the order of 1 in 10,000 years. The facility is expected to perform its structural and safety confinement functions adequately in the LANL design-basis earthquake (estimated peak horizontal and vertical ground accelerations of 0.47 *g* and 0.51 *g*,[11] respectively, with a return interval of about 2,500 years).

Beyond-Design-Basis Accident – Earthquake-Induced Collapse plus Fire.[12] This *SPD Supplemental EIS* also evaluates the potential radiological impacts of an earthquake so severe that it would cause major structural damage to the heavily reinforced PF-4. This earthquake was assumed to damage the internal structures causing the collapse of the roof onto the first floor and collapse of the first floor into the basement. The analyses assume that radioactive materials within PF-4 are subjected to spills, impacts from falling structural materials, and a major fire. This accident scenario postulates an earthquake that is of greater intensity than the LANL design-basis earthquake. The assumed extent of damage is highly unlikely even in an earthquake with ground motion much higher than the design-basis earthquake. Although there could be a substantial release of radioactive material following such an earthquake accompanied by a major fire, loss of life within the facility and within the region due to seismic damage, not a release of radiation from the damaged PF-4, would be the predominant impact of such an earthquake.

For this beyond-design-basis event, the MAR would include that estimated for the design-basis events plus additional material in the basement and vaults that could be affected by falling debris and fires. The MAR assumed for this beyond-design-basis accident was 12,000 kilograms (26,000 pounds) of plutonium material.

<u>Safety-Basis Beyond-Design-Basis Accident – Earthquake-Induced Collapse plus Fire Scenario.</u> Although a source term for a beyond-design-basis accident scenario is not typically calculated in the safety-basis analyses, LANL has prepared an addendum to the safety-basis documents for the PF-4 facility that addresses a hypothetical total collapse and subsequent fire (LANL 2013). The analyses include two cases – a bounding case and a more realistic case. The bounding case, performed to ensure the maximum potential impacts had been evaluated, uses extremely conservative, near-worst-case parameters. In the bounding case analysis, the DR for all material on the first floor was assumed to be 1, for material in the basement it was assumed to range from 0.1 to 1, and for the remainder of the material (in vaults and other locations) it was assumed to range from 0.01 to 1. The LPF for the bounding case, regardless of the location of the material or release mechanism was assumed to be 1. The source terms and consequences calculated using the bounding parameters were 31 to 34 times higher than those discussed below using more realistic parameters. This analysis represents a bounding case, but is not sufficiently realistic for planning purposes.

The more realistic case is conservative and likely over-estimates the potential releases, but uses more realistic parameters. That case makes differing assumptions depending on the location and type of MAR,

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[11] *g = acceleration relative to free fall.*

[12] *For purposes of this* SPD Supplemental EIS*, a seismically initiated collapse of the roof and first floor of the PF-4 building, with widespread damage to containers causing spills and impacts from debris, followed by widespread fires involving much of the MAR on the first floor, basement, and vaults is identified as the "Beyond-Design-Basis Accident – Earthquake-Induced Collapse plus Fire" scenario. Until ongoing seismic upgrades to the PF-4 structures are completed (scheduled for early 2016), an earthquake with a return interval of about 1 in 8,300 years might initiate structural damage to the facility. Although the earthquake by itself is not a beyond-design-basis event, the level of damage, spills, impacts, and fires postulated for this scenario is estimated to decrease the probability of releases of the magnitude considered by a factor of 10 to 100; hence, the overall event is extremely unlikely. Once seismic upgrades are completed, the overall probability of a seismically initiated event of this magnitude is expected to be extremely unlikely to beyond extremely unlikely (greater than 1 in 100,000 years).*

but considers a DR of 0.1 for the oxide and metal from spills and fires and 0.5 from impacts on both the main floor and basement of PF-4. For some of the other more volatile materials, DRs of 1 are assumed. Since a wide range of materials were assumed to be vulnerable to spills, impacts from falling debris, and long-burning external fires, median or average ARFs and RFs from the DOE Handbook 3010 (DOE 1994) were assumed. Extremely high LPFs were also assumed. For releases due to spills, an LPF of 0.3 was assumed. For releases due to impacts and fires, an LPF of 0.5 was assumed. Estimated releases to the atmosphere for this case are 321 grams (11 ounces) of plutonium-239 equivalent under the lower throughput case, and 362 grams (13 ounces) of plutonium-239 equivalent under the higher throughput case. Of these releases, materials associated with the Surplus Plutonium Disposition Program would account for approximately 18 percent of the release under the lower throughput case and 32 percent under the higher throughput case.

The frequency of an earthquake that results in wide-scale damage and loss of confinement for the building, coupled with a widespread seismically initiated fire, was estimated to be in the range of 1×10^{-5} to 1×10^{-7} per year or lower (extremely unlikely to beyond extremely unlikely) (see footnote 12).

SEIS Beyond-Design-Basis Accident – Earthquake-Induced Collapse plus Fire Scenario. The SEIS Scenario relies on the more realistic total collapse scenario analyzed in the addendum to the current DSA. While some of the key factors used for the PF-4 analysis are higher and others lower than those used for the SRS facilities, the overall level of conservatism is similar. Therefore, the more realistic analysis in the DSA addendum discussed for the Safety Basis Beyond-Design-Basis Accident – Earthquake-Induced Collapse plus Fire Scenario is also used as the basis for the SEIS Beyond-Design-Basis Accident – Earthquake-Induced Collapse plus Fire Scenario in the current analysis.

Wildfires. The potential impacts of wildfires on LANL were evaluated in Appendix D of the 2008 *LANL SWEIS* (DOE 2008b). Wildfires are a reasonably expected event in the region; in the *LANL SWEIS*, the annual frequency of occurrence was estimated to be 0.05 (once every 20 years). The evaluation included in the *LANL SWEIS* identified the facilities most at risk of radiological release in the event of a wildfire and did not include any buildings in TA-55. Wildfires such as the Las Conchas fire of June 2011 and Cerro Grande fire of May 2000 are not expected to threaten these facilities because the shells of these facilities are constructed of noncombustible materials and a buffer area free of combustible materials is maintained around them. In recognition of the hazards of wildfire, forests are thinned as part of the ongoing Wildfire Mitigation Program at LANL. The purpose of the thinning is to reduce the fuel load available in the event of a fire.

A wildfire in the LANL region could indirectly affect operations at LANL by interrupting electrical services and limiting access to roadways. In the event of a wildfire, the LANL emergency operations center would be activated and, as with the Las Conchas fire, if determined to be necessary, LANL and the townsite would be preemptively evacuated. If a regional wildfire disrupted the power provided to PF-4, emergency backup power would be provided locally to maintain the most important systems. Emergency backup power would be provided to PF-4 by the TA-3 power plant. Emergency backup generators dedicated to PF-4 would provide power to that facility. Plutonium materials stored within LANL plutonium facilities or in ongoing operations are generally stable in their configuration and would not require active cooling systems to keep them stable. Therefore, maintenance of power is not necessary to prevent significant releases to the environment.

Volcanism. A preliminary evaluation of volcanic hazards at LANL was reported in the *Preliminary Volcanic Hazards Evaluation for Los Alamos National Laboratory Facilities and Operations* (Keating et al. 2010). Based on an evaluation of information on the volcanic history of the region surrounding LANL, the report described the potential volcanic hazards to LANL from future eruptions in the region. The preliminary calculation of the recurrence rate for silicic eruptions is about 1×10^{-5} per year in the Valles caldera study region. Similarly, the preliminary calculation of the recurrence rate for basaltic eruptions along the Rio Grande rift is 2×10^{-5} per year. These recurrence rates were calculated by dividing the number of eruptive events by the active eruption period. The estimates of past recurrences rate are not the same as the probability of future eruptions that might affect a given facility. Although it cannot be ruled out, volcanism in the vicinity of TA-55 within the lifetime of the PF-4 operations is unlikely (Keating 2011).

DOE Standard: Natural Phenomena Hazards Site Characterization Criteria (DOE-STD-1022-94) identifies the potential hazards associated with volcanoes, including lava flows, ballistic projections, ash falls, pyroclastic flows and debris avalanches, mud flows and flooding, seismic activity, ground deformation, tsunami, atmospheric effects, and acid rains and gases (DOE 2002c). The primary hazard to PF-4 from a silicic eruption would likely be fallout of volcanic ash and pumice from a silicic volcanic eruption plume. Based on the areal distribution of the deposits from past eruptions, the high terrain of the caldera rim to the west of LANL is expected to limit the eastward extent of lava flows and pyroclastic flows. Hazards from ballistic projections, ground deformation, and volcanic gases are also expected to be limited to a similar area within the topographic rim of the Valles caldera to the west of LANL. In the absence of local bodies of surface water, tsunamis are not expected to pose a hazard to TA-55. Atmospheric effects (volcanogenic thunderstorms with lightning) and acid rains may affect facilities at TA-55, but are not expected to result in acute effects on operations and materials within the confines of PF-4.

Ash fall may produce roof loading; loadings associated with ash fall may be sufficient to exceed design load limits for the TA-55 facilities. In that event, structural failure could occur. In such case, vaults and interior rooms should remain relatively intact. A related hazard would be secondary mobilization of ash fall by rain, forming mudflows. This possible hazard would be naturally mitigated by the relatively low slopes at TA-55 and the presence of deep canyons that would channel flows from the Jemez Mountains west of Los Alamos.

Lava flows may engulf or bury surface infrastructure and buildings. Basaltic lava flows may extend several kilometers from a vent and be up to several meters thick, with a temperature of 1,652 to 2,192 °F (900 to 1,200 °C). Explosions and surges may damage surface and subsurface facilities within several hundred meters of a vent. Because ash falls have the potential to affect large areas, the probability of volcanism producing an eruptive vent, explosions and surges, or lava flows near the area of TA-55 likely would be lower than the probability of ash fall affecting TA-55.

Based on the expected similarities between the facility impacts of a seismically induced spill plus fire event and the volcanic ash fall event, it is expected that the seismically induced event would result in consequences and risks similar to or greater than those for the volcanic ash fall event. The PF-4 seismic scenarios conservatively assumed that the following mechanisms would be available for release: powder spills such as those associated with the seismically initiated building collapse; localized fire-induced pressurized releases of powder from storage containers; and localized fires such as those associated with the fire scenario. Localized fire-induced pressurized releases of powder from a limited number of storage containers were assumed to occur. Typical temperatures of ash falls, as indicated by the Pinatubo and Mount St. Helens eruptions are relatively cool (less than 86 °F [30 °C]) (Keating 2011) and should not significantly impact the probability of fires associated with structural failures.

Because the release associated with structural failure resulting from ash fall loads is driven by the same physical phenomena, the MAR and the release mechanisms should be similar to those for the analyzed seismic events. Thus, conservative DRs and respirable release fractions applied to the material released as a result of impact or thermal stress for seismic events are applicable to the volcanic ash fall event. The building LPF conservatively assumed for the seismic analysis is expected to be the same as or higher than the LPF associated with volcanic ash fall events because the ash would contribute to the tortuousness of the leak path.

The frequency of the earthquake that results in wide-scale damage and loss of confinement for the building (on the order of once in 100,000 years), coupled with a widespread seismically initiated fire, was conservatively assumed to be 0.00001 per year for risk calculation purposes. This is expected to be the same order of magnitude as the upper limit for the volcanic events described above.

Airplane crash. The potential release of radioactive materials from an unintentional airplane crash into a building was considered in the safety documents. In accordance with DOE Standard 3014, an aircraft impact analysis was performed for PF-4 (LANL 2013). This analysis concluded that the largest aircraft that would exceed the DOE Standard 3014 evaluation guideline of 10^{-6} (1 chance in 1 million) per year for an aircraft crash into PF-4 would be a general aviation aircraft (LANL 2013). The overall probability of an aircraft crashing into PF-4 in a given year was calculated to be 5.6×10^{-6}. Accident impacts from larger aircraft were not considered further in this *SPD Supplemental EIS*. The impacts of a general aviation aircraft crash into PF-4 were evaluated and the facility structure and interior gloveboxes and containers are robust enough that only minor interior spills, but no substantial release from the building, are expected. This accident is bounded by other accidents addressed in this *SPD Supplemental EIS*.

Accident scenarios and source terms for pit disassembly and conversion capability in PF-4 are presented in **Table D–9**.

Table D–9 Accident Scenarios and Source Terms for the Los Alamos National Laboratory Plutonium Facility Pit Disassembly and Conversion Capability

Accident Frequency (per year)	*Scenario*	*MAR (grams Pu)* [a]	*DR*	*ARF*	*RF*	*LPF*	*Release (grams)* [a]
Criticality 1×10^{-4} to 1×10^{-6} (extremely unlikely)	Safety-Basis & SEIS Scenario	–	–	–	–	–	1×10^{19} fissions
Spill in ARIES 1×10^{-4} to 1×10^{-6} (extremely unlikely)	Safety-Basis Scenario	4,500	1	0.002	0.3	0.05	0.14 Pu 0.28 PuE
	SEIS Scenario	4,500	1	0.002	0.3	0.005	0.014 Pu 0.028 PuE
Glovebox fire in the pyro-chemical metal preparation 1×10^{-4} to 1×10^{-6} (extremely unlikely)	Safety-Basis Scenario	9,000	1	0.0005	0.5	0.1	0.22 Pu 0.48 PuE
	SEIS Scenario	9,000	1	0.0005	0.5	0.005	0.011 Pu 0.024 PuE
Fire in TA-55 vault 1×10^{-5} to 1×10^{-7} (extremely unlikely to beyond extremely unlikely)	Safety-Basis Scenario	1.5×10^{6}	1	0.0005	0.5	0.05	19 Pu 39 PuE
	SEIS Scenario	1.5×10^{6}	0.1	0.0005	0.5	0.005	0.19 Pu 0.39 PuE
Hydrogen deflagration resulting from the dissolution of plutonium metal 1×10^{-5} to 1×10^{-7} (extremely unlikely to beyond extremely unlikely)	Safety-Basis Scenario	1,040 in salts	1	0.2	1	0.05	10 Pu 22 PuE
		1,040 in PuO_2	1	0.005	0.3	0.05	0.078 Pu 0.16 PuE
	SEIS Scenario	1,040 in salts	1	0.2	1	0.005	1.0 Pu 2.2 PuE
		1,040 in PuO_2	1	0.005	0.3	0.005	0.0078 Pu 0.016 PuE

Accident Frequency (per year)	***Scenario***	***MAR (grams Pu)*** [a]	***DR***	***ARF***	***RF***	***LPF***	***Release (grams)*** [a]
Design-basis earthquake with spill (spill contribution only) [a] 1×10^{-4} to 1×10^{-6} (extremely unlikely)	Bounding Safety-Basis Scenario	2.6×10^6 in metal oxides and salts, including 3.8×10^5 to 6.4×10^5 for SPD	1	Varies	Varies	0.05 Pu 1 tritium	82 PuE (2 MT case) 121 PuE (35 MT case)
	SEIS Scenario	2.6×10^6 in metal oxides and salts, including 3.8×10^5 to 6.4×10^5 for SPD	0.25	Varies	Varies	0.005 Pu 1 tritium	2.0 PuE (2 MT case) 3.0 PuE (35 MT case)
Design-basis earthquake with fire (fire contribution only) [a] 1×10^{-4} to 1×10^{-6} (extremely unlikely)	Bounding Safety-Basis Scenario	2.6×10^6 in metal oxides and salts, including 3.8×10^5 to 6.4×10^5 for SPD	1	Varies	Varies	0.18 Pu 1 tritium	169 PuE (2 MT case) 306 PuE (35 MT case)
	SEIS Scenario	2.6×10^6 in metal oxides and salts, including 3.8×10^5 to 6.4×10^5 for SPD	0.25	Varies	Varies	0.005 Pu 1 tritium	1.8 PuE (2 MT case) 3.0 PuE (35 MT case)
Design-basis earthquake with spill plus fire [b] 1×10^{-4} to 1×10^{-6} (extremely unlikely)	Bounding Safety-Basis Scenario	2.6×10^6 in metal oxides and salts, including 3.8×10^5 to 6.4×10^5 for SPD	1	Varies	Varies	Spill portion: 0.05 Pu Fire portion: 0.18 Pu 1 tritium	250 PuE (2 MT case) 427 PuE (35 MT case)
	SEIS Scenario	2.6×10^6 in metal oxides and salts, including 3.8×10^5 to 6.4×10^5 for SPD	0.25	Varies	Varies	0.005 Pu 1 tritium	3.8 PuE (2 MT case) 6.0 PuE (35 MT case)
Beyond-design-basis accident – earthquake-induced collapse plus fire [c] 1×10^{-5} to 1×10^{-7} (extremely unlikely to beyond extremely unlikely)	Safety-Basis Addendum and SEIS Scenario	1.2×10^7 in metal oxides and salts, including 3.8×10^5 to 6.4×10^5 for SPD	Varies	Varies	Varies	0.3 to 0.5 Pu 1 tritium	321 PuE (2 MT case) 362 PuE (35 MT case)

ARIES = Advanced Recovery and Integrated Extraction System; ARF = airborne release fraction; DR = damage ratio; LPF = leak path factor; MAR = material at risk; MT = metric tons; Pu = plutonium; PuE = plutonium-239 dose equivalent; PuO$_2$ = plutonium dioxide; RF = respirable fraction; SEIS = Supplemental Environmental Impact Statement; SPD = surplus plutonium disposition; TA = technical area.

[a] The material at risk for facility process accidents included only material associated with the Surplus Plutonium Disposition Program; the specific mix of isotopes is classified so this material is presented as plutonium (Pu) in this table. After the release was calculated, this material was converted to a dose-consequence equivalent amount of plutonium-239 (PuE) for impacts analysis. The releases associated with natural phenomena-initiated accidents were based on a range of different plutonium mixtures and are presented only as plutonium-239 equivalents.

[b] Reported releases are for 2,600 kilograms of material at risk on the first floor of PF-4. Materials associated with the Surplus Plutonium Disposition Program would account for approximately 37 to 50 percent of the release for the lower throughput (2 metric tons) case and 63 to 74 percent for the higher throughput (35 metric tons) case.

[c] Reported releases are for the entire quantity of material at risk in PF-4. Materials associated with the Surplus Plutonium Disposition Program would account for approximately 18 percent of the release for the lower throughput (2 metric tons) case and 32 percent for the higher throughput (35 metric tons) case. Releases associated with this scenario reflect use of more realistic parameters, particularly for the ARF and RF, than those assumed for the bounding safety-basis scenario; releases for the bounding safety-basis scenario would be a factor of 31 to 34 higher.

Note: To convert grams to ounces, multiply by 0.035274.

Source: LANL 2013.

D.2 Radiological Impacts of Facility Accidents

D.2.1 K-Area Storage/K-Area Interim Surveillance Capability

Table D–10 summarizes the impacts related to various accident scenarios for K-Area storage and the KIS capability based on the source terms from Table D–1. Because only limited materials would be present at KIS, and there are few sources of energy, the likelihood of a major accident is very remote. Most incidents would not involve much energy, and any spill would be confined to the glovebox, with no radiological impact. For the bounding accidents identified in the *KIS DSA Addendum* (WSRC 2006), radiological impacts on workers in the immediate vicinity of the incident and on those exposed to released material could be relatively high. The radiological impacts from beyond-design-basis earthquakes on involved and noninvolved workers could be high as well, but these seismic events would be of sufficient magnitude that the workers also would be at substantial risk of injury or death due to falling structural materials.

D.2.2 Pit Disassembly and Conversion Facility at F-Area

The potential source terms and consequences of postulated bounding facility accidents for PDCF are presented in **Table D–11**. These scenarios and source terms were identified in Table D–2 and are based on accident scenarios and source terms summarized for purposes of this *SPD Supplemental EIS* in the *PDC NEPA Source Document* (DOE/NNSA 2012). For several scenarios, the accident sequences and source terms developed in the safety analyses did not take credit for designated safety controls that are expected to continue functioning during and after design-basis accidents. For these bounding accidents, the source terms developed may not be credible, and these accident frequencies are considered "extremely unlikely to beyond extremely unlikely."

D.2.3 Pit Disassembly and Conversion Project at K-Area

The potential source terms and consequences of postulated bounding facility accidents for PDC are presented in **Table D–12**. These scenarios and source terms were identified in Table D–3 and are based on accident scenarios summarized for purposes of this *SPD Supplemental EIS* in the *PDC NEPA Source Document* (DOE/NNSA 2012). For several scenarios, the accident sequences and source terms developed in the safety analyses did not take credit for designated safety controls that are expected to continue functioning during and after design-basis accidents. For these bounding accidents, the source terms developed may not be credible, and these accident frequencies are considered "extremely unlikely to beyond extremely unlikely."

D.2.4 Pit Disassembly Capability at the K-Area Complex

The potential source terms and consequences of postulated bounding facility accidents for pit disassembly are presented in **Table D–13**. These scenarios and source terms were identified in Table D–4 and are based on accident scenarios summarized for purposes of this *SPD Supplemental EIS* in the *PDC NEPA Source Document* (DOE/NNSA 2012). For several scenarios, the accident sequences and source terms developed in the safety analyses did not take credit for designated safety controls that are expected to continue functioning during and after design-basis accidents. For these bounding accidents, the source terms developed may not be credible, and these accident frequencies are considered "extremely unlikely to beyond extremely unlikely."

D.2.5 Immobilization Capability at K-Area

The potential source terms and consequences of postulated bounding facility accidents for the K-Area immobilization capability that were identified in Table D–5 are presented in **Table D–14**. For this facility, all of the plutonium involved is assumed to be non-pit plutonium. This material is assumed to have an americium-241 content of 6.25 percent. The relative inhalation hazard of this material is 6.47 times higher than that of plutonium-239 and about 3.1 times more hazardous than weapons-grade plutonium. If the accidents involved pit plutonium instead of non-pit plutonium, the plutonium-239-dose-equivalent MAR, doses, and risks would be about a factor of 3.1 lower than those reported in Table D–14.

Table D–10 Accident Impacts for the K-Area Storage/K-Area Interim Surveillance

Accident	Source Term [a] (grams)	Frequency (per year)	Impacts on Noninvolved Worker		Impacts on an MEI at the Site Boundary [b]		Impacts on Population within 50 Miles	
			Dose (rem)	**Probability of an LCF [c]**	**Dose (rem)**	**Probability of an LCF [c]**	**Dose (person-rem)**	**LCFs [d]**
Criticality	–-	Not credible	–	–	–	–	–	–
Fire in KIS vault with 3013 can rupture at 1,000 psig	5.7 PuE	Extremely unlikely to beyond extremely unlikely	4.5	3×10^{-3}	0.18	1×10^{-4}	52	0 (0.03)
Explosion (deflagration of 3013 can during puncturing; can assumed to be at 700 psig)	3.2 PuE	Extremely unlikely to beyond extremely unlikely	2.5	2×10^{-3}	0.10	6×10^{-5}	29	0 (0.02)
Design-basis earthquake-vibration release	0.20 PuE	Unlikely	0.16	9×10^{-5}	0.0063	4×10^{-6}	1.8	0 (0.001)
Beyond-design-basis fire (unmitigated transuranic waste drum fire)	1.3 PuE	Beyond extremely unlikely	1.4	9×10^{-4}	0.042	3×10^{-5}	12	0 (0.007)
Beyond-design-basis earthquake with fire (bounded by unmitigated pressurized 3013 can due to an external fire and vault release [1,000 psig])	280 PuE	Beyond extremely unlikely	310	0.4	9.1	5×10^{-3}	2,500	2

KIS = K-Area Interim Surveillance; LCF = latent cancer fatality; MEI = maximally exposed individual; psig = pounds per square inch gauge; PuE = plutonium-239 dose equivalent; rem = roentgen equivalent man.

[a] Calculated using the source terms in Table D–1.

[b] A site boundary distance of 5.5 miles was used.

[c] For hypothetical individual doses equal to or greater than 20 rem, the probability of a latent cancer fatality was doubled.

[d] Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses for when the reported result is 1 or less.

Note: To convert grams to ounces, multiply by 0.035274; miles to kilometers by 1.6093.

Table D–11 Accident Impacts for the Pit Disassembly and Conversion Facility at F-Area

			Impacts on Noninvolved Worker		*Impacts on an MEI at the Site Boundary* [b]		*Impacts on Population within 50 Miles*	
Accident	***Source Term* [a] *(grams)***	***Frequency (per year)***	***Dose (rem)***	***Probability of an LCF* [c]**	***Dose (rem)***	***Probability of an LCF***	***Dose (person-rem)***	***LCFs* [d]**
Criticality	1×10^{19} fissions	Extremely unlikely	0.073	4×10^{-5}	0.0051	3×10^{-6}	1.5	0 (0.0009)
Product NDA room fire	3.4 PuE	Extremely unlikely	0.77	5×10^{-4}	0.088	5×10^{-5}	40	0 (0.02)
Multi-room fire	15 PuE	Extremely unlikely	3.4	2×10^{-3}	0.039	2×10^{-4}	180	0 (0.1)
Direct metal oxidation glovebox fire	2.4 PuE	Extremely unlikely	0.54	3×10^{-4}	0.062	4×10^{-5}	28	0 (0.02)
Overpressurization of oxide storage cans	20 PuE	Extremely unlikely	4.5	3×10^{-3}	0.52	3×10^{-4}	240	0 (0.1)
Design-basis earthquake with fire (limited)	7.7 PuE	Extremely unlikely to beyond extremely unlikely	1.7	1×10^{-3}	0.20	1×10^{-4}	91	0 (0.05)
Beyond-design-basis earthquake with fire	650 PuE	Extremely unlikely to beyond extremely unlikely	720	1	19	1×10^{-2}	7,900	5

LCF = latent cancer fatality; MEI = maximally exposed individual; NDA = nondestructive assay; PuE = plutonium-239 dose equivalent; rem = roentgen equivalent man.

[a] Calculated using the source terms in Table D–2.

[b] A site boundary distance of 5.85 miles was used.

[c] Individual doses in excess of 400 to 450 rem are assumed to result in a fatality.

[d] Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses for when the reported result is 1 or less.

Note: To convert grams to ounces, multiply by 0.035274; miles to kilometers, by 1.6093.

Table D–12 Accident Impacts for the Pit Disassembly and Conversion Project at K-Area

			Impacts on Noninvolved Worker		*Impacts on an MEI at the Site Boundary* [b]		*Impacts on Population within 50 Miles*	
Accident	***Source Term* [a] *(grams)***	***Frequency (per year)***	***Dose (rem)***	***Probability of an LCF* [c]**	***Dose (rem)***	***Probability of an LCF***	***Dose (person-rem)***	***LCFs* [d]**
Criticality	1×10^{19} fissions	Extremely unlikely	0.065	4×10^{-5}	0.0055	3×10^{-6}	1	0 (0.0006)
Fire in direct metal oxidation glovebox	2.0 PuE	Extremely unlikely	0.38	2×10^{-4}	0.056	3×10^{-5}	18	0 (0.01)
Product NDA room fire with pit plutonium	2.1 PuE	Extremely unlikely	0.39	2×10^{-4}	0.058	4×10^{-5}	19	0 (0.1)
Multi-room fire	5.3 PuE	Extremely unlikely	1.0	6×10^{-4}	0.15	9×10^{-5}	47	0 (0.03)
Overpressurization of oxide storage cans	12 PuE	Extremely unlikely	2.3	1×10^{-3}	0.33	2×10^{-4}	110	0 (0.06)
Design-basis earthquake with fire	6.5 PuE	Extremely unlikely	1.2	7×10^{-4}	0.18	1×10^{-4}	58	0 (0.03)
Beyond-design-basis earthquake with fire	690 PuE	Extremely unlikely to beyond extremely unlikely	770	1	22	3×10^{-2}	6,300	4

LCF = latent cancer fatality; MEI = maximally exposed individual; NDA = nondestructive assay; PuE = plutonium-239 dose equivalent; rem = roentgen equivalent man.

[a] Calculated using the source terms in Table D–3. All design-basis releases would be through a new HEPA filter and stack, assumed to be 150 feet high.

[b] A site boundary distance of 5.5 miles was used.

[c] For hypothetical individual doses equal to or greater than 20 rem, the probability of a latent cancer fatality was doubled. Individual doses in excess of 400 to 450 rem are assumed to result in a fatality.

[d] Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses for when the reported result is 1 or less.

Note: To convert grams to ounces, multiply by 0.035274; miles to kilometers, by 1.0693.

Table D–13 Accident Impacts for the Pit Disassembly Capability in the K-Area Complex

			Impacts on Noninvolved Worker		*Impacts on an MEI at the Site Boundary* [b]		*Impacts on Population within 50 Miles*	
Accident	*Source Term* [a] *(grams)*	*Frequency (per year)*	*Dose (rem)*	*Probability of an LCF*	*Dose (rem)*	*Probability of an LCF*	*Dose (person-rem)*	*LCFs* [c]
Criticality	1×10^{19} fissions	Extremely unlikely	0.18	1×10^{-4}	0.0066	4×10^{-6}	1.1	0 (6×10^{-4})
Multi-room fire	0.0052 PuE	Extremely unlikely	0.0041	2×10^{-6}	0.00016	1×10^{-7}	0.047	0 (3×10^{-5})
Design-basis earthquake with fire (limited)	0.011 PuE	Extremely unlikely	0.0087	5×10^{-6}	0.00035	2×10^{-7}	0.010	0 (6×10^{-5})
Beyond-design-basis earthquake with fire	0.88 PuE	Extremely unlikely to beyond extremely unlikely	0.98	6×10^{-4}	0.029	2×10^{-5}	8.0	0 (5×10^{-3})

LCF = latent cancer fatality; MEI = maximally exposed individual; PuE = plutonium-239 dose equivalent; rem = roentgen equivalent man.

[a] Calculated by using the source terms in Table D–4.

[b] A site boundary distance of 5.5 miles was used.

[c] Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses for when the reported result is 1 or less.

Note: To convert grams to ounces, multiply by 0.035274; miles to kilometers, by 1.6093.

Table D–14 Accident Impacts for the Can-in-Can Immobilization Capability at K-Area

			Impacts on Noninvolved Worker		*Impacts on an MEI at the Site Boundary* [b]		*Impacts on Population within 50 Miles*	
Accident	***Source Term* [a] *(grams)***	***Frequency (per year)***	***Dose (rem)***	***Probability of an LCF* [c]**	***Dose (rem)***	***Probability of an LCF***	***Dose (person-rem)***	***LCFs* [d]**
Criticality	1×10^{19} fissions	Extremely unlikely	0.1	6×10^{-5}	0.0061	4×10^{-6}	1.1	0 (6×10^{-4})
Explosion in direct metal oxidation furnace	70 PuE	Extremely unlikely to beyond extremely unlikely	27	3×10^{-2}	2.1	1×10^{-3}	630	0 (4×10^{-1})
Glovebox fire (direct metal oxidation furnace)	0.00084 PuE	Extremely unlikely	0.00033	2×10^{-7}	0.000025	2×10^{-8}	0.0076	0 (5×10^{-6})
Melter eruption	0.018 PuE	Unlikely	0.0070	4×10^{-6}	0.00054	3×10^{-7}	0.16	0 (1×10^{-4})
Melter spill	0.011 PuE	Unlikely	0.0043	3×10^{-6}	0.00033	2×10^{-7}	0.099	0 (6×10^{-5})
Design-basis earthquake	1.1 PuE	Unlikely	0.43	3×10^{-4}	0.033	2×10^{-5}	9.9	0 (6×10^{-3})
Beyond-design-basis earthquake	11 PuE	Extremely unlikely to beyond extremely unlikely	12	7×10^{-3}	0.36	2×10^{-4}	100	0 (6×10^{-2})

LCF = latent cancer fatality; MEI = maximally exposed individual; PuE = plutonium-239 dose equivalent; rem = roentgen equivalent man.

[a] Calculated using the source terms in Table D–5. Materials at risk are assumed to be non-pit plutonium. If accidents involved pit plutonium, the plutonium-239-dose-equivalent materials at risk, doses, and risks would be about a factor of 3.1 lower.

[b] A site boundary distance of 5.5 miles was used.

[c] For hypothetical individual doses equal to or greater than 20 rem, the probability of a latent cancer fatality was doubled.

[d] Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses for when the reported result is 1 or less.

Note: To convert grams to ounces, multiply by 0.035274; miles to kilometers, by 1.6093.

D.2.6 Mixed Oxide Fuel Fabrication Facility

The potential source terms and consequences of postulated bounding facility accidents at MFFF are presented in **Table D–15**. These scenarios and source terms were identified in Table D–6 and are based on accident scenarios and source terms developed for the *SPD EIS* (DOE 1999) and the *MFFF EIS* (NRC 2005) for the MFFF and the *PDC NEPA Source Document* (DOE/NNSA 2012) for the optional metal oxidation process. If a metal oxidation process were added to the MFFF, the incremental and total impacts are also listed.

D.2.7 Waste Solidification Building

The potential source terms and consequences of postulated bounding facility accidents for each facility option are presented in **Table D–16**. These scenarios and source terms for WSB were identified in Table D–7 and are based on accident scenarios and source terms developed for the *WSB DSA* (WSRC 2009). For several scenarios, the accident sequences and source terms developed in the *WSB DSA* did not take credit for designated safety controls that are expected to continue functioning during and after design-basis accidents. For these bounding accidents, the source terms developed may not be credible, and the accident frequencies for scenarios with source terms of the magnitude indicated are likely “extremely unlikely to beyond extremely unlikely” even though the table may indicate that the frequency of some of the accidents may be “unlikely.”

D.2.8 H-Canyon/HB-Line

The potential source terms and consequences for the postulated bounding facility accidents identified in Table D–8 for H-Canyon and HB-Line are presented in **Table D–17**. These scenarios and source terms were developed for surplus plutonium processing activities only and do not reflect other H-Canyon and HB-Line activities, including plutonium-238 and legacy contamination activities.

The H-Canyon safety documents (SRNS 2011a) evaluated a seismic event that results in damage to H-Canyon containment followed by fires that occur in the Hot Crane Maintenance Area, Truck Well, and Railroad Tunnel. This event was evaluated with both building confinement and the sand filters functioning as expected and with the hypothetical unmitigated case and a LPF of 1. For the postulated design basis seismic event with fires, the MEI dose at the site boundary was estimated to be 0.36 rem, a much larger value than that found for H-Canyon-related surplus plutonium procession activities. For the unmitigated case, with a hypothetical LPF of 1, the MEI dose was found to be 12 rem. A beyond-design-basis seismic event followed by multiple fires was postulated to involve more material at risk, but was not evaluated in detail. If a more realistic LPF of 0.25 were assumed, the MEI doses for non-SPD activities would be similar to those for H-Canyon and HB-Line activities.

At HB-Line, the postulated surplus plutonium disposition activities MAR is similar to the administrative limits in place for activities on the fifth and sixth levels that would support the proposed processing. Legacy equipment and process cabinets on the third and fourth levels contain some plutonium-238 contamination, but the safety documents (SRNS 2011b) indicate that even widespread fires on those levels with an unmitigated release would result in small offsite doses compared to the postulated process operations. Thus, the projected impacts to the public from a beyond-design-basis earthquake that causes failure of building confinement for H-Canyon and HB-Line are dominated by the postulated MAR associated with processing activities in HB-Line.

D.2.9 Los Alamos National Laboratory Plutonium Facility

The potential source terms and consequences for the postulated bounding facility accidents identified in Table D–9 for PF-4 are presented in **Table D–18**. These scenarios and source terms were developed for surplus plutonium processing activities in addition to ongoing activities. The impacts correspond to the SEIS Scenario source terms from Table D–9. The Safety-Basis Scenario source terms would yield higher dose impacts. Those impacts can be calculated by multiplying the Table D–18 impacts by the ratio of the Safety-Basis Scenario source term to the SEIS Scenario source term.

Table D–15 Accident Impacts for the Mixed Oxide Fuel Fabrication Facility Including the Metal Oxidation Capability

Accident	*Source Term [a] (grams)*	*Frequency (per year)*	*Impacts on Noninvolved Worker*		*Impacts on an MEI at the Site Boundary [b]*		*Impacts on Population within 50 Miles*	
			Dose (rem)	*Probability of an LCF [c]*	*Dose (rem)*	*Probability of an LCF*	*Dose (person-rem)*	*LCFs [d]*
Criticality	1×10^{19} fissions	Extremely unlikely	2.2×10^{-1}	1×10^{-4}	9.4×10^{-3}	6×10^{-6}	1.6	0 (9×10^{-4})
Explosion in sintering furnace	0.0012 PuE	Extremely unlikely	1.1×10^{-3}	7×10^{-7}	5.1×10^{-5}	3×10^{-8}	0.014	0 (9×10^{-6})
Fire	8.3×10^{-6} PuE	Unlikely	7.9×10^{-6}	5×10^{-9}	3.5×10^{-7}	2×10^{-10}	0.00010	0 (6×10^{-8})
Spill	1.0×10^{-5} PuE	Extremely unlikely	9.6×10^{-6}	6×10^{-9}	4.2×10^{-7}	3×10^{-10}	0.00012	0 (7×10^{-8})
<u>Metal oxidation capability only</u>: Fire in direct metal oxidation glovebox causing pressurized release of oxide from cans and equipment [e]	0.0056 PuE	Extremely unlikely	5.4×10^{-3}	3×10^{-6}	2.4×10^{-4}	1×10^{-7}	0.067	0 (4×10^{-5})
Design-basis earthquake	0.00017 PuE	Unlikely	1.6×10^{-4}	1×10^{-7}	7.2×10^{-6}	4×10^{-9}	0.0020	0 (1×10^{-6})
Beyond-design-basis fire	0.13 PuE	Beyond extremely unlikely	1.4×10^{-1}	9×10^{-5}	5.6×10^{-3}	3×10^{-6}	1.6	0 (9×10^{-4})
Beyond-design-basis earthquake induced fire – additional metal oxidation contribution	55 PuE	Beyond extremely unlikely	61	7×10^{-2}	2.4	1×10^{-3}	670	0 (4×10^{-1})
Beyond-design-basis earthquake (MFFF only)	20 PuE	Extremely unlikely to beyond extremely unlikely	22	3×10^{-2}	0.86	5×10^{-4}	240	0 (1×10^{-1})
Beyond-design-basis earthquake (MFFF plus metal oxidation in MFFF)	75 PuE	Extremely unlikely to beyond extremely unlikely	83	1×10^{-1}	3.2	2×10^{-3}	910	1 (5×10^{-1})

LCF = latent cancer fatality; MEI = maximally exposed individual; MFFF = Mixed Oxide Fuel Fabrication Facility; PuE = plutonium-239 dose equivalent; rem = roentgen equivalent man.

[a] Calculated using the source terms in Table D–6.

[b] A site boundary distance of 4.67 miles was used.

[c] For hypothetical individual doses equal or greater than 20 rem, probability of a latent cancer fatality was doubled.

[d] Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses for when the reported result is 1 or less.

[e] Scenario parameters for the metal oxidation capability are from DOE/NNSA 2012.

Note: To convert grams to ounces, multiply by 0.035274; miles to kilometers, by 1.6093.

Table D–16 Accident Impacts for the Waste Solidification Building

Accident	Source Term [a] (grams americium-241 dose equivalent)	Frequency (per year)	Impacts on Noninvolved Worker		Impacts on an MEI at the Site Boundary [b]		Impacts on Population within 50 Miles	
			Dose (rem)	Probability of an LCF [c]	Dose (rem)	Probability of an LCF	Dose (person-rem)	LCFs [d]
Criticality	-	Not credible	–	–	–	–	–	–
High-activity waste process vessel hydrogen explosion	0.00014	Extremely unlikely	0.010	6×10^{-6}	0.00046	3×10^{-7}	0.13	0 (8×10^{-5})
High-Activity Waste Process Room fire	5.5×10^{-6}	Extremely unlikely	0.00042	3×10^{-7}	0.000019	1×10^{-8}	0.0053	0 (3×10^{-6})
Leak/spill	7.2×10^{-5}	Unlikely	0.0055	3×10^{-6}	0.00024	1×10^{-7}	0.069	0 (4×10^{-5})
Design-basis earthquake	0.00014	Unlikely	0.010	6×10^{-6}	0.00046	3×10^{-7}	0.13	0 (8×10^{-5})
Aircraft crash	0.55	Beyond extremely unlikely	49	6×10^{-2}	1.9	1×10^{-3}	530	0 (3×10^{-1})
Beyond-design-basis red oil explosion	0.0042	Beyond extremely unlikely	0.32	2×10^{-4}	0.014	8×10^{-6}	4	0 (2×10^{-3})
Beyond-design-basis earthquake	0.18	Extremely unlikely to beyond extremely unlikely	16	1×10^{-2}	0.62	4×10^{-4}	180	0 (1×10^{-1})

LCF = latent cancer fatality; MEI = maximally exposed individual; rem = roentgen equivalent man.

[a] Calculated using the source terms and scenarios in Table D–7.

[b] A site boundary distance of 4.67 miles was used.

[c] For hypothetical individual doses equal or greater than 20 rem, probability of a latent cancer fatality was doubled.

[d] Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses for when the reported result is 1 or less.

Note: To convert grams to ounces, multiply by 0.035274; miles to kilometers, by 1.6093.

Table D–17 Accident Impacts for H-Canyon/HB-Line

Accident [a]	**Source Term** [b] **(grams)**	**Frequency (per year)**	***Impacts on Noninvolved Worker***		***Impacts on an MEI at the Site Boundary*** [c]		***Impacts on Population within 50 Miles***	
			Dose (rem)	***Probability of an LCF*** [d]	***Dose (rem)***	***Probability of an LCF*** [d]	***Dose (person-rem)***	***LCFs*** [e]
Criticality	1.0×10^{19} fissions	Extremely unlikely	0.034	2×10^{-5}	0.0028	2×10^{-6}	1.3	0 (0.0008)
Hydrogen explosion in H-Canyon dissolver	0.29 PuE	Extremely unlikely	0.017	1×10^{-5}	0.0046	3×10^{-6}	3.1	0 (0.002)
Fire (level-wide in HB-Line)	26 PuE	Extremely unlikely	1.6	9×10^{-4}	0.41	2×10^{-4}	280	0 (0.2)
Leak/spill of nuclear material (H-Canyon)	1.0 PuE	Unlikely	0.060	4×10^{-5}	0.016	9×10^{-6}	11	0 (0.006)
Design-basis earthquake with fire (H-Canyon)	0.071 PuE	Unlikely	0.0042	3×10^{-6}	0.0011	7×10^{-7}	0.76	0 (0.0005)
Design-basis earthquake with fire (HB-Line)	26 PuE	Extremely unlikely	1.6	9×10^{-4}	0.41	2×10^{-4}	280	0 (0.2)
Beyond-design-basis earthquake with fire	1,300 PuE (ground level)	Extremely unlikely to beyond extremely unlikely	1,400	1	26	3×10^{-2}	15,000	9

LCF = latent cancer fatality; MEI = maximally exposed individual; PuE = plutonium-239 dose equivalent; rem = roentgen equivalent man.

[a] These scenarios and source terms were developed for surplus plutonium processing activities only and do not reflect other H-Canyon and HB-Line activities, including plutonium-238 and legacy contamination activities. The projected doses from these other activities are similar to or smaller than those indicated above.

[b] Calculated using the scenarios and source terms in Table D–8. These scenarios and source terms were developed for surplus plutonium processing activities only and do not reflect other H-Canyon and HB-Line activities, including plutonium-238 and legacy contamination activities.

[c] A site boundary distance of 7.3 miles was used.

[d] For hypothetical individual doses equal to or greater than 20 rem, the probability of a latent cancer fatality was doubled. Individual doses in excess of 400 to 450 rem are assumed to result in a fatality.

[e] Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses for when the reported result is 1 or less.

Note: To convert grams to ounces, multiply by 0.035274; miles to kilometers, by 1.6093.

Table D–18 Accident Impacts for the Los Alamos National Laboratory Plutonium Facility

			Impacts on Noninvolved Worker		*Impacts on an MEI at the Site Boundary* [b]		*Impacts on Population within 50 Miles*	
Accident	***Source Term* [a] *(grams)***	***Frequency (per year)***	***Dose (rem)***	***Probability of an LCF* [c]**	***Dose (rem)***	***Probability of an LCF* [c]**	***Dose (person-rem)***	***LCFs* [d]**
Criticality	1×10^{19} fissions	Extremely unlikely	0.33	0.0002	0.017	1×10^{-5}	3.5	0 (0.002)
Spill in ARIES	0.028 PuE	Extremely unlikely	0.048	0.00003	0.0014	9×10^{-7}	0.31	0 (0.0002)
Glovebox fire in the pyrochemical metal preparation	0.024 PuE	Extremely unlikely	0.041	0.00002	0.0012	7×10^{-7}	0.28	0 (0.0002)
Fire in TA-55 vault (elevated release due to heat from the fire)	0.39 PuE	Extremely unlikely to beyond extremely unlikely	0.025	0.00002	0.0046	3×10^{-6}	3.4	0 (0.002)
Hydrogen deflagration resulting from the dissolution of plutonium metal	2.2 PuE	Extremely unlikely to beyond extremely unlikely	3.7	0.002	0.11	7×10^{-5}	26	0 (0.02)
Design-basis earthquake with spill (spill contribution only) [e, f]	2.0 PuE (2 MT case)	Extremely unlikely	3.5	0.002	0.10	6×10^{-5}	24	0 (0.01)
	3.0 PuE (35 MT case)		5.1	0.003	0.15	9×10^{-5}	36	0 (0.02)
Design-basis earthquake with fire (fire contribution only) [e, f]	1.8 PuE (2 MT case)	Extremely unlikely	3.0	0.002	0.088	5×10^{-5}	21	0 (0.01)
	3.0 PuE (35 MT case)		5.0	0.003	0.15	9×10^{-5}	35	0 (0.02)
Design-basis earthquake with spill plus fire [e, f]	3.8 PuE (2 MT case)	Extremely unlikely	6.5	0.004	0.19	1×10^{-4}	45	0 (0.03)
	6.0 PuE (35 MT case)		10	0.006	0.30	2×10^{-4}	71	0 (0.04)
Beyond-design-basis accident – earthquake-induced collapse plus fire [e, g]	321 PuE (2 MT case)	Extremely unlikely to beyond extremely unlikely	550	1	16	1×10^{-2}	3,800	2
	362 PuE (35 MT case)		620	1	18	1×10^{-2}	4,300	3

ARIES = Advanced Recovery and Integrated Extraction System; LCF = latent cancer fatality; MEI = maximally exposed individual; MT = metric ton; PuE = plutonium-239 dose equivalent; rem = roentgen equivalent man; TA-55 = Technical Area 55.

[a] Calculated using the SEIS Scenario source terms in Table D–9. The Safety-Basis Scenario source terms would yield higher dose impacts. Those impacts can be calculated by multiplying the Table D–18 impacts by the ratio of the Safety-Basis Scenario source term to the SEIS Scenario source term.

[b] A site boundary distance of 0.75 miles was used.

[c] For hypothetical individual doses equal to or greater than 20 rem, the probability of a latent cancer fatality was doubled. Individual doses in excess of 400 to 450 rem are assumed to result in a fatality.

[d] Numbers of LCFs in the population are whole numbers; the statistically calculated values are provided in parentheses for when the reported result is 1 or less.

[e] Earthquake impacts assume a 10-minute puff release. For an 8-hour release, MEI doses would be 43 percent lower, non-involved worker doses would be 43 percent lower, and population doses would be 2 percent lower due to additional wind dispersion.

[f] Reported impacts are for 2,600 kilograms of material at risk on the first floor of PF-4. Materials associated with the Surplus Plutonium Disposition Program would account for approximately 37 to 50 percent of the impacts for the lower throughput (2 metric tons) case and 63 to 74 percent for the higher throughput (35 metric tons) case.

[g] Reported impacts are for the entire quantity of material at risk in PF-4. Materials associated with the Surplus Plutonium Disposition Program would account for approximately 18 percent of the impact for the lower throughput (2 metric tons) case and 32 percent for the higher throughput (35 metric tons) case.

Note: Sums and products presented in the table may differ from those calculated from table entries due to rounding. To convert grams to ounces, multiply by 0.035274; metric tons to tons, by 1.1023; miles to kilometers, by 1.6093.

D.2.9.1 Potential Land Contamination Following Severe Earthquakes

Seismic events that result in failure of building containment of plutonium facilities have the potential to release substantial quantities of plutonium, leading to concerns regarding surface contamination in the immediate vicinity of the facility. Even for severe earthquakes that could lead to major damage within the facility and building structure and failure of confinement systems, there should not be large energy sources to drive the materials that would typically be used in PF-4 out of the damaged building and rubble. Seismic collapse scenarios that result primarily in spills could release plutonium materials through the rubble, but that material generally would not travel far from the building site. Seismic collapse scenarios that involve large fires have the potential to loft materials such that transport of radioactive materials downwind might result in land contamination at levels that could require monitoring or additional actions.

Land contaminated with TRU waste material at levels above some screening level would likely require additional monitoring and evaluations to determine whether cleanup were appropriate. Estimations of land areas that might be contaminated are highly dependent on specific accident source terms and meteorological modeling assumptions. This is because the amount of radioactive material that may accumulate on the ground is highly dependent on the size of the particles that get through the building rubble and are released to the environment (which determines how fast they settle back to the ground), the specific accident conditions (e.g., whether or not a fire occurs), and specific meteorological conditions during the earthquake. In general, unless there is a fire that can effectively loft the plutonium particles into the air, most of the particles would return to the ground within a few hundred meters of the building location.

Areas with contamination at levels above some screening level would potentially need further action, such as radiation surveys or cleanup. Costs associated with these efforts, as well as continued monitoring activities, could vary widely depending upon the characteristics of the contaminated area and could range in the hundreds of million dollars per square kilometer for land decontamination (NASA 2006). In addition to the potential direct costs of radiological surveys, potential cleanup, and monitoring following an accident, there are potential secondary societal costs associated with the mitigation from large-consequence accidents. Those costs could include, but may not be limited to, the following:

- Temporary or longer-term relocation of residents
- Temporary or longer-term loss of employment
- Destruction or quarantine of agricultural products
- Land use restrictions (which could affect real estate values, businesses, and recreational activities)
- Public health effects and medical care

D.2.9.2 Combined Impacts from TA-55 Building Collapses and Fires Resulting from a Beyond-Design-Basis Earthquake

If a very severe earthquake were to occur in the Los Alamos area, nearby individuals could receive impacts from several facilities that might be damaged. Individuals close to and downwind from TA-55 might receive exposure from releases at the existing PF-4, other facilities in TA-55, and facilities in adjacent TAs such as the Radiochemistry Building in TA-48 and waste management facilities in TA-50. PF-4 was originally designed to withstand a peak horizontal ground acceleration of about 0.33 *g*, but it is in the process of being upgraded to withstand higher seismic loadings. When all upgrades are complete, PF-4 is expected to be able to survive the current design-basis earthquake (0.47 *g*) with limited releases. The upgraded PF-4 and the other facilities would have multi-layered defenses to limit releases from storage containers, gloveboxes, equipment, vaults, and the buildings. The release mechanisms for the PF-4 or other facilities would be similar, and the total amount of radioactive material that could be released would depend on the form of the material, but would be roughly proportional to the amounts of materials that might be at risk in each facility. Other facilities in TA-55 and adjacent TAs would likely have much less MAR in a severe seismic event than PF-4.

D.3 Chemical Accidents

D.3.1 Savannah River Site

The potential for accidents involving hazardous chemicals associated with the proposed surplus plutonium disposition operations to affect noninvolved workers or the public is quite limited. The potential for hazardous chemical impacts on noninvolved workers and the public has been evaluated for many of the facilities that might use larger quantities of hazardous chemicals (SRNS 2010; WGI 2005), and no substantial impacts were found for noninvolved workers or the public. For the proposed pit disassembly and conversion project, potential hazardous chemicals were screened to determine whether any of the proposed chemicals or amounts that might be used poses a threat to collocated workers 100 meters (328 feet) from a spill or to an offsite individual. All potential concentrations from spills were found to be below the applicable protective guidelines (DOE/NNSA 2012).

Existing SRS facilities were evaluated for hazardous chemical impacts. Controls, such as inventory controls, are in place to limit those impacts. For example, the F/H Area Laboratory SAR indicates that chemical inventories are low enough when compared to emergency response planning guidelines to classify the facility as a general use facility in accordance with SRS guidelines (SRNS 2010).

Inventories of hazardous chemicals are maintained for each facility. The inventories for most chemicals are small, and the chemical accident risks are primarily to workers directly handling the chemicals. DOE safety programs are in place to minimize the risks to workers from both routine operations and accidents involving these materials.

Regarding risks from handling toxic or hazardous chemicals, worker safety programs at SRS are enforced via required adherence to Federal and state laws; DOE Orders and regulations; Occupational Safety and Health Administration and U.S. Environmental Protection Agency (EPA) guidelines; and plans and procedures for performing work, including training, monitoring, use of personal protective equipment, and administrative controls. Although chemical inventories have varied to a limited extent in recent years, administrative controls continually ensure that quantities do not approach those levels that pose undue risk due to storage, concentration, bulk quantity, or logistical factors.

Because of SRS's remote location and large size, there is no risk of chemical exposure to the surrounding public population resulting from normal site operations or accidents. Nevertheless, monitoring efforts and baseline studies are regularly performed. However, certain workers at SRS are at risk of chemical exposure depending upon their job function and proximity to various sources.

D.3.2 Los Alamos National Laboratory

The research nature of PF-4 operations requires the use, handling, and storage of a large variety of chemicals, but in relatively small quantities (e.g., a few grams to a few hundred liters). As such, there is an extensive list of chemicals that may be present for programmatic purposes, with quantities of regulated chemicals far below the threshold quantities set by EPA (40 CFR 68.130). The hazards associated with these chemicals are well understood and, because of the small quantities, can be managed using standard hazardous material and/or chemical handling programs. They pose minimal potential hazards to public health and the environment in an accident condition. Prior to initiating a new activity, a probabilistic hazards analysis would be performed to ensure that no onsite inventory exceeds the screening criterion of DOE-STD-1189, Appendix B (DOE 2008a). Accidents involving small laboratory quantities of chemicals would primarily present a risk to the involved worker in the immediate vicinity of the accident. There are limited quantities of bulk quantities of chemicals stored at PF-4, and no bulk quantities would be needed to support the surplus plutonium disposition activities.

D.4 Uncertainties

The purpose of the analysis in this appendix is to compare the potential impacts from accidents related to alternatives for disposition of surplus plutonium, including the pit disassembly and conversion options and plutonium disposition options that may be implemented at SRS or LANL. The analyses are based on studies, data, and models that introduce levels of uncertainty into the analyses. The following paragraphs address recognized uncertainties in the analyses.

In the application of the MACCS2 v1.13.1 computer code, dose conversion factors from Federal Guidance Report 11 (EPA 1988) were used. A more recent version of dose conversion factors has been developed and is included in Federal Guidance Report 13 (EPA 1999). Using the updated dose conversion factors in Federal Guidance Report 13, the estimated doses from DOE facility accidents would increase for some key isotopes and decrease for other key isotopes. Overall, these differences are expected to be well within the much larger uncertainties associated with what might actually happen during an accident; for example, the amount of radioactive material that might actually escape a facility or the weather conditions at the time of the accident.

The analysis estimated the risk of a latent fatal cancer as a result of exposure to radiation by applying a constant factor of 0.0006 LCFs per rem or person-rem to all doses (except for individual doses of 20 rem or larger, the risk factor is doubled). This linear no-threshold extrapolation is the standard method for determining the health consequences of an accident, but may produce a misperception that these LCFs would actually occur. In reality, many of the individuals in the affected population could receive such a small dose of radiation that they would not suffer any health effects from the radiation. As discussed in Appendix C, Section C.3, a number of radiation health scientists and organizations have expressed reservations that the currently used cancer risk conversion factors, which are based on epidemiological studies of high doses (doses exceeding 5 to 10 rem), may not apply at low doses. In addition, because the affected population would receive increased health monitoring in the event of the accidents considered in this *SPD Supplemental EIS*, early detection of cancers may result in a lower number of cancer fatalities in the affected population than in a similar, unmonitored population. Nevertheless, the accident human health risk analysis in this appendix uses the linear no-threshold dose risk assumption.

D.5 References

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