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Title: CMRR-NF Hazards Analysis Information

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This document is broadly broken into 2 sections, the Hazard Analysis Methodology and the Accident Analysis.

Hazards Analysis Methodology for CMRR

The HA provides a comprehensive assessment of facility hazards and hazard scenarios that could produce undesirable consequences for workers and the public.
The HA is divided into five major parts:

1. Hazard Identification (ID)
2. Unmitigated Hazard Evaluation
3. Mitigated Hazard Evaluation
4. Evaluation and Identification of Safety Controls (including SS SSCs)
5. Identification of DBAs (for further analysis)

Part 1 - Hazard ID

The hazard ID and unmitigated hazard evaluation present a comprehensive evaluation of potential process-related, natural events, along with man-made external hazards that can affect the public, workers, and environment.

Figure 1 provides a sequential flowchart of the steps in this process along with a notation in red where this information may be found in the PDSA. Using this flowchart, any reviewer or user of this PDSA can easily find information related to various steps in the process.
The hazard ID process is intended to accomplish the following:

- Identify all hazards (i.e., radioactive material, chemicals, energy sources) of potential consequence to the facility from internal, external, and natural phenomena events that could result in adverse consequences.
- Screen out certain hazards from further consideration, such as routine hazards and Standard Industrial Hazards (SIHs) that are regulated by the Occupational Safety and Health Administration (OSHA) or other regulatory requirements.
- Characterize hazardous energy sources and material inventories, forms, and locations.
- Determine the hazard category (HC) of the facility.

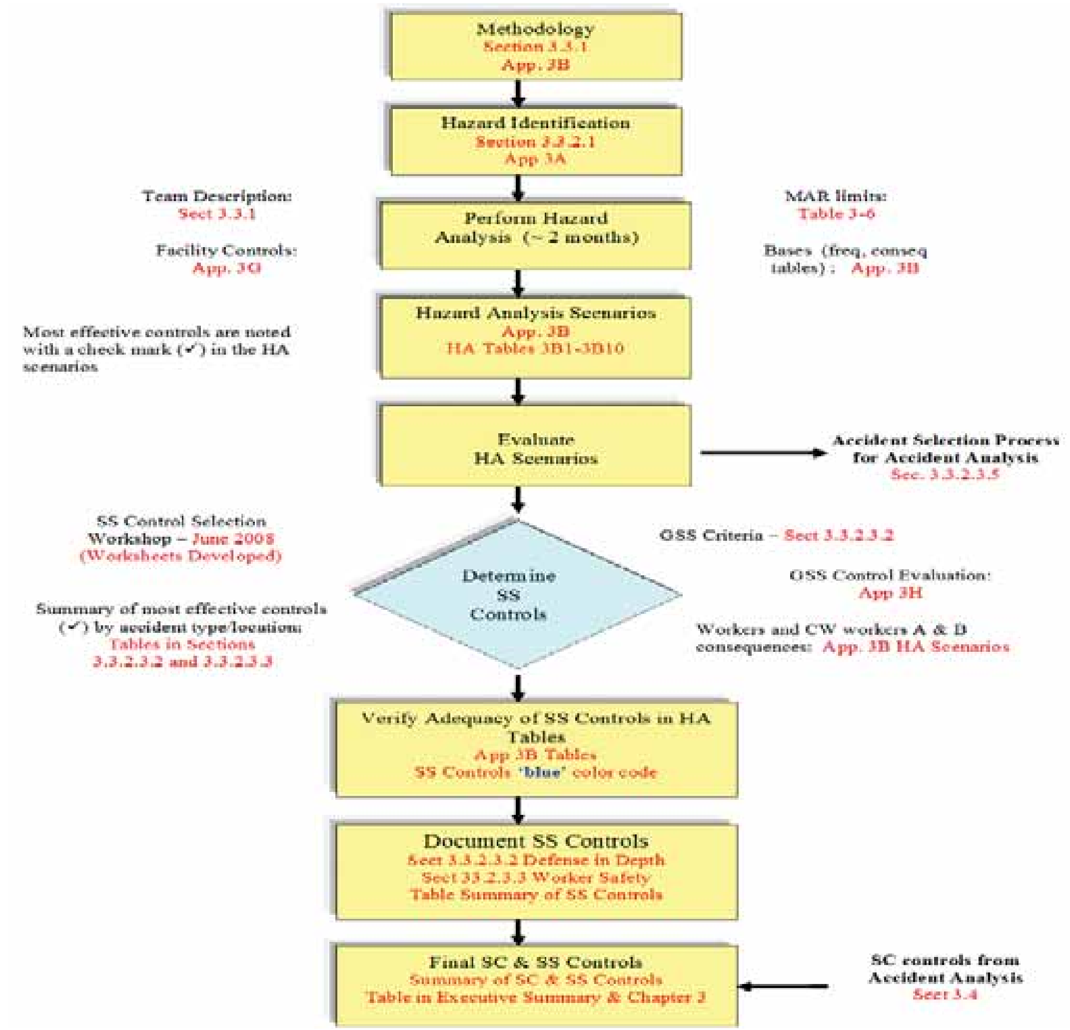

Figure 1 Road Map to the CMRR PDSA Hazard Analysis

To facilitate the HA and to ensure its thoroughness, the analysis was divided into twelve basic sets of activities or areas. Table 1 lists ten basic process operations and describes the general activities involved in these operations along with the other two areas always evaluated (natural phenomena and external events).

Table 1, HA Process Activities

IDs	Description	Type of Activity
1. TO	Transportation and Outside Operations	Movement of hazardous and radioactive material to support CMRR facility operations. Also, any activities that are located and conducted outside the NF (Nuclear Facility) as part of the facility mission. Activities included in this category are: • Material movements to and from shipping/receiving docks and within tunnels • Material movements between NF laboratory area and basement • Transport activities using forklifts, hand carts, elevators, etc. • Diesel fuel oil receiving and storage outside the facility.
2. MTS	Material Transfer System	Movement of hazardous and radioactive material to support NF operations using the MTS.
3. NFL	Nuclear Facility Laboratories	Measurements and analysis of radioactive material, including: • Processes within Gloveboxes (GBs), open-front boxes, and fume hoods • Preparation of material for transport in the MTS • Routing of hazardous gas and liquid utilities within laboratory areas • Local storage in laboratory areas • Non-Destructive Assay (NDA) activities
4. LVA	Large Vessel Activities	Operations at the NF with Large (Test) Vessels, including: • Reclamation of material within the vessel for reuse or disposal • Cleaning of large vessels for reuse or disposal • Movement and translation to support processing
5. MM	Material Management	Operations in Material Management GBs and rooms associated with each laboratory wing, including: • Local staging in the laboratory area and storage in laboratory area cabinets • Routing of hazardous gas and liquid utilities within laboratory areas Storage in the NF basement is not included.
6. LVS	Long Term Vault storage (SNM)	Storage/staging of radioactive material in the NF, specifically SNM containers in the Long-Term Vault (LTV). LTV storage is for material not expected to be accessed on a routine basis. Local storage in laboratory areas and storage of radioactive waste material are not included.
7. SVS	Short Term Vault Storage (SNM)	Storage/staging of radioactive material in the NF, specifically SNM containers in the Short-Term Vault (STV).). STV storage is for material that is expected to be accessed on a routine basis. Local storage in laboratory areas and storage of radioactive waste material are not included.
8. SRW	Storage and Staging of Radioactive Waste	Storage of radioactive material in the NF (primarily in the basement). Activities in this category do not include: • Movement of radioactive material • Local storage in laboratory area cabinets
9. SHM	Storage and Staging of Hazardous Material	Storage of hazardous material in the NF (primarily the basement), including storage of gas cylinders and liquid/solid containers of known and unknown composition. Movement of hazardous material and local staging in material management laboratories are not included.

Table 1, HA Process Activities (continued)

10. AB	Auxiliary Building (utilities)	Utility services provided from the Auxiliary Building and adjacent RLUOB considered include: • Utilities in the Auxiliary Building • Utilities from the RLUOB through the connecting utility trench.
11. EE	External Events	External events are those man-made or initiated events that are external to the CMRR NF and its mission but that could cause an impact on the NF.
12. NPH	Natural Phenomena Hazard	Natural phenomena occurrences (non-man-made) such as seismic events and weather can cause an impact on the NF and its mission.

In an effort to develop a comprehensive list of hazards, the HA team used a hazard ID checklist based on the one included in the Safety Basis Division's procedure. This checklist is applied It encompasses operational hazards (kinetic energy/mechanical events, chemical reactions and toxicity events, electrical, thermal and pressure events, radiation events, radiation events) natural phenomena hazards (meteorological hazards, geological events) and external hazards (infrastructure hazards, nearby facility hazards and transportation hazards) in Appendix 3A of the CMRR PDSA.

The second step is to screen out certain hazards from further consideration. As discussed in DOE-STD-3009, the hazard ID process identifies hazards that are not SIHs and might be a threat to the health and safety of workers, the public, or the environment. It also determines which hazards require more detailed evaluation or analysis based on their potential to cause harm.

The HA team examined each hazard and, if the hazard was identified as requiring further analysis, the team assigned the term Analysis Required (A/R) to the hazard and noted that analysis status.

DOE-HDBK-1163-2003, Table 3was used as a means to readily identify the hazards of concern for the CMRR facility. The radiological thresholds are based on HC quantities listed in DOE-STD-1027. The toxicological thresholds are based on Reportable Quantities (RQs) in 40 CFR 302 for hazardous substances, and Threshold Planning Quantities (TPQs) in 40 CFR 355 for extremely hazardous substances. Consideration of hazards associated with materials in quantities of at least 10% of the HC-3 thresholds in DOE-STD-1027, or at least 25% of the RQs in 40 CFR 302 or TPQs in 40 CFR 355, will ensure that meaningful quantities of materials considered as hazardous in federal regulations are not screened out early in the HA process. Hazards involving inventories above the thresholds listed in Table 3-3 were retained for further analysis in the What-If analysis. Comments in parenthesis contain CMRR specific information.

The third step is to more fully characterize those hazards that were carried over from the previous step. The relevant characterization information includes hazard type (material, energy source, or action), hazard form and quantity (mass, composition, volume, pressure, temperature, voltage, height, etc.), and hazard location.

The fourth step is to determine/confirm the facility hazard categorization. DOE-STD-1027 provides a categorization methodology for nuclear facilities based on radioactive material inventory. This standard also provides guidance on the graded approach for safety analysis. There are three radiological hazard categories in order of decreasing potential consequences: HC-1 (potential for significant offsite consequences), HC-2 (potential for significant onsite consequences), and HC-3 (potential for only significant localized consequences).

In summary, the final products of the hazard ID/facility categorization task are:

(1) a set of hazards that exceed the screening thresholds,

(2) their characterization, and

(3) the facility's hazard categorization.

Hazard evaluation is an organized and systematic method to identify and analyze the significance of potential accident scenarios that are associated with the hazards of concern to operations conducted at the facility. Methodologies for performing a hazard evaluation are described and evaluated in Guidelines for Hazard Evaluation Procedures (2nd ed.) [Ref. 5].

Each of the hazard evaluation methods applies best to specific types of processes and systems. LANL has evaluated these methods and determined that the What-If methodology best applies to most LANL facilities and processes. This method is supplemented by other methods as necessary when other methods are determined to be better suited. For example, to supplement the What-If analysis for the overall facility, a FMEA was conducted to evaluate the failure modes of utilities and services provided to the NF, along with the effects of those failures on the radiological and hazardous materials located within the NF.

Part 2 Uncontrolled Evaluation (Unmitigated)

The first step is to identify an initial set of HA scenarios for those hazards that are not screened out in the hazard ID process for each of the NF operations. To support this task, a modified What-If analysis methodology was used and supplemented with a FMEA.

As each scenario was identified, the HA team systematically identified the frequency and consequences for each scenario (without consideration of controls) and established a corresponding risk ranking.

Part 3: Controlled Evaluation (Mitigated)

Following the identification of possible controls, the HA team examined the effects of the identified controls on the HA scenarios. At this stage, the controls considered were primarily engineered controls with a limited number of administrative controls. In addition, although it is not an engineered control, radiological inventory control also was deemed appropriate to be included in the analysis. Inventory control is an important SAC that is a baseline assumption to each postulated HA scenario. Analogous to the radiological inventory control is the chemical Chemical Management Program (ChemPgm) that provides a similar means for chemical inventory control along with other protective features.

Hazard Analysis Scenarios

The following items are determined for each scenario considered in the PDSA (approximately 500 in total).

- **Hazard Initiator:** The What-If scenarios are grouped according to several accident categories, as identified below. Some of the categories listed below are not included in the analysis based on the absence of corresponding hazards, per the hazard ID process. This approach allows for grouping scenarios that may have the same initiators and/or require the same controls to prevent the scenarios or mitigate their consequences. Hazard initiators could include impact, drop, explosion, chemical reaction, incorrect materials, and so on.
- **Hazard Configuration:** One consideration in performing the What-If analysis is the specific radioactive or hazardous source present at locations for NF operations. To clarify scenarios for each source configuration that might be present, a set of generally bounding source configurations is developed during the hazard ID process. Typical source configurations may include SNM or radiography equipment.
- **Hazard Scenario:** Each HA scenario is described in sufficient detail to allow an understanding of how the scenario progresses. Information to be provided includes the cause or initiating event, enabling events, and the effect on material at risk (MAR). Their magnitude or severity is also identified in the description. The (uncontrolled) scenario frequency and consequence are derived from the description given in this entry. Scenarios postulated from natural phenomena and external events are presumed to occur during any (and all) operational activities.
- **Consequences:** The What-If scenarios are systematically analyzed without controls in place. The configurations and locations of the hazards are considered for each scenario to determine the consequences. The most severe (bounding) qualitative consequences are identified and listed for each scenario. Consequence types that may be used in the What-If tables include radioactive material dispersion (spills), fire with radioactive material dispersion, high explosive violent reaction (HEVR) with radioactive material dispersion, other hazardous material dispersion (e.g., due to pressure), fissile material criticality, radioactive contamination, or radiation exposure affecting the worker.
- **Comments/Assumptions:** Clarifying information for each scenario is provided in this column, such as the amount of MAR involved or other important assumptions that, in general, need to

be “protected” through the imposition of a control, although full definition of administrative controls will occur during DSA preparation. The comments section is also a place to provide notes, recommendations, and/or expectations for actions that are planned for the final design stage.

- **Control ID and Type:** Controls that could reduce the frequency of occurrence or the consequences of the postulated HA scenarios are identified in the What-If tables. Each control is designated as either a preventive control (if it serves to reduce the scenario’s frequency of occurrence) or a mitigative control (if it serves to reduce the consequences of the scenario). Some controls could either prevent an occurrence, or if the scenario does occur, contribute to reducing the consequences. Only those controls currently present in the NF design are included in the analysis. Programmatic controls (such as training and procedures) and administrative controls (such as vehicle refueling restrictions) are not included. Those controls deemed capable of significantly reducing the frequency or consequences are identified with a check mark (✓). This list of preventive and mitigative controls gives an indication of the extent of DID they provide.

- **(Uncontrolled) Frequency:** Each postulated HA scenario is assigned a frequency category based on a qualitative estimate of the scenario occurrence. Frequency categories represent numerical *ranges or bins*, not absolute values. The uncontrolled frequency estimate for each HA scenario is based on the assumption that no controls are in place to reduce the frequency of occurrence. Only passive design features designed to survive the HA scenario event, and attributes of the affected hazards, are used to determine the uncontrolled frequency.

- **(Uncontrolled) Consequences—Public, Worker, and Collocated Worker:** Consequence severity categories are estimated qualitatively for the public, collocated workers at 100 m from the site, and the facility workers, and then are assigned to each postulated HA scenario. Only passive design features designed to survive the HA scenario are used in determining the uncontrolled consequences (except that no credit is taken for leak path factor [LPF] reduction). The public consequence refers to a hypothetical maximally-exposed offsite individual (MOI) located at the site boundary. The worker consequence refers to the worker closest to the hazard for all HA scenarios (i.e., the worker expected to be the most adversely affected or endangered by the hazard).

- **(Uncontrolled) Risk—Public, Worker, and Collocated Worker:** The scenario frequency and consequence estimates are used to risk rank the postulated scenarios in a relative manner. Note that risk is not used as a significant parameter in the PDSA hazard evaluation process. DOE-STD-3009 allows for use of the risk ranking process, but utilizes a consequence-based approach to select safety SSCs.

- **(Controlled) Frequency:** Controlled frequency estimates qualitatively assess the benefit provided by the listed controls in reducing the frequency of occurrence for a postulated scenario.
- **(Controlled) Consequences—Public, Worker, and Collocated Worker:** Controlled consequences are estimated to assess the benefit provided by the listed controls in mitigating the consequences of a HA scenario.
- **(Controlled) Risk—Public, Worker, and Collocated Worker:** The estimated frequency of occurrence and consequences after applying the listed controls are used to assign a controlled risk rank to each scenario for the public and workers.

The methodology adopted utilizes a set of frequency, consequence, and risk ranking bins. These bins provide a means to characterize each postulated accident scenario. In this manner, each scenario can be evaluated on a relative basis. Those scenarios with higher consequences can then be further evaluated to determine the need for SS control designations. The frequency, consequence, and risk ranking category tables are provided in the more detailed description accompanying the HA tables in Appendix 3B.

Part 4. Evaluation and Identification of Safety Controls (including SS SSCs)

SSCs and design features of the current NF preliminary design that are identified by the HA team in the HA tables are evaluated for SS SSC designation. This determination is based on how significantly the control reduces the frequency of occurrence of the scenario (for preventive controls) or the consequences of the scenario (for mitigative controls). Controls found to provide a significant reduction are identified with a check mark (✓) in the What-If tables. Controls that do not provide a significant reduction, or simply serve a redundant function, may be considered part of the DID control set (i.e., important-to-safety [ITS] controls). Each control is evaluated for one scenario at a time. A control that is considered insignificant for one scenario could be identified as a candidate SS control for another. Note that the SC SSC designation is reserved for the Accident Analysis and not the hazard evaluation process described in this section.

The *CMRR Nuclear Safety Design Strategy Document* adopted criteria for safety SSC designation based on the criteria presented in DOE G 420.1-1. In the Nuclear Safety Strategy, the seven criteria in the DOE G 420.1-1 are designated as generic safety strategy (GSS) criteria 1 through 7. For the PDSA, this terminology is adopted for consistency with the CMRR project strategy and prior safety basis documentation. The GSS criteria are considered when designating hazard controls as SS, SC, or ITS.

The GSS criteria 1 through 7 are listed as follows:

- GSS-1 Minimization of hazardous materials (i.e., MAR) is the first priority.
- GSS-2 Safety SSCs are preferred over administrative controls.

- GSS-3 Passive SSCs are preferred over active SSCs.
- GSS-4 Preventive controls are preferred over mitigative controls.
- GSS-5 Facility safety SSCs are preferred over personal protective equipment.
- GSS-6 Controls closest to the hazard protect both workers and the public.
- GSS-7 Controls that are effective for multiple hazards can be resource-effective.

Part 5. Identification of DBAs (Accident Selection)

In transitioning from the hazard evaluation process to the accident analysis (AA) process, a limited set of DBAs is identified. A DBA is defined in DOE G 420.1-1 as "an accident postulated for the purpose of establishing functional and performance requirements for safety structures, systems, and components." As noted in DOE-STD-3009, DBAs "represent a complete set of bounding conditions." DBAs have the potential for either exceeding or challenging the DOE EG. The accident selection activity entails selecting two types of accident scenarios—unique or representative:

- A unique accident scenario is a scenario with sufficiently high-risk estimates to warrant individual examination. A unique scenario is generally considered to challenge or exceed the public EG; for example, a single fire with consequences approaching or exceeding the EG.

- A representative accident scenario is a scenario that bounds similar accidents in a given category (e.g., fire, spill).

Consequences are described by a letter ranking of A-E (most severe to negligible consequence). At least one bounding accident from each of the major accident types (i.e., fire, explosion, spill, etc.), as determined in the HA, should be selected (identified as a representative accident) unless the bounding consequences are low or negligible (i.e., category C or D) and do not challenge the DOE EG. Then a representative accident must be selected to provide at least one accident to be analyzed in that category.

This process is consistent with the criteria listed below:

- Those operational accidents that exceed or challenge the EG when unmitigated (e.g., those with an unmitigated consequence category of A or B) shall be analyzed. Note that some category C accidents may be in the rem range. These are also analyzed in the PDSA.

- Natural events that exceed or challenge the EG when unmitigated and have a phenomenon-initiating frequency as specified in DOE O 420.1B and applicable standards.

- Externally initiated man-made events that exceed or challenge the EG when unmitigated and have a conservatively calculated frequency greater than 10^{-6} per year.

- Representative accidents that bound a given category when that accident category is not represented by a unique accident.

Bounding accident scenarios were selected based on the public consequence category estimated for each scenario. The specific methodology used in this PDSA for selecting accidents follows:

- All What-If hazard scenarios were tabulated. The first selection criterion was unmitigated public dose. All consequence A and B accidents were identified for further consideration, regardless of accident category (e.g., operational, NPH, external).
- The high public consequence accidents were then sorted by accident category and grouped by activity and hazard initiator (i.e., impact, drop, etc.).
- Representative and unique accidents were consolidated as the final selectees and each What-If scenario was linked to a specific accident to be analyzed. Consequence 'C' accidents were evaluated to determine if they were fully represented by the 'A' and 'B' scenarios.

Selected Hazard Analysis Scenarios

What follows are some selected HA scenarios. Included are examples of large fires, seismic events with fires, and an aircraft impact. These are among the more bounding accidents and include an operations type event, a natural phenomena event and an external event. The most bounding cases are selected for further consideration in the AA. Material at Risk (MAR) values have been removed from the following examples of What If scenario tables (from the CMRR Hazard Analysis).

The firs scenario (Scenario 1) is from the Nuclear Facility Laboratories (NFL) tab of the HA. A lab wing catches fire with the maximum allowable MAR permitted in the laboratory spaces. The unmitigated accident has a frequency of occurring between once every year and once every 100 years (bin II). The unmitigated doses to the public, collocated worker and immediate worker are consequence B, A and B, respectively (the thresholds for lettered consequences are different for each, so it is possible that each may have different dose consequences for the same accident). As controls are evaluated for consideration, they are added to the list as preventers, mitigators or both. They may be engineered or administrative controls. Their individual contributions to frequency/consequence reduction are evaluated and a final "Controlled" frequency and consequence set are produced. In this case, with the application of 14 controls, the controlled or mitigated frequency falls to 1 in 100 years to 1 in 10,000 years and consequences fall to D, D and C for the public, collocated worker and worker, respectively. Key controls include the fire suppression system, fire barriers to prevent the spread of the fire, containers that hold and protect the MAR, and HEPA filtered ventilation system to prevent any materials from escaping the facility. Not all controls impact frequency and consequences. Similarly, not all apply to all receptors. Zone 2 HEPA filtered active ventilation will serve to reduce consequences to the public or collocated worker, but is not credited with protecting the immediate worker. The control set highlighted blue are those that ultimately became Safety Significant or Safety Class after evaluation of the HA and subsequent AA.

Hazard Scenario Evaluation o Nuclear Facility Laboratories						Risk Analysis								
ID Activity-86	Hazard		Hazard Scenario	Consequences	Comments/ Assumptions	Control ID	Control Type	Freq.	Conseq			Risk		
	Initiator	Config.						Signif. Reducer (✔)	Public	C. Worker	Worker	Public	C. Worker	Worker
NFL-047	Thermal	SNM	Wing fire (multiple modules) from combustibles in modules, flammable chemicals, pump oil, etc. SNM from gloveboxes/hood/open front boxs or containers disperses in room. Bounds fires from YAG laser (400 W) in AC or from maintenance activities. SF-Fire Sup., confinement MOD-FD, observation	Disp-Fire	MAR ≤ XXX kg PuE (entire lab inventory). Y kg limit for liquids Bounds Z g Cs -137	Uncontrolled ==>		II	B	A	B	2	1	1
						FacDsn-Struc	PE/ME	✔	✔	✔	✔	Struc fail-abnormal		
						Contain-DD	PE/ME	✔	✔	✔	✔	Confinement		
						Contain-LTV	PE/ME	✔	✔	✔	✔	Confinement		
						Contain-STV	PE/ME	✔	✔	✔	✔	Confinement		
						FacDsn-Confine	ME		✔	✔		Confinement-accident		
						FireBar	PE/ME	✔	✔	✔	✔	Fire prop-internal		
						FireDet-Alarm	ITS-E							
						FireSupp	PE/ME	✔	✔	✔	✔	Protect MAR, struc		
						GB-Confine	ME		✔	✔	✔	Confinement-fire		
						HEPA-FirePro	ME		✔	✔		Fire prop (SC)		
						HEPA-Zone1	ME		✔	✔	✔	Confinement-accident		
						HEPA-Zone2	ME		✔	✔		Confinement-accident		
						Hood-Chem	ITS-E							
						WIPP-Contain	PE/ME	✔	✔	✔	✔	Confinement		
						Controlled ===>		III	D	D	C	3	4	3

Scenario 1 Large Fire

The seismic event with fire in the Long Term Vault scenario follows (Scenario 2). This is from the NPH (Natural Phenomena Hazard) tab in the PDSA, Appendix 3B. In this event, the maximum facility MAR is assumed. The unmitigated doses to the public, collocated worker and immediate worker are consequence A, A and B. With the application of multiple controls, the consequences fall to D, D, and C. Key controls will include the facility structure design to allow it to survive a design basis earthquake, seismic qualification of various SSCs within the facility, containers used in the vault and HEPA filtered active ventilation.

Hazard Scenario Evaluation o Natural Phenomena						Risk Analysis								
ID Activity-86	Hazard		Hazard Scenario	Consequences	Comments/ Assumptions	Control ID	Control Type	Freq.	Conseq			Risk		
	Initiator	Config.						Signif. Reducer (✔)	Public	C. Worker	Worker	Public	C. Worker	Worker
NPH-031	Seismic Events	SNM	Earthquake leads to extensive facility damage and breach of container(s) in LTV. Bounds subsidence events. SF-confinement MOD-observation	Disp-Rad	Up to XXX kg PuE.	Uncontrolled ==>		III	A	A	B	2	2	2
						ARDS (a,b)	ITS-E							
						Contain-LTV	ME		✔	✔	✔	Confinement		
						FacDsn-Confine	ME		✔	✔	✔	Confinement-NPH		
						FacDsn-Struc	PE	✔				Struc fail-NPH		
						HEPA-Vault	ME		✔	✔		Confinement-NPH		
						LTV-MM	PE	✔				Protect contain-DBE		
						HEPA-Zone2	ME		✔	✔		Confinement-NPH		
						SeismicQual	PE	✔				Seismic prot SC SSC		
						Storage-LT Vault	PE	✔				Struc fail-NPH		
						Controlled ===>		IV	D	D	C	4	4	4

Scenario 2 Seismic Event in Long Term Vault

The following small aircraft impact is from the EE (External Events) tab in the PDSA (see Scenario 3). The PDSA evaluates the unmitigated frequency as being between 10^{-4} per year and 10^{-6} per year. Appendix 3D of the PDSA discusses the calculation to determine frequency (3.6 x 10^{-5} per year). The unmitigated doses to the public, collocated worker and immediate worker are consequence A, A and B. With the application of multiple controls, the consequences fall to E, E, and E (negligible consequence). Key controls will include the facility structure design to allow it to survive a light aircraft impact and fire barriers to control spread of any fires. Many other controls are listed, but they are not credited as major contributors to safety since a structure designed to survive the impact means the MAR is well protected, MAR will not be released and the other SSCs are not needed to provide a high level of protection.

Hazard Scenario Evaluation o External Events						Risk Analysis								
ID Activity-##	Hazard		Hazard Scenario	Consequences	Comments/ Assumptions	Control ID	Control Type	Freq.	Conseq			Risk/SF		
	Initiator	Config.						Signif. Reducer (✓)	Public	C. Worker	Worker	Public	C. Worker	Worker
EE-008	Aircraft Impact	SNM	Aircraft impacts Security Category 1 Building. Fire ensues. SNM released. Crash and spill/fire into HVAC intake structure is considered incredible. SF-Fire Sup., structural failure MOD-observation, FD	Disp-Fire	XXX kg PuE (entire inventory)	Uncontrolled ==>		IV	A	A	B	2	2	3
						Contain-DD	ITS-E							
						Contain-Liquid	ITS-E							
						Contain-LTV	ITS-E							
						Contain-STV	ITS-E							
						FacDsn-Confine	ME		✓	✓	✓	Confinement		
						FacDsn-Struc	PE/ME	✓	✓	✓	✓	Struc NH-EE		
						FireBar	ME		✓	✓	✓	Fire prop-internal		
						FireDet-Alarm	ITS-E							
						FireSupp	ME		✓	✓	✓			
						GasDlvy-Dsg	ITS-E							
						GB-Confine	ITS-E							
						GB-FSS	ITS-E							
						GB-Inert	ITS-E							
						HEPA-FirePro	ITS-E							
						HEPA-Zone1	ITS-E							
						HEPA-Zone2	ITS-E							
						HEPA-Zone3	ITS-E							
						Matl/XfrSys	ITS-E							
						SeismicQual	ITS-E							
						Storage-LT Vault	ITS-E							
						SNMShelving	ITS-E							
						Controlled ===>		V	E	E	E	4	4	4

Scenario 3 Aircraft Impact

Note that there are no hazardous material scenarios in the HA that exceed the DOE-STD-1189 threshold for safety significant controls (AEGL-3/ERPG-3/TEEL-3 at 100 m, AEGL-2/ERPG-2/TEEL-2 at the site boundary), so hazardous chemicals are not pursued further in the accident analysis. Hazardous Chemical inventory will be controlled via a Special Administrative Control.

Accident Analysis at CMRR

They include operational fires, operational spills, operational explosions or deflagrations, nuclear criticality, natural phenomena and external events. Specifically, the DBAs analyzed are:

1. Fire in a Laboratory Level (all three wings)] **
2. Fire in a Wing
3. Fire in a Single Laboratory Room
4. Fire in a GB or GB Line
5. Fire in the Long-Term/Short-Term Vaults
6. Fire in the LVH Area
7. Fire or Waste/LV Spill near/on Loading Dock **
8. Elevator Drop Accident
9. Spill From a Large Vessel drop
10. Loss of Cooling in Vaults
11. Spill from STV/NDA Shelf Failure
12. Hydrogen Deflagration in Battery Recharging Station
13. Hydrogen evolution/deflagration in Vaults
14. Nuclear Criticality**
15. Seismic Spill **
16. Seismic Induced Fire**
17. Natural Gas Explosion
18. Aircraft Crash**

** Accidents summarized in the subsequent sections.

Among the most unique and severe, DBAs 1, 14, 15, 16 and 18 are summarized herein
In each DBA, a summary table describes the crediting of controls and affect on dose.

The five-factor formula (i.e., MAR*DR*ARF*RF*LPF) is used to derive the source term (ST). A dose estimate to the MOI and CW is then calculated from the product of the source term and the dose-to-source term ratio. Each of the table entries is briefly described below.

Case: This entry is used to assign a unique identification number to each of the DBA scenarios being considered. The uncontrolled scenario is always presented first and labeled as Case No 1. Subsequent scenarios (which include credit for one or more controls) are assigned higher case numbers, starting with the number “2.” In many instances, a scenario is subdivided into multiple sub-scenarios. For sub-scenarios, the scenario number is combined with an alphabetical identifier (e.g., Case 2a, 2b, 2c).

Scenario: This field provides a brief summary of the DBA and the specific scenario being evaluated. For controlled scenarios and sub-scenarios, reference is made to incrementally credited controls.

Controls: This field lists credited controls for controlled scenarios. Incrementally credited controls are shaded, whereas any controls credited from previous scenarios or sub-scenarios are listed but not shaded. Corresponding changes to parameters (e.g., DR, LPF) attributed to incrementally added control(s) are explicitly displayed in the shaded row(s) associated with the incrementally added control(s).

Safety Designation: Individual controls are assigned a safety designation (e.g., safety class, safety significant) depending on their effectiveness on consequence reduction. Because the assignment of safety designation is accident and scenario-specific, it is possible that the safety designation of a given control might vary among different accidents. The overall safety designation of a control in the PDSA is based on the highest safety designation of that control among all of the AA scenarios.

Confinement Configuration: The status of the facility confinement system is represented by three potential configurations. Passive confinement mode is designated by use of the term “Off” in the “Ventilation” subcolumn. The LPF assigned to passive confinement is independent of the status of the building doors. The “Doors” subcolumn for this configuration is labeled as “Open or Closed.” Active confinement is designated by use of the term “On” in the “Ventilation” subcolumn. Two configurations are postulated for active confinement, one with building doors open, and the other with building doors closed.

MAR (Material At Risk): MAR limits assumed for each scenario are listed in this field.

DR (Damage Ratio): This field represents the DR assigned to a particular scenario or sub-scenario. For uncontrolled scenarios, the DR is set to 1.0. For controlled scenarios and sub-scenarios, the DR is based on the effectiveness of any controls incrementally added to that scenario or sub-scenario. DRs associated with individual sub-scenarios are multiplicative, such that the composite DR for a given scenario is derived from the product of the DRs for each sub-scenario.

ARF (Airborne Release Fraction): The ARF is specifically adjusted to represent the conditions and attributes of the associated scenario or sub-scenario, including the influence of any credited controls.

RF (Respirable Fraction): The RF is specifically adjusted to represent the conditions and attributes of the associated scenario or sub-scenario, including the influence of any credited controls.

LPF (Leak Path factor): By default, the LPF is set to 1.0 unless credit has been taken for facility confinement. As described above, the status of confinement is represented by three potential configurations, specifically passive confinement, active ventilation with doors open, and active ventilation with doors closed. The LPF for these three cases has been conservatively set to 0.1, 0.01, and 0.001, respectively.

ST (g) (Source Term): This field represents the source term (in grams of PuE) as calculated from the five-factor formula.

Dose/ST (rem/g PuE): This field represents the dose-to-source term ratio for the public and CW from Appendix 3C.

Dose to MOI (rem) and CW: The dose to the MOI and CW is calculated by the product of the ST and the dose-to-source ratio (Dose/ST). Individual MOI and CW dose estimates are provided for each control incrementally credited in reducing the dose to the MOI.

Fire in Laboratory Level (all 3 wings affected)

This accident depicts a fire in multiple laboratories (Fire in all 3 wings) (defined as the uncontrolled or unmitigated fire). The magnitude of this fire is assumed to be approximately 50 MW, a value required to reach flashover in the multiple laboratory area. The fire will not challenge the Security Category I Building walls and ceiling/floor (rated for 2 hr at 1,850°F) between the laboratory level and other levels, and other areas (vaults and LVH area). It is however, hypothetically assumed that the internal NF fire rated walls or partitions are defeated (e.g., by open doors), so a fire in a lab or lab wing could spread into other adjacent laboratories or wings.

Without the benefit of fire suppression, the fire can heat the ventilation exhaust air (even after mixing in the ducting with normal air from other exhaust flows) to a temperature that could threaten the performance of HEPA filters downstream. HEPA filters are to be qualified for a minimum of 250°F continuous service temperature per AG-1-2003 FC-1121. HEPA filters are to be qualified for 5-minute exposure to 700°F +/- 50°F per AG-1-2003 FC-5151. However, the fire sprinkler actuation analysis predicts system actuation well within 5 min (based on fire sprinkler parametric fires response calculations [Ref. 40]. The sprinklers drastically reduce the peak air temperature to a level that precludes a challenge to HEPA filters.

For fires in which the entire laboratory is involved, the first SC control expected to be relied upon are the passive fire barriers that limit the fire scenario to the accident size being analyzed. The fire barriers form the boundary for the postulated accident and resultant fire modeling and analysis.

Fire sprinklers are credited next, as the FSS is closer to the fire area of origin than the HEPA filters, and the expectation is that fire sprinklers will actuate prior to high temperatures being achieved at the HEPA filtration systems, or even at the plenum spray cool down system. This is supported by the relatively fast fire sprinkler actuation times in the severe fires modeled and the less than 5-minute response in the fire sprinkler parametric response fires.

The uncontrolled likelihood of a fire in the three laboratory wings is postulated as the "OCCASIONAL or anticipated" frequency category (once every 1 to 100 yr). This is based on the frequency of fires in typical industrial facilities (per the frequency estimates in Appendix 3B) as conservatively assumed for incipient fires in nuclear facilities, and the failure of multiple passive engineering controls such as 1- and 2-hr rated walls and penetrations.

The following SSCs prevent this accident and other representative accidents in this category. These and other SSCs will vary in their applicability depending on the specific accident, and have the potential for being elevated to SC.

- An inerting system in a GB to help prevent a fire. This feature applies only to GBs that are intended to handle pyrophoric or reactive material (such as Pu metal fines) and GBs with furnaces/SNM.
- An oxygen monitoring system in a GB to help prevent a fire. This feature applies only to GBs that are intended to handle pyrophoric or reactive material (such as Pu metal fines), GBs with furnaces/SNM, and lathe operations.
- A GB FSS in GBs that are not normally inerted.

- A non-explosive resin formulation in a GB ion-exchange column to prevent the resin from exploding or catching fire.
- Heat removal from equipment (such as furnaces), vessels for exothermic chemical reactions, and other heat sources in or near a GB to prevent fire.
- Electrical safety design: Approved electrical equipment within and near the laboratories to prevent fire from electrical faults, NEMA-rated electrical enclosures to prevent fire from electrical faults, and grounding of electrical equipment to prevent fire from static discharge and lightning.
- Forklift charging station ventilation and location constraints to prevent the initiation of a fire/explosion from flammable hydrogen by limiting the buildup of this gas.
- A facility design that excludes natural gas sources/distribution to eliminate this flammable chemical as a fire hazard.

The likelihood of this accident with the above SSCs in place significantly lowers the likelihood (per the frequency estimates in Appendix 3B to the "IMPROBABLE" frequency category [10^{-4} to 10^{-6}/yr]) with the above engineering controls, thus reducing risk to more acceptable levels.

The most likely pathway for a potential release of airborne radioactive material to the environment in this accident will be the building ventilation exhaust stack. With normal ventilation in the building, radioactive material will enter the ventilation exhaust from the enclosures, the laboratories, and the corridors via separate streams. Without active ventilation, radioactive material can potentially migrate from the process area to outside areas while intervening doors are open for evacuation of personnel.

The following SSCs will mitigate a potential release to the environment in the event the primary means of confinement (the enclosure or container) is breached. Note that fire barriers can be considered to be both preventors and/or mitigators, but are being shown here as mitigators.

1) Facility structure (including fire barriers) prevents propagation of fires from one area to another. This includes lab and wing doors to the corridor(s).
2) A FSS to control and potentially control a fire in areas with radioactive material in containers or enclosures, therefore minimizing the dispersion of material.
3) A facility confinement system to confine airborne radioactive material and mitigate its release to the environment. It includes the facility doors, doors (particularly those between ventilation zones), penetration seals, ventilation ducting, intake bubble tight dampers, and HEPA filters.
4) HEPA-filtered active ventilation systems to pull airborne radioactive material from the building areas and trap it in HEPA filters, thereby preventing or reducing migration of airborne radioactive material within the building and/or into the environment.
5) A cooling water spray in the ventilation system to prevent damage to HEPA filters or loss of filtration efficiency from hot air heated by fire in a building area.
6) Robust containers (not credited for small fires with direct flame impingement when fire sprinklers do not actuate.) of radioactive material to withstand a rupture from fire caused by either thermal degradation or internal pressure from the heat (radioactive material is

expected to be unprotected inside GB enclosures); no credit is given for containers outside GBs in the laboratory areas.

7) Fire barriers around the exterior perimeter of the Security Category I Building (rated for 2 hr at 1,850°F).

8) Fire barriers around the perimeter of the entire laboratory (3 wings combined, rated for 2 hr at 1,850°F) to mitigate a fire and prevent its spread outside the laboratory area.

9) Fire barriers between laboratory wings (rated for 2 hr at 1,850°F) to mitigate a fire and prevent its spread from one laboratory wing to another.

10) Fire barriers (wall partitions) between adjacent laboratories in a wing (rated for 1 hr at 1,700°F) to mitigate a fire and prevent it propagation from one laboratory room to another.

11) GB fire resistant doors segregating GBs within a GB line. The GB fire doors will be maintained normally closed, thereby precluding an internal fire from propagating to nearby GBs and spread to the room through glove burn out. It is important to notice that these doors will have very limited effectiveness for fires that could be propagated from the lab areas to the GBs.

12) Fire resistant doors in the MTS cross town trolley to mitigate a fire and to limit the propagation of fire from one laboratory to another via the MTS tunnel, and from one wing to another via the MTS tunnel.

13) Fire resistant MTS drop box doors to mitigate a fire and to limit the propagation of fire from one laboratory room to another via the wing trolley system.

14) Fire barriers between the laboratory (or basement) level and other building areas (rated for 2 hr at 1,850°F) to stop the propagation of fire in to or out of the level.

15) Fire detection to provide a timely alert for fire department response and personnel evacuation.

16) Fireproof cabinets for chemicals to prevent additional fueling of the fire.

17) HEPA filters are to be qualified for 250°F continuous service temperature per AG-1-2003 FC-1121. HEPA filters are to be qualified for 5-minute exposure to 700°F +/- 50°F per AG-1-2003 FC-5151.

Consequence Analysis

Dose calculations for the uncontrolled and controlled scenarios are summarized in Table 2. This table includes estimates of consequence reduction achieved through the incremental addition of controls. Information presented in the tables is used to help justify the categorization of individual controls as being safety class or safety significant.

[Public] The uncontrolled dose to the MOI is 6.8 rem.

[Collocated Worker] For the collocated worker, the uncontrolled consequence is 240 rem.

Controlled Scenario No 2a:
(Fire with fire barriers, facility structure, and FSS)

The fire barriers (including facility structure), and the FSS reduces the Public dose to 3.3 rem by decreasing the DR. Credit for passive and active ventilation further reduces this controlled dose to the MOI.

For the collocated worker the mitigated dose using the SC and SS controls applied to the public is less than 15 rem.

Comparison to the EG

[Public] The unmitigated scenario (Sub-scenario 1a) where fire spreads throughout the entire laboratory level (all three laboratory wings) could potentially expose the MOI to 6.8 rem, which challenges the DOE EG of 25 rem. For this reason, SC SSCs are expected to be designed for use in the CMRR NF for this scenario.

Controlled Scenario No. 2b

With credit for the fire barriers, facility structure, and FSS (Sub-scenario 2a), the public dose is reduced to approximately 3.3 rem. At this point, the dose level (3.3rem) is below the "5 rem range" and thus is not considered to challenge the EG. The controls credited in reducing the dose to this level are therefore designated as safety class, as indicated in Table 3-22. These safety class controls are the fire barriers that bound the 3 laboratory wings, facility structure, and the FSS.

The mode of the confinement ventilation system also contributes to further dose reductions; thus, the active and passive ventilation are designated as safety significant as further defense in depth controls, given that they are not needed to reduce the dose level below the "5 rem range."

[Collocated Worker] With the SC and SS controls identified in Table 3-9, the dose to the collocated worker is less than the 100 rem EG.

Table 2 Derivation of Doses to MOI and CW for Fire in the Laboratory Level

Case	Scenario	Controls	Safety Desig	Confinement Configuration Ventilation	Doors	MAR (kg)	DR	ARF	RF	LPF	ST (g)	MOI Dose/ST (rem/g PuE)	Dose to MOI (rem)	CW Dose/ST (rem/g PuE)	Dose to CW (rem)
1	Uncontrolled Scenario:														
1	Fire initiated in a laboratory level.			N/A	N/A	270	1.0E+00	5.0E-04	0.5	1.0E+00	6.8E+01	6.76E-02	4.6E+00	2.19E+00	1.5E+02
				N/A	N/A	25	1.0E+00	6.0E-03	1.00E-02	1.0E+00	1.5E+00	6.76E-02	1.0E-01	2.19E+00	3.3E+00
						5	1.0E+00	2.0E-03	1	1.0E+00	1.0E+01	2.11E-01	2.1E+00	8.46E+00	8.5E+01
		Note=liquids use Medium (M) Pu solubility for Dose/ST											**6.8E+00**		**2.4E+02**
2	Controlled Scenario														
2a	Case 1 with: - Facility Structure - Fire Suppression	Fire Barriers (FireBar)	SC												
		Facility Structure (FacDsn-Struc)	SC												
		Zone 2 HVAC (HEPA-Zone2) Fire Barrier function	SC												
		Zone 1 HVAC (HEPA-Zone1) Fire Barrier function	SC												
		Fire Suppression System (FireSupp)	SC												
				N/A	N/A	270	2.6E-01	5.0E-04	0.5	1.0E+00	1.8E+01	6.76E-02	1.2E+00	2.19E+00	3.8E+01
				N/A	N/A	25	0.0E+00	6.0E-03	1.00E-02	1.0E+00	0.0E+00	6.76E-02	0.0E+00	2.19E+00	0.0E+00
						5	1.0E+00	2.0E-03	1	1.0E+00	1.0E+01	2.11E-01	2.1E+00	8.46E+00	8.5E+01
													3.3E+00		**1.2E+02**
2b	Case 2a with: - Facility Confinement	Fire Barriers (FireBar)	SC												
		Facility Structure (FacDsn-Struc)	SC												
		Fire Suppression System (FireSupp)	SC												
		Zone 2 HVAC (HEPA-Zone2) Fire Barrier function	SC												
		Zone 1 HVAC (HEPA-Zone1) Fire Barrier function	SC												
		Zone 1 HVAC, Zone 2 HVAC, Zone 3 HVAC (HEPA-Zone 1, HEPA-Zone 2, HEPA-Zone 3)	SS	On	Closed					1.0E-03					
				On	Closed	270	2.6E-01	5.0E-04	0.5	1.0E-03	1.8E-02	6.76E-02	1.2E-03	2.19E+00	3.8E-02
						25	0.0E+00	6.0E-03	1.00E-02	1.0E-03	0.0E+00	6.76E-02	0.0E+00	2.19E+00	0.0E+00
						5	1.0E+00	2.0E-03	1	1.0E-03	1.0E-02	2.11E-01	2.1E-03	8.46E+00	8.5E-02
													3.3E-03		**1.2E-01**
			SS	On	Open					1.0E-02					
				On	Open	270	2.6E-01	5.0E-04	0.5	1.0E-02	1.8E-01	6.76E-02	1.2E-02	2.19E+00	3.8E-01
						25	0.0E+00	6.0E-03	1.00E-02	1.0E-02	0.0E+00	6.76E-02	0.0E+00	2.19E+00	0.0E+00
						5	1.0E+00	2.0E-03	1	1.0E-02	1.0E-01	2.11E-01	2.1E-02	8.46E+00	8.5E-01
													3.3E-02		**1.2E+00**
			SS	Off	Open or Closed					1.0E-01					
				Off	Open or Closed	270	2.6E-01	5.0E-04	0.5	1.0E-01	1.8E+00	6.76E-02	1.2E-01	2.19E+00	3.8E+00
						25	0.0E+00	6.0E-03	1.00E-02	1.0E-01	0.0E+00	6.76E-02	0.0E+00	2.19E+00	0.0E+00
						5	1.0E+00	2.0E-03	1	1.0E-01	1.0E+00	2.11E-01	2.1E-01	8.46E+00	8.5E+00
													3.3E-01		**1.2E+01**

Spill (or Fire) in the Loading Dock

This accident scenario was selected to represent a wide range of spills and fires that may occur outside the CMRR facility associated with the loading dock. This scenario is postulated to involve waste containers being shipped from the loading dock, or a large vessel being delivered to the facility for processing or cleanup.

This scenario is postulated to occur due to a variety of initiating events including, among others, vehicle (trucks/forklifts) impacts, mishandling of containers in the loading dock, firearms discharges, and missiles created from pressurized containers or lines. Because this scenario also includes fire scenarios, other initiating events may include fires due to refueling activities near the facility, fires due to vehicle impacts, and equipment and miscellaneous fires near the loading dock. The rational for including both spills and fires under this accident scenario is because controls that will prevent or mitigate these types of scenarios are for the most part common to both. Note that the shipping and receiving dock is elevated. There will be no staging of drums on the ground as any material to be shipped will be loaded onto a truck from the dock. Therefore, a scenario that involves a vehicle severely impacting the entire 6 kg inventory of drums with a spill or a fire involving all of the drums is not a credible concern. Waste containers in this DBA are taken to be either TRU waste drums or Standard Waste Boxes (SWB).

The most relevant type of cause of this type of scenario, at least from the facility design perspective, is the impact to containers due to mechanical impacts from vehicles or mishandling of containers during shipping and receiving activities on the loading dock. Alternately, a fire could be initiated from combustibles, a fuel leak or spill in the dock vicinity. A less likely scenario is a drop or fire accident involving a single Large Vessel.

The uncontrolled likelihood of a loss of containment due to mechanical insults due to vehicles or drops is postulated to be in the "OCCASIONAL" frequency category (once every 1 to 100 years), while the likelihood of a loss of containment due to thermal insults is postulated to be "PROBABLE" (100 to 10,000 years). This is based on the likelihood of human errors associated with vehicles or mishandling activities and conditional probability of a fire being initiated due to such initiating events.

The following SSCs can prevent this accident and other representative accidents in this category. These and other SSCs will vary in their applicability depending on the specific accident.

- Vehicle barriers to keep vehicles from impacting containers of radioactive waste staged on the loading dock. The facility design does not allow for any outside storage area beyond the dock. The most relevant vehicle barrier in the loading dock is the actual elevation of the loading dock (≤4 ft) and its structural capability to withstand potential mechanical insults from vehicles being used to ship these containers.
- A dock leveler for unloading containers of radioactive material from a truck bed onto the dock (or loading containers onto a truck) to prevent drops of containers. Note: At this stage it is not clear about the inclusion of this feature in the final design of the facility.

- TRU Waste containers, including SWBs, which would be shipped from the CMRR. CMRR will be a waste generating facility, so the containers shipped would have newly generated waste.
- Large Vessel, which will be shipped in for processing. Only one vessel will be on the dock or in the facility as controlled by the MAR limits.

  Note: LVs that could be accepted at the CMRR facility in any future mission must meet rigorous requirements to assure that they meet the design safety function and performance requirements determined in this PDSA. Design and engineering documents must validate the LV pedigree. A final specification will be produced or referenced if the LV activities become an actual future mission. This design specification document provides detailed engineering and quality specification for a very robust designed vessel that must be able to meet rigorous confinement specifications.

Because of the location of these postulated events, any release will be released directly to the environment. Thus, the only mitigated control available will be the containers themselves, in reducing the amount of radioactive material that could potentially be released to the environment. As the LV container is more robust for drops or fires than the TRU waste drums, the accident analysis is analyzed as if all MAR on the dock was in TRU containers. Additionally, the release fractions for combustible waste are significantly higher than the material in a LV so the analysis with waste is more conservative.

Scenarios evaluated for this accident are listed below. Along with the unmitigated accident, a couple of mitigated scenarios were also evaluated. As previously done, the mitigated scenario is evaluated in a series of discrete steps, where each step represents the development of an individual sub-scenario. As successive sub-scenarios are developed, controls are incrementally added to the set of controls credited in the previous sub-scenario. As will be demonstrated, analysis of individual sub-scenarios facilitates judgments regarding consequence-reduction benefits associated with individual controls.

- Uncontrolled scenario

  Spill of waste containers in the loading dock (Scenario 1a) and
  fire involving the waste in these waste containers (Scenario 1b)
- Controlled scenarios (incremental addition of controls as described below)

  Waste containers for spill scenarios (Scenario 2a)

Source Term for Unmitigated Waste Drum Fire (Scenario 1b)

Due to the involved logic directed by STD-5506 for evaluating waste drums burning in a fuel pool, the following is provided to summarize the source term derived for Scenario 1b in the next section and Table 6.

Unmitigated Source Term for Drum Array Inside Burning Fuel Pool
(4 pallets, 3 pallets in a 2 x 2 x 2 array and a 4th pallet in a 4 bottom and 2 top array)

Based on Std 5506, Figure 4.4.3-1

- MAR per drum = 200
- Total # drums = 30
- Drums on top tier = 14
- Drums on bottom tier = 16
- 25% of drums on top tier lose lids = 4
- 1/3 contents are ejected = 266 grams
  - ST Unconfined burning = ARF (1E-2) * RF (1) * 266 = 2.66 grams Pu
  - ST Flexing in air = ARF (1E-3)* RF (0.1) * 266 = 0.03 grams Pu
- 2/3 contents confined burning = 534 grams
  - ST burning confined = 534 * ARF (5E-4) * RF (1) = 0.27
- 75% of drums on top (10) + 100% of drums on lower tier (16 = 26
  - ST burning confined ST = 26 * 200 * 5E-4 * 1 = 2.6 grams Pu
  - Total unmitigated Source Term (Scenario 1b) = 5.56 grams Pu

Consequence Analysis

Table 6 summarizes the consequence calculations for the unmitigated and mitigated scenarios. This table includes estimates of consequence reduction achieved through the incremental addition of controls. Information presented in the tables is used to help justify the categorization of individual controls as being safety class or safety significant.

Uncontrolled Scenario No. 1

For spills, the uncontrolled dose to the MOI is 0.40 rem for Sub-scenario 1a. For fires, the uncontrolled dose to the MOI is 0.38 rem for Sub-scenario 1b.

For the CW the uncontrolled dose (spill) is 13 rem and for the fire is 12 rem.

Controlled Scenario No. 2
(Spill of waste containers)

The waste containers reduce the dose to the MOI to 0.04 rem. This is based on the impact the waste containers have on the DR in a mechanical scenario (0.1 from STD 5506).

The controlled case for the fire is not calculated since the unmitigated results of 0.38 (scenario 1b) are already much less than the 5-rem threshold for SC designation and the credit for containers is inherently accounted for in the source term calculation from DOE-STD-5506.

[Collocated Worker] For the collocated worker, the unmitigated consequences for both spill and fire are less than 15 rem.

Comparison to the EG

The unmitigated scenarios for the public, 1a and 1b of 0.42 and 0.39 rem, respectively, or their combination do not challenge the EG value of 5 rem that is considered the threshold for SC designation (see note below). For this reason, SC SSCs are not required in the CMRR Nuclear Facility for this accident.

Note: Approved DOE-STD-5506 methodology was used to determine the source terms for waste drum accidents since this recent standard provides a more comprehensive treatment of waste drum accidents. Doses resulting from the unmitigated and unmitigated accidents do not challenge the EG. DOE-STD-5506 provides further guidance on updated dose conversion factors from International Commission on Radiological Protection (ICRP) 68/72 publications that are more suitable for use. The DOE-STD-1189 (Integrating Safety Into Design Projects) also adopts the ICRP 68/72 factors and also directs that any MOI dose < 5 rem is not considered to challenge the EG.

[Collocated Worker] With the SC and SS controls identified in Table 6, the dose to the collocated worker is less than 100 rem. As such, no additional SS controls beyond those identified for the public are necessary.

Table 6, Derivation of Doses to MOI and CW for Fire/Spill on Loading Dock

Case	Scenario	Controls	Safety Designation	Confinement Configuration Ventilation	Doors	MAR (kg)	DR	ARF	RF	LPF	ST (g)	MOI Dose/ST (rem/g PuE)	Dose to MOI (rem)	CW Dose/ST (rem/g PuE)	Dose to CW (rem)
	Uncontrolled Scenario														
1a	Damage to waste containers on the loading dock (unmitigated) - Spill			N/A	N/A	6	1.0E+00	1.0E-03	1.0	1.0E+00	6.0E+00	6.63E-02	**4.0E-01**	2.19E+00	**1.3E+01**
1b	Fire involving waste containers on the loading dock			N/A	N/A	0.266	1.0E+00	1.00E-02	1.0	1.0E+00	2.7E+00	6.76E-02	1.8E-01	2.19E+00	5.8E+00
				N/A	N/A	0.266	1.0E+00	1.00E-03	0.1	1.0E+00	2.7E-02	6.76E-02	1.8E-03	2.19E+00	5.8E-02
				N/A	N/A	0.534	1.0E+00	5.00E-04	1.0	1.0E+00	2.7E-01	6.76E-02	1.8E-02	2.19E+00	5.8E-01
				N/A	N/A	5.2	1.0E+00	5.00E-04	1.0	1.0E+00	2.6E+00	6.76E-02	1.8E-01	2.19E+00	5.7E+00
													3.8E-01		**1.2E+01**
2	Controlled Spill Scenario - Waste containers														
2a	Case 1a with waste containers	Waste - Containers (WIPP-Contain)	SS				1.0E-01								
		Facility Structure (BLDGC) [Elevated Loading Dock]	SS												
				N/A	N/A	6	1.0E-01	1.0E-03	1.0	1.0E+00	6.0E-01	6.63E-02	**4.0E-02**	2.19E+00	**1.3E+00**

Inadvertent Criticality

Operations in the CMRR NF will involve the handling and staging of significant quantities of fissile materials in the form of metal or powder, although some material will be in solutions. As a result there are a number of potential hazard scenarios that could result in a nuclear criticality in the CMRR NF, which include:

- Fissile material is configured incorrectly during handling activities including over-batching, and transfers to containers or leakage into an unfavorable geometry.
- A moderator is introduced to significant quantities of fissile materials during staging or handling operations because of inadvertent actuation of the FSS or actuation of the FSS in response to a fire.
- Reflector or moderator materials are introduced to significant quantities of fissile materials, or the geometry of fissile materials or components are changed, during handling or staging operations because of fire, mechanical impact, or seismic events.

- Fissile material is reconfigured; moderator and/or reflectors are introduced during a DBA, such as during a seismic event.

Material is stored in STV containers in vault chambers that can be accessed on a daily basis. These containers can each contain up to 6 kg of SNM as a solid metal or oxide material. Within each of the 10 chambers up to 100 kg can be stored. The intent is to store the material on shelving with adequate geometry (spacing) and other criticality protection measures. In the event of a breakdown of procedures and training of individuals and without engineering features there could be too much material added to a location resulting in a criticality event.

Another potential scenario is the isolated failure of a shelf with multiple containers, which could lead to failure of other lower shelves. In either case the single or multiple shelf failure, the SNM in an unmitigated fashion could be reconfigured into a critical mass.

The uncontrolled likelihood of a criticality event in the STV is postulated in the 'Occasional or anticipated' frequency bin II (once every 1 to 100 years) if there are no engineering or administrative controls in place.

The likelihood of this accident and those within the criticality accident family, with the criticality preventing SSCs in place in the PDSA is expected to be significantly lower, in the frequency bin IV, IMPROBABLE (10^{-4} to 10^{-6}/yr) or lower. This lower likelihood is also supported by general nuclear industry data, in which there are relatively few criticality events which have occurred in many hundreds of operating years for the full set of nuclear facilities throughout the industry.

In the event of a criticality event, there are no identified SSCs that will significantly mitigate the consequences to a worker in the immediate area. The Criticality Alarm System (CAS) is required by ANS standards and would alarm to ensure all workers evacuate. [Ref. 78] This would provide some mitigation of the consequences to area workers from the post criticality fission product inventory in the area, which could results in dose due to external radiation (beta, gamma) or internal inhalation. Should a second criticality pulse occur, the evacuation of workers would mitigate potential consequences.

The LANL Safety Basis division has evaluated [Ref. 49] a criticality event associated with a fissile yield corresponding to the design criteria for a criticality alarm system in ANSI/ANS 8.3. This fission yield, 2×10^{19} fissions, corresponds to the magnitude of a 'solution criticality,' which is calculated to be a significantly higher yield than a metal/oxide solid criticality. The calculation indicates that the dose consequences may be linearly scaled for a fission yield less than this value. The types of criticality events that are considered credible, without controls, in the CMRR NF are powder, metal, or an event where SNM is fully moderated due to water from fire suppression (or other sources). Section 6 of the DOE Handbook 3010 places estimates of Fully moderated and reflected solids having a reference value of 1×10^{18} fissions in a single burst is the very conservative bounding value. Dry powder and metal are estimated at a value of 1×10^{17} fissions is given as the total fission yield for dry solid systems.

A high yield fissile solution criticality is not considered a credible event because the only place fissile solution is expected is in the analytical chemistry processes and the amounts of dissolved fissile material is very low (gram quantities or less). Based on the DOE-HDBK-3010 bounding values and the discussion above, the bounding fission yield (single or multiple pulses) for the CMRR NF criticality DBA is taken to be 1×10^{18} fissions, a conservative value.

Consequence Analysis

[Public] The consequence results from the referenced calculation [Ref. 49] for the reference yield of 2 x 10^{19} fissions is 5 rem based on three different methods; 5.0 rem from the NRC Reg Guide 3.35, 4.6 rem from DOE/EH-0070, and 3.4 rem from a FGR 12 methodology. The external dose from beta radiation accounts for the majority of the dose. The external gamma dose to internal organs is about 20-35% of the total, and the inhalation dose is negligible (~ 2%).

Conservatively scaling the above results (based on the NRC method yielding 5 rem) to the CMRR yield of 1 x 10^{18} fissions results in an offsite dose of 0.25 rem.

[Collocated Worker] For the collocated worker, scaling the dose to source term ratio, the unmitigated consequences are less than 10 rem.

Comparison to the EG

The dose to the MOI, 0.25 rem TEDE, from an inadvertent criticality does not challenge the EG, thus there is no need for identifying SC SSCs. As stated above in the accident progression and source term discussions, this dose is very conservative.

[Collocated Worker] The dose to the collocated worker is less than 100 rem.

Safety significant controls for worker protection are required. Preliminary Criticality Safety Evaluations (PCSE) performed by the criticality safety SME(s) evaluate the set of facility and process-specific. These PCSEs were performed in accordance with DOE STD 1189. No Safety Class controls are needed.

Spill from Mechanical Damage by Earthquake

Accidents involving spills from containers of radioactive material (including a large vessel) and enclosures (GBs, hoods, open-front boxes, and the MTS tunnel) can occur from natural phenomena hazards (NPHs). These spills could result from an earthquake that causes a mechanical impact directly or indirectly (such as overhead objects falling during the earthquake).

This accident depicts an earthquake that simultaneously causes substantial mechanical damage to enclosures and containers of radioactive material throughout the Security Category I Building, resulting in a significant loss of confinement.

The uncontrolled likelihood of this accident is postulated as the "PROBABLE" frequency category (once every 100 to 10,000 yr), based on the frequency of a PC-3 earthquake and a postulated conditional probability of 1 that enclosures and containers are breached with dispersion of radioactive material.

The following SSCs can prevent the adverse effects of an earthquake and other representative accidents in this category. These and other SSCs will vary in their applicability depending on the specific accident.

- Enclosures to withstand damage from NPH events.
- Vault storage designs that hold containers of radioactive material (i.e., the shelves in the STVand NDA and the floor matrix of cells in the LTV) to withstand damage from NPH events.
- Robust containers of radioactive material to withstand impact damage from NPH events.
- Bracing and mounting of enclosures and storage designs to prevent damage from NPH events.
- A facility structure to protect the SSCs within from NPH events, including support for overhead equipment that may impact radioactive material during NPH events.
- Reinforced walls or barriers in the LVH area to withstand the impact of a large vessel.

If the ventilation systems remain operational after the earthquake, the most likely path for a potential release of airborne radioactive material to the environment in this accident will be the building ventilation exhaust stack. If the ventilation systems are fully or partially impaired (from mechanical damage or loss of electrical power), radioactive material can potentially migrate to the outside through penetrations and doors, including those open for evacuation of personnel. The following SSCs could be expected to mitigate a potential release to the environment in the event the primary means of confinement (the enclosure or container) is breached:

- A facility structure that preserves the integrity of various facility features during a seismic event, including internal and external structural elements.
- HEPA-filtered active ventilation systems to pull airborne radioactive material from the building areas and trap it in HEPA filters, thereby preventing or reducing migration of airborne radioactive material within the building and/or into the environment.
- A passive confinement mode to confine airborne radioactive material and mitigate its release to the environment. It includes the facility doors, doors (particularly those between ventilation zones), penetration seals, ventilation ducting, intake bubble tight dampers, and HEPA filters.

- A backup power system to keep the ventilation systems operating if the NPH event causes a loss of normal power.

Scenarios evaluated for this accident are listed below. To facilitate the accident evaluation process, separate evaluations were made of the LTV, STV, and floor areas, for both uncontrolled and controlled scenarios. These individual analyses were later combined to develop a building-wide assessment.

When combined, the three groups of controlled scenarios (i.e., LTV, STV, and floor areas) form the basis for developing a controlled scenario for building-wide response.

1. Uncontrolled scenario (seismic event)
    a. Total collapse of LTV.
    b. Total collapse of STV.
    c. Total collapse of floor area.
    d. Total collapse of entire building (sum of 1a, b, and c)
2. Controlled scenario for 1a: LTV (with incremental addition of controls described below)
    a. Facility structure.
    b. Containers (LTV), floor storage matrix.
    c. Crane (LTV Material Movement system or LTV-MM).
    d. Facility confinement (HEPA-filtered ventilation).
3. Controlled scenario for 1b: STV (with incremental addition of controls described below)
    a. Facility structure, STV containers, and shelving.
    b. Facility confinement (HEPA-filtered ventilation).
4. Controlled scenario for 1c: Floor areas (with incremental addition of)
    a. Facility structure.
    b. Overhead protection, seismic design (II/I protection), GBs structural design.
    c. Facility confinement (HEPA-filtered ventilation).
5. Controlled scenario to represent building-wide assessment (aggregate of controlled scenarios 2, 3, and 4), with credit for above controls associated with LTV, STV, and floor areas.

Consequence Analysis

Dose calculations for the uncontrolled and controlled scenarios are summarized in Table 4, This table includes estimates of consequence reduction achieved through the incremental addition of controls. Information presented in the tables is used to help justify the categorization of individual controls as being safety class or safety significant.

[Public] In the LTV, the unmitigated consequences (1a) are 9.9 E-02 rem. The mitigated consequences are 0 (scenario 2c) after crediting the structure, LTV containers, the LTV floor storage matrix, and LTV-MM crane support.

For the STV, unmitigated consequences are 9.9E-01 rem (1b) and the mitigated consequences are 0 (scenario 3a) after crediting the structure, the STV containers, and STV shelving.

For the building floor areas, the unmitigated consequences (1c) are 4.9 rem and the mitigated consequences are 2.5 rem (scenario 4b) after taking credit for the structure, seismic design for overhead equipment, and the GB structural design.

For the building-wide assessment, with controls applied (Scenario 5), the dose numbers were calculated by adding those associated with individual building areas (i.e., LTV, STV, and floor areas). With all credited controls in place, doses are as follows:

- LTV 0 rem;
- STV 0 rem; and
- Floor area 2.5 rem.

Thus, the doses shown in Scenario 5 are entirely associated with MAR released from floor areas (scenario 4b). This overall dose is 2.5 rem.

[Collocated Worker] For the collocated worker, the unmitigated consequences are 2.6E+04 rem. Mitigated dose using the SC and SS controls applied to the public 66 rem (without confinement) or 6.6 rem (with confinement) for the collocated worker.

Comparison to the EG

In Sub-scenarios 1a (LTV collapse), 1b (STV collapse), 1c (floor area collapse), and 1d (building collapse), the dose to the MOI greatly exceed the DOE EG of 25 rem. For this reason, SC SSCs are appropriate for use in the CMRR NF for this accident. Results related to individual controlled scenarios are provided below and are summarized in Table 3-33.

During the seismic event, there is a chance that some of the containers stored on STV shelving or in laboratory enclosures could spill prior to being impacted by the seismic event. This component was not considered in Table 3, since the spill is overwhelmed by the unmitigated consequences of the seismic event with debris impact. A quick evaluation of the spill component indicates that up to a conservative maximum of 1000 kg (600 in STV and 300 in laboratory enclosures) could potentially spill. A spill ARF/RF of 2E-3/0.3 is applicable which is less than the debris impact ARF/RF. Using these values, an unmitigated spill component would add 49 rem to the 990 rem unmitigated value given in scenario 1d of Table 3-33 and given in the above paragraph. This is about a 5% increase in the unmitigated consequences. Note that in controlled scenarios 3 and 4 discussed below, the SC controls prevent the material from being spilled, therefore the overall results and safety functions do not change.

Controlled Scenario No. 2 (LTV)

With credit for the facility structure (Sub-scenario 2a), the unmitigated dose of 990 rem is reduced by almost 900 rem, to 99 rem. With subsequent addition of the long-term containers and floor storage matrix (Sub-scenario 2b), the dose is further to about 20 rem. When credit is taken for seismically qualified LTV-MM cranes, which are part of the facility structure, (Sub-scenario 2c), the dose is reduced to zero. These three controls (facility structure, including seismically mounted cranes; long-term containers; and floor storage matrix) are therefore designated as safety class.

For this scenario, the facility confinement (Sub-scenario 2d) in not needed to reduce the dose below the EG. However, the active and passive mode of the facility confinement system has an important dose-reduction role in other accident scenarios, and is thus designated as safety significant because of their defense-in-depth role in potentially reducing the MOI doses even further.

Controlled Scenario No. 3 (STV)

In scenario 3a, with credit for the facility structure, seismically qualified shelving and the STV containers the dose is reduced to zero. These three controls (facility structure, shelving, and short-term containers) are therefore designated as safety class.

For this scenario, the facility confinement (Sub-scenario 3b) in not needed to reduce the dose below the EG. However, the SS active and passive mode of the facility confinement system has an important dose-reduction role in other accident scenarios, and is thus designated as safety significant because of their defense-in-depth role in potentially reducing the MOI doses even further.

Controlled Scenario No. 4 (Floor Areas)

With credit for the facility structure (Sub-scenario 4a), the unmitigated dose of 52 rem is reduced to 19 rem. Through addition of overhead protection, seismically qualified GBs, and seismically qualified MTS tunnel (Sub-scenario 4b), the dose is reduced to 2.5 rem.

Controlled Scenario No. 5 (Building-Wide Assessment)

With credited controls, including passive confinement (Scenario 5), the building-wide dose to the MOI is 2.5 rem. This is the summation of scenarios 2c, 3a, and 4b.

[Collocated Worker] With the SC and SS controls identified in Table 3, the dose to the collocated worker is less than 100 rem so no additional SS controls are necessary.

Table 3. Derivation of Doses to MOI and CW for Spill from Mechanical Damage by an Earthquake

Case	Scenario	Controls	Safety Desig	Confinement Configuration Ventilation	Doors	MAR (kg)	DR	ARF	RF	LPF	ST (g)	MOI Dose/ST (rem/g PuE)	Dose to MOI (rem)	CW Dose/ST (rem/g PuE)	Dose to CW (rem)
1	Uncontrolled Scenario														
1a	Total collapse of LTV			N/A	N/A	6000	1.0E+00	1.0E-02	0.2	1.0E+00	1.2E+04	8.23E-02	**9.9E+02**	2.19E+00	**2.6E+04**
1b	Total collapse of STV			N/A	N/A	600	1.0E+00	1.0E-02	0.2	1.0E+00	1.2E+03	8.23E-02	**9.9E+01**	2.19E+00	**2.6E+03**
1c	Total collapse of floor area			N/A	N/A	300	1.0E+00	1.0E-02	0.2	1.0E+00	6.0E+02	8.23E-02	**4.9E+01**	2.19E+00	**1.3E+03**
1d	Total collapse of Facility			N/A	N/A	6000	1.0E+00	1.0E-02	0.2	1.0E+00	1.2E+04	8.23E-02	**9.9E+02**	2.19E+00	**2.6E+04**
2	Controlled Scenario: LTV														
2a	Case 1a with: - Facility Structure	Facility Structure (FacDsn-Struc)	SC				1.0E-01								
				N/A	N/A	6000	1.0E-01	1.0E-02	0.2	1.0E+00	1.2E+03	8.23E-02	**9.9E+01**	2.19E+00	**2.6E+03**
2b	Case 2a with: - Containers for LTV - Floor Storage Matrix	Facility Structure (FacDsn-Struc)	SC												
		Containers for LT Storage (Contain-LTV)	SC												
		Storage Design in Long Term Vaults (Storage-LT Vault)	SC				2.2E-02								
				N/A	N/A	6000	2.2E-02	1.0E-02	0.2	1.0E+00	2.6E+02	8.23E-02	**2.2E+01**	2.19E+00	**5.8E+02**
2c	Case 2b with: - Crane	Facility Structure (FacDsn-Struc)	SC												
		Containers for LT Storage (Contain-LTV)	SC												
		Storage Design in Long Term Vaults (Storage-LT Vault)	SC												
		Long Term Vault Crane (LTV-MM)	SC				0.0E+00								
				N/A	N/A	6000	0.0E+00	1.0E-02	0.2	1.0E+00	0.0E+00	8.23E-02	**0.0E+00**	2.19E+00	**0.0E+00**
2d	Case 2c with: - Facility Confinement	Facility Structure (FacDsn-Struc)	SC												
		Containers for LT Storage (Contain-LTV)	SC												
		Storage Design in Long Term Vaults (Storage-LT Vault)	SC												
		Long Term Vault Crane (LTV-MM)	SC												
		Vault HVAC (HEPA-Vault)	SS	On	Open					1.0E+00					
				On	Open	6000	0.0E+00	1.0E-02	0.2	1.0E+00	0.0E+00	8.23E-02	**0.0E+00**	2.19E+00	**0.0E+00**
		Zone 1 HVAC, Zone 2 HVAC, Zone 3 HVAC (HEPA-Zone 1, HEPA-Zone 2, HEPA-Zone 3)	SS	On	Closed					1.0E-03					
				On	Closed	6000	0.0E+00	1.0E-02	0.2	1.0E-03	0.0E+00	8.23E-02	**0.0E+00**	2.19E+00	**0.0E+00**
			SS	On	Open					1.0E-02					
				On	Open	6000	0.0E+00	1.0E-02	0.2	1.0E-02	0.0E+00	8.23E-02	**0.0E+00**	2.19E+00	**0.0E+00**
			SS*	Off	Open or Closed					1.0E-01		6.63E-02			
				Off	Open or Closed	6000	0.0E+00	1.0E-02	0.2	1.0E-01	0.0E+00	6.63E-02	**0.0E+00**	2.19E+00	**0.0E+00**

Table 3, Derivation of Doses to MOI and CW for Spill from Mechanical Damage by an Earthquake (continued)

Case	Scenario	Controls	Safety Desig	Confinement Configuration Ventilation	Doors	MAR (kg)	DR	ARF	RF	LPF	ST (g)	MOI Dose/ST (rem/g PuE)	Dose to MOI (rem)	CW Dose/ST (rem/g PuE)	Dose to CW (rem)
1	Uncontrolled Scenario														
1a	Total collapse of LTV			N/A	N/A	6000	1.0E+00	1.0E-02	0.2	1.0E+00	1.2E+04	8.23E-02	**9.9E+02**	2.19E+00	**2.6E+04**
1b	Total collapse of STV			N/A	N/A	600	1.0E+00	1.0E-02	0.2	1.0E+00	1.2E+03	8.23E-02	**9.9E+01**	2.19E+00	**2.6E+03**
1c	Total collapse of floor area			N/A	N/A	300	1.0E+00	1.0E-02	0.2	1.0E+00	6.0E+02	8.23E-02	**4.9E+01**	2.19E+00	**1.3E+03**
1d	Total collapse of Facility			N/A	N/A	6000	1.0E+00	1.0E-02	0.2	1.0E+00	1.2E+04	8.23E-02	**9.9E+02**	2.19E+00	**2.6E+04**
3	Controlled Scenario: STV														
3a	Case 1b with: - Shelving - Containers for STV	Facility Structure (FacDsn-Struc)	SC												
		SNM Shelving Design (SNM Shelving)	SC												
		Containers for ST Vault Storage (Contain-STV)	SC				0.0E+00	1.0E-03	1.0E-01						
				N/A	N/A	600	0.0E+00	1.0E-03	1.00E-01	1.0E+00	0.0E+00	8.23E-02	**0.0E+00**	2.19E+00	**0.0E+00**
3b	Case 3a with: - Facility Confinement	Facility Structure (FacDsn-Struc)	SC												
		SNM Shelving Design (SNM Shelving)	SC												
		Containers for ST Vault Storage (Contain-STV)	SC												
		Vault HVAC (HEPA-Vault)	SS	On	Open					1.0E+00					
				On	Open	6000	0.0E+00	1.0E-03	1.00E-01	1.0E+00	0.0E+00	8.23E-02	**0.0E+00**	0.00E+00	**0.0E+00**
		Zone 1 HVAC, Zone 2 HVAC, Zone 3 HVAC (HEPA-Zone 1, HEPA-Zone 2, HEPA-Zone 3)	SS	On	Closed					1.0E-03					
				On	Closed	600	0.0E+00	1.0E-03	1.00E-01	1.0E-03	0.0E+00	8.23E-02	**0.0E+00**	2.19E+00	**0.0E+00**
			SS	On	Open					1.0E-02					
				On	Open	600	0.0E+00	1.0E-03	1.00E-01	1.0E-02	0.0E+00	8.23E-02	**0.0E+00**	2.19E+00	**0.0E+00**
			SS*	Off	Open or Closed					1.0E-01		6.63E-02			
				Off	Open or Closed	600	0.0E+00	1.0E-03	1.00E-01	1.0E-01	0.0E+00	6.63E-02	**0.0E+00**	2.19E+00	**0.0E+00**

Table 3, Derivation of Doses to MOI and CW for Spill from Mechanical Damage by an Earthquake (continued)

Case	Scenario	Controls	Safety Desig	Confinement Configuration Ventilation	Doors	MAR (kg)	DR	ARF	RF	LPF	ST (g)	MOI Dose/ST (rem/g PuE)	Dose to MOI (rem)	CW Dose/ST (rem/g PuE)	Dose to CW (rem)
1	Uncontrolled Scenario														
1a	Total collapse of LTV			N/A	N/A	6000	1.0E+00	1.0E-02	0.2	1.0E+00	1.2E+04	8.23E-02	**9.9E+02**	2.19E+00	**2.6E+04**
1b	Total collapse of STV			N/A	N/A	600	1.0E+00	1.0E-02	0.2	1.0E+00	1.2E+03	8.23E-02	**9.9E+01**	2.19E+00	**2.6E+03**
1c	Total collapse of floor area			N/A	N/A	300	1.0E+00	1.0E-02	0.2	1.0E+00	6.0E+02	8.23E-02	**4.9E+01**	2.19E+00	**1.3E+03**
1d	Total collapse of Facility			N/A	N/A	6000	1.0E+00	1.0E-02	0.2	1.0E+00	1.2E+04	8.23E-02	**9.9E+02**	2.19E+00	**2.6E+04**
4	Controlled Scenario: Floor Areas														
4a	Case 1c with: - Facility Structure	Facility Structure (FacDsn-Struc)	SC				1.0E-01								
				N/A	N/A	300	1.0E-01	1.0E-02	0.2	1.0E+00	6.0E+01	8.23E-02	4.9E+00	2.19E+00	1.3E+02
										Falling Debris on Bulk Powder					
							9.0E-01	2.0E-03	0.3						
				N/A	N/A	300	9.0E-01	2.0E-03	0.3	1.0E+00	1.6E+02	8.23E-02	1.3E+01	2.19E+00	3.5E+02
										Spill of Glovebox Contents (powder)					
												Subtotal	**1.8E+01**	**Subtotal**	**4.9E+02**
4b	Case 4a with: - Overhead Protection - Glove Boxes (structure and MTS)	Facility Structure (FacDsn-Struc)	SC												
		Seismic Design Mounting (II/I protection) (SeimicQual)	SC (PC-3)												
		Glove Boxes - structural (GB-Structural)	SC (PC-3)												
							0.0E+00								
				N/A	N/A	300	0.0E+00	1.0E-02	0.2	1.0E+00	0.0E+00	8.23E-02	**0.0E+00**	2.19E+00	**0.0E+00**
										Falling Debris on Bulk Powder					
							1.0E+00	1.0E-03	0.1						
				N/A	N/A	300	1.0E+00	1.0E-03	0.1	1.0E+00	3.0E+01	8.23E-02	**2.5E+00**	2.19E+00	**6.6E+01**
										Vibration and/or Impact of Internal Equip Inside Glovebox					
												Subtotal	**2.5E+00**	**Subtotal**	**6.6E+01**
4c	Case 4b with: - Facility Confinement	Facility Structure (FacDsn-Struc)	SC												
		Seismic Design Mounting (II/I protection) (SeimicQual)	SC (PC-3)												
		Glove Boxes - structural (GB-Structure)	SC (PC-3)												
		Zone 1 HVAC, Zone 2 HVAC, Zone 3 HVAC (HEPA-Zone 1, HEPA-Zone 2, HEPA-Zone 3)	SS	On	Closed					1.0E-03					
				On	Closed	300	1.0E+00	1.0E-03	0.1	1.0E-03	3.0E-02	8.23E-02	**2.5E-03**	2.19E+00	**6.6E-02**
			SS	On	Open					1.0E-02					
				On	Open	300	1.0E+00	1.0E-03	0.1	1.0E-02	3.0E-01	8.23E-02	**2.5E-02**	2.19E+00	**6.6E-01**
			SS*	Off	Open or Closed					1.0E-01		6.63E-02			
				Off	Open or Closed	300	1.0E+00	1.0E-03	0.1	1.0E-01	3.0E+00	6.63E-02	**2.0E-01**	2.19E+00	**6.6E+00**

Table 3, Derivation of Doses to MOI and CW for Spill from Mechanical Damage by an Earthquake (continued)

Case	Scenario	Controls	Safety Desig	Confinement Configuration		MAR (kg)	DR	ARF	RF	LPF	ST (g)	MOI Dose/ST (rem/g PuE)	Dose to MOI (rem)	CW Dose/ST (rem/g PuE)	Dose to CW (rem)
				Ventilation	Doors										
1	Uncontrolled Scenario														
1a	Total collapse of LTV			N/A	N/A	6000	1.0E+00	1.0E-02	0.2	1.0E+00	1.2E+04	8.23E-02	**9.9E+02**	2.19E+00	**2.6E+04**
1b	Total collapse of STV			N/A	N/A	600	1.0E+00	1.0E-02	0.2	1.0E+00	1.2E+03	8.23E-02	**9.9E+01**	2.19E+00	**2.6E+03**
1c	Total collapse of floor area			N/A	N/A	300	1.0E+00	1.0E-02	0.2	1.0E+00	6.0E+02	8.23E-02	**4.9E+01**	2.19E+00	**1.3E+03**
1d	Total collapse of Facility			N/A	N/A	6000	1.0E+00	1.0E-02	0.2	1.0E+00	1.2E+04	8.23E-02	**9.9E+02**	2.19E+00	**2.6E+04**
5	Controlled Scenarios: Case 2c (LTV), Case 3a (STV), and Case 4b														
		Facility Structure (FacDsn-Struc)	SC												
		Containers for LT Storage (Contain-LTV)	SC												
		Floor Storage Matrix - LT Vault Storage Design (Storage-LTV)	SC												
		Long Term Vault Crane (LTV-MM)	SC									Sum (excludes Confinement)	2.5E+00	Sum (excludes Confinement)	6.6E+01
		Shelving - ST Vault Storage Design (Storage-STV)	SC												
		Containers for ST Vault Storage (Contain-STV)	SC												
		Seismic Design Mounting (II/I protection) (SeimicQual)	SC (PC-3)												
		Glove Boxes - structural (GB-Structure)	SC (PC-3)												
		Glove Box Confinement (GB-Confine)	SS												

Fire from Earthquake in Nuclear Facility

Accidents involving fires from an earthquake can cause mechanical or thermal insults to containers and enclosures. These accidents involve fires initiated in enclosures (GBs, hoods, open-front boxes, and the MTS tunnel) and fires in building areas such as the vaults and the basement. The fires can be initiated from events triggered by an earthquake, such as faults in electrical equipment, spills of hot chemicals from process vessels in GBs and hoods, and spills of flammable chemicals from ruptured containers. Additionally, the initial fire can propagate to other areas.

This accident depicts an earthquake that simultaneously causes substantial mechanical damage to enclosures and containers of radioactive material throughout the Security Category I Building, resulting in a significant loss of confinement. The earthquake also initiates a fire somewhere in the facility. This DBA conservatively assumes that multiple fires can be simultaneously in progress.

The uncontrolled likelihood of this accident is postulated as the "PROBABLE" frequency category (once every 100 to 10,000 yr), based on the frequency of a PC-3 earthquake and a postulated conditional probability of 1 that enclosures and containers are breached with dispersion of radioactive material via spills and fires.

The following SSCs can prevent the adverse effects of an earthquake and other representative accidents in this category. These and other SSCs will vary in their applicability depending on the specific accident.

- Enclosures to withstand damage from NPH events.
- Vault storage designs that hold containers of radioactive material (i.e., the shelves in the STV and the floor matrix of cells in the LTV) to withstand damage from NPH events.
- Robust containers of radioactive material to withstand impact damage from NPH events.
- Bracing and mounting of enclosures and storage designs to prevent damage from NPH events.
- A facility structure to protect the SSCs within from NPH events, including support for overhead equipment that may impact radioactive material during NPH events.
- Reinforced walls or barriers in the LVH area to withstand the impact of a large vessel
- Fire barriers around the exterior perimeter of the Security Category I Building (rated for 2 hr at 1,850°F) to prevent an external fire from starting a fire within the facility.

The likelihood of this accident to result in facility-wide spills and fires with the above SSCs in place is anticipated to be in the "IMPROBABLE" frequency category (once every 10,000 to 1,000,000 yr).

If the ventilation systems remain operational after the earthquake, the most likely path for a potential release of airborne radioactive material to the environment in this accident will be the building ventilation exhaust stack.

- The following SSCs could be expected to mitigate a potential release to the environment in the event the primary means of confinement (the enclosure or container) is breached:
- A facility structure that preserves the integrity of various facility features during a seismic event, including internal and external structural elements, fire barriers.

- HEPA-filtered active ventilation systems to pull airborne radioactive material from the building areas and trap it in HEPA filters, thereby preventing or reducing migration of airborne radioactive material within the building and/or into the environment.
- A passive confinement system to confine airborne radioactive material and mitigate its release to the environment. It includes the facility doors, doors (particularly those between ventilation zones), penetration seals, ventilation ducting, intake bubble tight dampers, and HEPA filters.
- A backup power system to keep the ventilation systems operating if the NPH event causes a loss of normal power.
- A FSS to extinguish or quench a fire in areas with radioactive material in containers or enclosures, therefore minimizing the dispersion of material.
- A cooling water spray in the ventilation system to prevent damage to HEPA filters or loss of filtration efficiency from hot air heated by fire in a building area.
- Robust containers of radioactive material to withstand a rupture from fire caused by either thermal degradation or internal pressure from the heat.
- Fire barriers between interconnected GBs to hinder the propagation of fire from one GB to another.
- Fire barriers to stop the propagation of fires:
    a. between adjacent laboratories in a wing (rated for 1 hr at 1,700°F)
    b. around the perimeter of a laboratory wing (rated for 2 hr at 1,850°F), including the fire barriers around the cross-town MTS tunnel passing through the interstitial corridors
    c. in the MTS drop boxes (for both wing and cross-town tunnel branches)
    d. between the laboratory (or basement) level and other building areas (rated for two hours at 1,850°F)
    e. between vault storage areas (rated for 2 hr at 1,850°F)
    f. between the vaults and non-vault building areas (rated for 2 hr at 1,850°F)
    g. around the perimeter of the LVH area
    h. Fire detection to provide a timely alert for fire department response and personnel evacuation.
    i. HEPA filters are to be qualified for 250^{o}F continuous service temperature per AG-1-2003 FC-1121. HEPA filters are to be qualified for 5-minute exposure to 700^{o}F +/- 50^{o}F per AG-1-2003 FC-5151.

Scenarios evaluated for this accident are listed below. To facilitate the accident evaluation process, separate evaluations were made of the LTV, STV, and floor areas, for both uncontrolled and controlled scenarios. These individual analyses were later combined to develop a building-wide assessment.

1. Uncontrolled scenario (seismic event and subsequent fires)
    a. LTV collapses, all material is spilled, subsequent fires in LTV chambers
    b. STV collapses, all material is spilled, subsequent fire in STV
    c. Floor area collapses, all material is spilled, subsequent fires in floor areas
    d. Total collapse of entire building, all material is spilled, subsequent fires throughout building

2. Controlled scenario for 1a: LTV (with incremental addition of controls as described) below
    a. Facility structure, floor storage matrix
    b. Containers (long-term), crane, Fire suppression
    c. Facility confinement (HEPA-filtered ventilation).
3. Controlled scenario for 1b: STV (with incremental addition of controls)
    a. Facility structure, shelving, containers (short-term)
    b. Fire suppression
    c. Facility confinement (HEPA-filtered ventilation).
4. Controlled scenario for 1c: Floor areas (with incremental addition of controls)
    a. Facility structure, overhead protection (floor), overhead protection (RCRA), GBs (structural), containers for waste
    b. Fire suppression
    c. Facility confinement (HEPA-filtered ventilation).
5. Controlled scenario to represent building-wide assessment (aggregate of controlled scenarios 2, 3, and 4), with credit for above controls associated with LTV, STV, and floor areas

In Sub-scenarios 1a (LTV collapse/fire), 1b (STV collapse/fire), 1c (floor area collapse/fire), and 1d (building collapse/fire), the dose to the MOI greatly exceed the DOE EG of 25 rem. For this reason, SC SSCs are appropriate for use in the CMRR NF for this accident. Results related to individual controlled scenarios are provided below:

Controlled Scenario No. 2 (LTV)

With credit for the facility structure, floor storage matrix, the LTV containers, the LTV-MM crane and FSS, the MOI dose is reduced to 2.0 rem. At this point, the dose level is below the "5 rem range", and thus is not considered to challenge the EG. These six controls (facility structure, fire barriers, floor storage matrix, long-term containers, cranes, and fire suppression) are therefore designated as safety class, as indicated Table 3-34.

Controlled Scenario No. 3 (STV)

With credit for the facility structure, fire barriers, STV shelves, STV containers, and the FSS the unmitigated dose is reduced to 0.024 rem. At this point, the dose level is below the 5 rem range", and thus is not considered to challenge the EG. These controls are designated safety class.

Controlled Scenario No. 4 (Floor Areas)

With credit for the facility structure, fire barriers, overhead protection for floor areas, overhead protection for RCRA areas, seismically qualified GBs, and FSS (Sub-scenario 4a), the unmitigated dose of 28,000 rem is reduced to approximately 1.6 rem. At this point, the dose level is below the 5 rem range, and thus is not considered to challenge the EG. Based on these results, the facility structure, overhead protection for floor areas, overhead protection for RCRA areas and seismically qualified GBs, are designated as safety class. Note that TRU containers retain their SS designation since the limited credit for these containers reflects the DOE-STD-5506 direction. Also, even in the unmitigated scenario, the waste contribution was well below 1 rem, so in the mitigated scenario the dose from the waste contribution is even less.

Controlled Scenario No. 5 (Building-Wide Assessment)

With credited controls, (Scenario 5b), the building-wide dose to the MOI is about 3.6 rem.

[Collocated Worker] With the SC and SS controls identified in Table 4, the dose to the collocated worker is less than 100 rem for scenarios 2-4. In scenario 5, with the SS controls, including ventilation confinement, the CW dose is reduced by at least a factor of 0.1 to under 100 rem.

Table 4. Derivation of Doses to MOI and CW for Spill from Mechanical Damage by Fire from an Earthquake

Case	Scenario	MAR Limit	Controls	Safety Desig	Confinement Configuration		MAR (kg)	DR	ARF	RF	LPF	ST (g)	MOI Dose/ST (rem/g PuE)	Dose to MOI (rem)	CW Dose/ST	Dose to CW (rem)
					Ventilation	Doors										
1	Uncontrolled Scenario															
1a	Total collapse of LTV and subsequent fires due to seismic event (unmitigated)	6,000 kg			N/A	N/A	6000	1.0E+00	1.0E-01	0.7	1.0E+00	4.2E+05	6.76E-02	**2.8E+04**	2.19E+00	**9.2E+05**
1b	Total collapse of STV and subsequent fires due to seismic event (unmitigated)	600 kg			N/A	N/A	600	1.0E+00	5.0E-03	0.4	1.0E+00	1.2E+03	6.76E-02	**8.1E+01**	2.19E+00	**2.6E+03**
1c	Total collapse of floor areas and subsequent fires due to seismic event (unmitigated)	300 kg			N/A	N/A	279	1.0E+00	5.0E-04	0.5	1.0E+00	7.0E+01	6.76E-02	4.7E+00	2.19E+00	1.5E+02
											Metal					
					N/A	N/A	1	1.0E+00	1.0E-02	1.0	1.0E+00	1.0E+01	6.76E-02	6.8E-01	2.19E+00	2.2E+01
											Uncontained Waste					
					N/A	N/A	20	1.0E+00	5.0E-04	1.0	1.0E+00	1.0E+01	6.76E-02	6.8E-01	2.19E+00	2.2E+01
											RCRA Waste					
					Floor Area MAR		300						Floor Area Dose	**6.1E+00**	Floor Area Dose	**2.0E+02**
1d	Total collapse of Facility and subsequent fires due to seismic event (unmitigated)	6,000 kg			Facility-Wide MAR		6000						Facility-Wide Dose	**2.8E+04**	Facility-Wide Dose	**9.2E+05**
2	Controlled Scenario: LTV															
2a	Case 1a with: - Facility Structure - Floor Storage Matrix	6,000 kg	Fire Barriers (FireBar)	SC												
			Zone 2 HVAC (HEPA Zone 2) fire barriers	SC												
			Facility Structure (FacDsn-Struc)	SC				3.6E-01								
			Storage Design in Long Term Vaults (Storage-LT Vault)	SC												
					N/A	N/A	6000	3.6E-01	1.0E-01	0.7	1.0E+00	1.5E+05	6.76E-02	**1.0E+04**	2.19E+00	**3.3E+05**
2b	Case 2a with: - Containers for LTV - Crane - Fire Suppression System	6,000 kg	Fire Barriers (FireBar)	SC												
			Zone 2 HVAC (HEPA Zone 2) fire barriers	SC												
			Facility Structure (FacDsn-Struc)	SC												
			Storage Design in Long Term Vaults (Storage-LT Vault)	SC												
			Containers for LT Storage (Contain-LTV)	SC												
			Long Term Vault Crane (LTV-MM)	SC												
			Fire Suppression System (FireSupp)	SC				7.0E-04	1.0E-02							
					N/A	N/A	6000	7.0E-04	1.0E-02	0.7	1.0E+00	2.9E+01	6.76E-02	**2.0E+00**	2.19E+00	**6.4E+01**
2c	Case 2b with: - Facility Confinement	6,000 kg	Fire Barriers (FireBar)	SC												
			Zone 2 HVAC (HEPA Zone 2) fire barriers	SC												
			Facility Structure (FacDsn-Struc)	SC												
			Storage Design in Long Term Vaults (Storage-LT Vault)	SC												
			Containers for LT Storage (Contain-LTV)	SC												
			Long Term Vault Crane (LTV-MM)	SC												
			Fire Suppression System (FireSupp)	SC												
			Vault HVAC (HEPA-Vault)	SS	On	Open					1.0E+00					
					On	Open	6000	7.0E-04	1.0E-02	0.7	1.0E+00	2.9E+01	6.76E-02	**2.0E+00**	2.19E+00	**6.4E+01**
			Zone 2 HVAC (HEPA-Zone 2)	SS	On	Closed					1.0E-03					
					On	Closed	6000	7.0E-04	1.0E-02	0.7	1.0E-03	2.9E-02	6.76E-02	**2.0E-03**	2.19E+00	**6.4E-02**
				SS	On	Open					1.0E-02					
					On	Open	6000	7.0E-04	1.0E-02	0.7	1.0E-02	2.9E-01	6.76E-02	**2.0E-02**	2.19E+00	**6.4E-01**
				SS*	Off	Open or Closed					1.0E-01					
					Off	Open or Closed	6000	7.0E-04	1.0E-02	0.7	1.0E-01	2.9E+00	6.76E-02	**2.0E-01**	2.19E+00	**6.4E+00**

Table 4 Derivation of Doses to MOI and CW for Spill from Mechanical Damage by Fire from an Earthquake (continued)

Case	Scenario	MAR Limit	Controls	Safety Desig	Confinement Configuration Ventilation	Doors	MAR (kg)	DR	ARF	RF	LPF	ST (g)	MOI Dose/ST (rem/g PuE)	Dose to MOI (rem)	CW Dose/ST	Dose to CW (rem)
1	Uncontrolled Scenario															
1a	Total collapse of LTV and subsequent fires due to seismic event (unmitigated)	6,000 kg			N/A	N/A	6000	1.0E+00	1.0E-01	0.7	1.0E+00	4.2E+05	6.76E-02	**2.8E+04**	2.19E+00	**9.2E+05**
1b	Total collapse of STV and subsequent fires due to seismic event (unmitigated)	600 kg			N/A	N/A	600	1.0E+00	5.0E-03	0.4	1.0E+00	1.2E+03	6.76E-02	**8.1E+01**	2.19E+00	**2.6E+03**
1c	Total collapse of floor areas and subsequent fires due to seismic event (unmitigated)	300 kg			N/A	N/A	279	1.0E+00	5.0E-04	0.5	1.0E+00	7.0E+01	6.76E-02	4.7E+00	2.19E+00	1.5E+02
											Metal					
					N/A	N/A	1	1.0E+00	1.0E-02	1.0	1.0E+00	1.0E+01	6.76E-02	6.8E-01	2.19E+00	2.2E+01
											Uncontained Waste					
					N/A	N/A	20	1.0E+00	5.0E-04	1.0	1.0E+00	1.0E+01	6.76E-02	6.8E-01	2.19E+00	2.2E+01
											RCRA Waste					
					Floor Area MAR		300						Floor Area Dose	**6.1E+00**	Floor Area Dose	**2.0E+02**
1d	Total collapse of Facility and subsequent fires due to seismic event (unmitigated)	6,000 kg			Facility-Wide MAR		6000						Facility-Wide Dose	**2.8E+04**	Facility-Wide Dose	**9.2E+05**
3	Controlled Scenario: STV															
3a	Case 1b with: - Facility Structure - STV Shelving - Containers for STV	600	Fire Barriers (FireBar)	SC												
			Zone 2 HVAC (HEPA Zone 2) fire barriers	SC												
			Facility Structure (FacDsn-Struc)	SC												
			Shelving - ST Vault Storage Design (Storage-STV)	SC					1.0E+00								
			Containers for ST Vault Storage (Contain-STV)	SC												
					N/A	N/A	600	1.0E+00	6.0E-03	0.01	1.0E+00	3.6E+01	6.76E-02	**2.4E+00**	2.19E+00	**7.9E+01**
3b	Case 3a with: - Fire Suppression System	600 kg	Fire Barriers (FireBar)	SC												
			Zone 2 HVAC (HEPA Zone 2) fire barriers	SC												
			Facility Structure (FacDsn-Struc)	SC												
			SNM Shelving Design (SNM Shelving)	SC												
			Containers for ST Vault Storage (Contain-STV)	SC												
			Fire Suppression System (FireSupp)	SC				1.0E-02								
					N/A	N/A	600	1.0E-02	6.0E-03	0.01	1.0E+00	3.6E-01	6.76E-02	**2.4E-02**	2.19E+00	**7.9E-01**
3c	Case 3b with: - Facility Confinement	600 kg	Fire Barriers (FireBar)	SC												
			Zone 2 HVAC (HEPA Zone 2) fire barriers	SC												
			Facility Structure (FacDsn-Struc)	SC												
			SNM Shelving Design (SNM Shelving)	SC												
			Containers for ST Vault Storage (Contain-STV)	SC												
			Fire Suppression System (FireSupp)	SC												
			Vault HVAC (HEPA-Vault)	SS	On	Open					1.0E+00					
					On	Open	6000	1.0E-02	6.0E-03	0.1	1.0E+00	3.6E+01	6.76E-02	**2.4E+00**	2.19E+00	**7.9E+01**
			Zone 2 HVAC (HEPA-Zone 2)	SS	On	Closed					1.0E-03					
					On	Closed	600	1.0E-02	6.0E-03	0.1	1.0E-03	3.6E-03	6.76E-02	**2.4E-04**	2.19E+00	**7.9E-03**
				SS	On	Open					1.0E-02					
					On	Open	600	1.0E-02	6.0E-03	0.1	1.0E-02	3.6E-02	6.76E-02	**2.4E-03**	2.19E+00	**7.9E-02**
				SS*	Off	Open or Closed					1.0E-01					
					Off	Open or Closed	600	1.0E-02	6.0E-03	0.1	1.0E-01	3.6E-01	6.76E-02	**2.4E-02**	2.19E+00	**7.9E-01**

Table 4 Derivation of Doses to MOI and CW for Spill from Mechanical Damage by Fire from an Earthquake (continued)

Case	Scenario	MAR Limit	Controls	Safety Desig	Confinement Configuration Ventilation	Doors	MAR (kg)	DR	ARF	RF	LPF	ST (g)	MOI Dose/ST (rem/g PuE)	Dose to MOI (rem)	CW Dose/ST	Dose to CW (rem)
1	Uncontrolled Scenario															
1a	Total collapse of LTV and subsequent fires due to seismic event (unmitigated)	6,000 kg			N/A	N/A	6000	1.0E+00	1.0E-01	0.7	1.0E+00	4.2E+05	6.76E-02	**2.8E+04**	2.19E+00	**9.2E+05**
1b	Total collapse of STV and subsequent fires due to seismic event (unmitigated)	600 kg			N/A	N/A	600	1.0E+00	5.0E-03	0.4	1.0E+00	1.2E+03	6.76E-02	**8.1E+01**	2.19E+00	**2.6E+03**
1c	Total collapse of floor areas and subsequent fires due to seismic event (unmitigated)	300 kg			N/A	N/A	279	1.0E+00	5.0E-04	0.5	1.0E+00	7.0E+01	6.76E-02	4.7E+00	2.19E+00	1.5E+02
					Metal											
					N/A	N/A	1	1.0E+00	1.0E-02	1.0	1.0E+00	1.0E+01	6.76E-02	6.8E-01	2.19E+00	2.2E+01
					Uncontained Waste											
					N/A	N/A	20	1.0E+00	5.0E-04	1.0	1.0E+00	1.0E+01	6.76E-02	6.8E-01	2.19E+00	2.2E+01
					RCRA Waste											
						Floor Area MAR	300						Floor Area Dose	**6.1E+00**	Floor Area Dose	**2.0E+02**
1d	Total collapse of Facility and subsequent fires due to seismic event (unmitigated)	6,000 kg				Facility-Wide MAR	6000						Facility-Wide Dose	**2.8E+04**	Facility-Wide Dose	**9.2E+05**
4	Controlled Scenario: Floor Areas															
4a	Case 1c with: - Facility Structure - Overhead Protection (Floor) - Glove Boxes - structural - Overhead Protection for RCRA areas - Containers for Waste		Fire Barriers (FireBar)	SC												
			Zone 1 HVAC, Zone 2 HVAC, Zone 3 HVAC (HEPA-Zone 1, HEPA-Zone 2, HEPA-Zone 3) fire barriers	SC												
			Facility Structure (FacDsn-Struc)	SC												
			Seismic Design Mounting (W/ protection) (SeimicQual)	SC (PC-3)	N/A	N/A	279	1.0E+00	5.0E-04	0.5	1.0E+00	7.0E+01	6.76E-02	4.7E+00	2.19E+00	1.5E+02
			Glove Boxes - structural (GB-Structural)	SC (PC-3)	Metal											
		20 kg Waste	Fire Barriers (FireBar)	SC												
			Zone 1 HVAC, Zone 2 HVAC, Zone 3 HVAC, Vault HVAC (HEPA-Zone 1, HEPA-Zone 2, HEPA-Zone 3, HEPA-Vault) fire barriers	SC												
			Facility Structure (FacDsn-Struc)	SC												
			Seismic Design Mounting (W/ protection) (SeimicQual)	SC (PC-3)	N/A	N/A	1	1.0E+00	1.0E-02	1.0	1.0E+00	1.0E+01	6.76E-02	6.8E-01	2.19E+00	2.2E+01
			WIPP Containers & Drums (WIPP-Contain)	SS	Uncontained Waste											
								5.0E-01	5.0E-04	1.0						
					N/A	N/A	20	5.0E-01	5.0E-04	1.0	1.0E+00	5.0E+00	6.76E-02	3.4E-01	2.19E+00	1.1E+01
					RCRA Waste											
													Subtotal	**5.7E+00**	**Subtotal**	**1.9E+02**
4b	Case 4a with: - Fire Suppression System	280 kg Metal	Fire Barriers (FireBar)	SC												
			Zone 1 HVAC, Zone 2 HVAC, Zone 3 HVAC, Vault HVAC (HEPA-Zone 1, HEPA-Zone 2, HEPA-Zone 3, HEPA-Vault) fire barriers	SC												
			Facility Structure (FacDsn-Struc)	SC												
			Seismic Design Mounting (W/ protection) (SeimicQual)	SC (PC-3)												
			Glove Boxes - structural (GB-Structural)	SC (PC-3)												
			WIPP Containers & Drums (WIPP-Contain)	SS												
			Fire Suppression System (FireSupp)	SC				2.7E-01								
					N/A	N/A	279	2.7E-01	5.0E-04	0.5	1.0E+00	1.9E+01	6.76E-02	1.3E+00	2.19E+00	4.1E+01
		20 kg Waste			Metal											
					N/A	N/A	1	2.7E-01	1.0E-02	1.0	1.0E+00	2.7E+00	6.76E-02	1.8E-01	2.19E+00	5.9E+00
					Uncontained Waste											
					N/A	N/A	20	[illegible]	1.0E-02	1.0	1.0E+00	2.0E+00	6.76E-02	1.4E-01	2.19E+00	4.4E+00
					RCRA Waste											
													Subtotal	**1.6E+00**	**Subtotal**	**5.2E+01**

Table 4, Derivation of Doses to MOI and CW for Spill from Mechanical Damage by Fire from an Earthquake (continued)

Case	Scenario	MAR Limit	Controls	Safety Desig	Confinement Configuration: Ventilation	Confinement Configuration: Doors	MAR (kg)	DR	ARF	RF	LPF	ST (g)	MOI Dose/ST (rem/g PuE)	Dose to MOI (rem)	CW Dose/ST	Dose to CW (rem)
1	Uncontrolled Scenario															
1a	Total collapse of LTV and subsequent fires due to seismic event (unmitigated)	6,000 kg			N/A	N/A	6000	1.0E+00	1.0E-01	0.7	1.0E+00	4.2E+05	6.76E-02	**2.8E+04**	2.19E+00	**9.2E+05**
1b	Total collapse of STV and subsequent fires due to seismic event (unmitigated)	600 kg			N/A	N/A	600	1.0E+00	5.0E-03	0.4	1.0E+00	1.2E+03	6.76E-02	**8.1E+01**	2.19E+00	**2.6E+03**
1c	Total collapse of floor areas and subsequent fires due to seismic event (unmitigated)	300 kg			N/A	N/A	279	1.0E+00	5.0E-04	0.5	1.0E+00	7.0E+01	6.76E-02	4.7E+00	2.19E+00	1.5E+02
											Metal					
					N/A	N/A	1	1.0E+00	1.0E-02	1.0	1.0E+00	1.0E+01	6.76E-02	6.8E-01	2.19E+00	2.2E+01
											Uncontained Waste					
					N/A	N/A	20	1.0E+00	5.0E-04	1.0	1.0E+00	1.0E+01	6.76E-02	6.8E-01	2.19E+00	2.2E+01
											RCRA Waste					
					Floor Area MAR		300						Floor Area Dose	**6.1E+00**	Floor Area Dose	**2.0E+02**
1d	Total collapse of Facility and subsequent fires due to seismic event (unmitigated)	6,000 kg			Facility-Wide MAR		6000						Facility-Wide Dose	**2.8E+04**	Facility-Wide Dose	**9.2E+05**
4c	Case 4b with: - Facility Confinement	280 kg Metal, and 20 kg waste	Fire Barriers (FireBar)	SC												
			Zone 1 HVAC, Zone 2 HVAC, Zone 3 HVAC, Vault HVAC (HEPA-Zone 1, HEPA-Zone 2, HEPA-Zone 3, HEPA-Vault) fire barriers	SC												
			Facility Structure (FacDsn-Struc)	SC												
			Seismic Design Mounting (II/I protection)	SC (PC-3)												
			Glove Boxes - structural (GB-Structural)	SC (PC-3)												
			WIPP Containers & Drums (WIPP-Contain)	SS												
			Fire Suppression System (FireSupp)	SC												
			Zone 1 HVAC, Zone 2 HVAC, Zone 3 HVAC (HEPA-Zone 1, HEPA-Zone 2, HEPA-Zone 3)	SS	On	Closed					1.0E-03					
					On	Closed	279	2.7E-01	5.0E-04	0.5	1.0E-03	1.9E-02	6.76E-02	1.3E-03	2.19E+00	4.1E-02
												Metal				
							1	2.7E-01	1.0E-02	1.0	1.0E-03	2.7E-03	6.76E-02	1.8E-04	2.19E+00	5.9E-03
												Uncontained Waste				
							20	1.0E-02	1.0E-02	1.0	1.0E-03	2.0E-03	6.76E-02	1.4E-04	2.19E+00	4.4E-03
												RCRA Waste				
													Subtotal	**1.6E-03**	**Subtotal**	**5.2E-02**
				SS	On	Open					1.0E-02					
					On	Open	279	2.7E-01	5.0E-04	0.5	1.0E-02	1.9E-01	6.76E-02	1.3E-02	2.19E+00	4.1E-01
												Metal				
							1	2.7E-01	1.0E-02	1.0	1.0E-02	2.7E-02	6.76E-02	1.8E-03	2.19E+00	5.9E-02
												Uncontained Waste				
							20	1.0E-02	1.0E-02	1.0	1.0E-02	2.0E-02	6.76E-02	1.4E-03	2.19E+00	4.4E-02
												RCRA Waste				
													Subtotal	**1.6E-02**	**Subtotal**	**5.2E-01**
				SS	Off	Open or Closed					1.0E-01					
					Off	Open or Closed	279	2.7E-01	5.0E-04	0.5	1.0E-01	1.9E+00	6.76E-02	1.3E-01	2.19E+00	4.1E+00
												Metal				
							1	2.7E-01	1.0E-02	1.0	1.0E-01	2.7E-01	6.76E-02	1.8E-02	2.31E+00	6.2E-01
												Uncontained Waste				
							20	1.0E-02	1.0E-02	1.0	1.0E-01	2.0E-01	6.76E-02	1.4E-02	2.19E+00	4.4E-01
												RCRA Waste				
													Subtotal	**1.6E-01**	**Subtotal**	**5.2E+00**

Table 4, Derivation of Doses to MOI and CW for Spill from Mechanical Damage by Fire from an Earthquake (continued)

Case	Scenario	MAR Limit	Controls	Safety Desig	Confinement Configuration: Ventilation	Confinement Configuration: Doors	MAR (kg)	DR	ARF	RF	LPF	ST (g)	MOI Dose/ST (rem/g PuE)	Dose to MOI (rem)	CW Dose/ST	Dose to CW (rem)
1	Uncontrolled Scenario															
1a	Total collapse of LTV and subsequent fires due to seismic event (unmitigated)	6,000 kg			N/A	N/A	6000	1.0E+00	1.0E-01	0.7	1.0E+00	4.2E+05	6.76E-02	**2.8E+04**	2.19E+00	**9.2E+05**
1b	Total collapse of STV and subsequent fires due to seismic event (unmitigated)	600 kg			N/A	N/A	600	1.0E+00	5.0E-03	0.4	1.0E+00	1.2E+03	6.76E-02	**8.1E+01**	2.19E+00	**2.6E+03**
1c	Total collapse of floor areas and subsequent fires due to seismic event (unmitigated)	300 kg			N/A	N/A	279	1.0E+00	5.0E-04	0.5	1.0E+00	7.0E+01	6.76E-02	4.7E+00	2.19E+00	1.5E+02
					Metal											
					N/A	N/A	1	1.0E+00	1.0E-02	1.0	1.0E+00	1.0E+01	6.76E-02	6.8E-01	2.19E+00	2.2E+01
					Uncontained Waste											
					N/A	N/A	20	1.0E+00	5.0E-04	1.0	1.0E+00	1.0E+01	6.76E-02	6.8E-01	2.19E+00	2.2E+01
					RCRA Waste											
					Floor Area MAR		300						Floor Area Dose	**6.1E+00**	Floor Area Dose	**2.0E+02**
1d	Total collapse of Facility and subsequent fires due to seismic event (unmitigated)	6,000 kg			Facility-Wide MAR		6000						Facility-Wide Dose	**2.8E+04**	Facility-Wide Dose	**9.2E+05**
5	Controlled Scenarios:															
5a	Case 2b (LTV) Case 3b (STV) Case 4b	6,000 kg	Fire Barriers (FireBar)	SC									**Sum (excludes confinement)**	3.60	**Sum (excludes confine-ment)**	116.71
			Zone 1 HVAC, Zone 2 HVAC, Zone 3 HVAC, Vault HVAC (HEPA-Zone 1, HEPA-Zone 2, HEPA-Zone 3, HEPA-Vault) fire barriers	SC												
			Facility Structure (FacDsn-Struc)	SC												
			Floor Storage Matrix - LT Vault Storage Design (Storage-LTV)	SC												
			Containers for LT Storage (Contain-LTV)	SC												
			Long Term Vault Crane (LTV-MM)	SC												
			Fire Suppression System (FireSupp)	SC												
			SNM Shelving Design (SNM Shelving)	SC												
			Containers for ST Vault Storage (Contain-STV)	SC												
			Seismic Design Mounting (II/I protection)	SC (PC-3)												
			Glove Boxes - structural (GB-Structural)	SC (PC-3)												
			WIPP Containers & Drums (WIPP-Contain)	SS												

* This control only provides SS functions (defense in depth) for this DBA. However, this control was designated as an SC -SSC in other DBAs.

Impact of Light Commercial Aircraft

This DBA represents a crash of a light commercial duty aircraft with and without a fire. This accident depicts an aircraft impact that simultaneously causes mechanical damage the building with a resultant fire. The aircraft impact also initiates fires in multiple locations in the facility, with some fires propagating to other building areas. The fires promote additional dispersion of radioactive material in areas with containers or enclosures.

The uncontrolled likelihood of this accident is postulated as being in the "IMPROBABLE" frequency category (once every 10,000 to 1,000,000 yr), based on the estimated overall crash frequency (all types of aircraft) on the CMRR NF (per Appendix 3D, CMRR PDSA), and a postulated conditional probability of 1 that the impact from a light aircraft crash causes dispersion of radioactive material via spills and fires.

The following SSCs can prevent the adverse effects of an aircraft impact:

- A facility structure to protect the SSCs within from aircraft impact events.
- Fire barriers around the exterior perimeter of the Security Category I Building (rated for 2 hr at 1,850°F) to prevent an external fire from starting a fire within the facility.
- The likelihood of this accident with the above SSCs in place is anticipated to be in the "REMOTE" frequency category (less than once every 1,000,000 yr).

The following SSCs could be expected to mitigate a potential release to the environment in the event the primary means of confinement (the enclosure or container) is breached:

- A FSS to extinguish or quench a fire in areas with radioactive material in containers or enclosures, therefore minimizing the dispersion of material.
- Robust containers of radioactive material to withstand a rupture from fire caused by either thermal degradation or internal pressure from the heat.
- Fire barriers that include the building perimeter and those internal to the facility to stop the propagation of fires:
- Fire detection to provide a timely alert for fire department response and personnel evacuation.

The scenarios evaluated for this accident include:

1. Unmitigated impact into the facility that breaches the facility and also causes numerous fires, and
2. Impact into the facility, which is now designed to withstand the impact.

Consequence Analysis

Table 5 summarizes the dose calculations for the unmitigated and mitigated scenarios. The unmitigated public consequences, 2.8×10^4, exceed the EG. For the collocated worker, unmitigated consequences are 9.2E+05 rem. Further, if we assume the Cessna engine/propellers could impact up to (a conservative) 50 kg of SNM (powder), the unmitigated dose would increased by 7 rem.

With credit for the facility structure, the DR is reduced to 0.0, thereby reducing the dose to 0 rem.

For the CW, the mitigated dose using the SC and SS controls applied to the public is zero rem for the collocated worker.

Table 5 , Derivation of Doses to MOI and CW for Impact by Light Commercial Aircraft

Case	Scenario	Controls	SSC Designation	Confinement Configuration		MAR	DR	ARF	RF	LPF	ST (g)	MOI Dose/ST (rem/g PuE)	Dose to MOI (rem)	CW Dose/ST (rem/g PuE)	Dose to CW (rem)
				Ventilation	Doors	(kg)									
1	Uncontrolled Scenario														
1a	Light aircraft impacts facility			N/A	N/A	6000	1.0E+00	1.0E-01	0.7	1.0E+00	4.2E+05	6.76E-02	**2.8E+04**	2.19E+00	**9.2E+05**
2	Controlled Scenario														
2a	Case 1a with: - Structure designed to withstand impact	Facility Structure (FacDsn-Struc)	SC				0.0E+00								
		Fire Barriers (FireBar)	SC												
				N/A	N/A	6000	0.0E+00	1.0E-01	0.7	1.0E-01	0.0E+00	6.76E-02	**0.0E+00**	2.19E+00	**0.0E+00**