15 ACCIDENT ANALYSIS

15.1 Conduct of Review

The staff evaluated the applicant's accident analysis by reviewing Chapter 8, Accident Analysis, of the SAR, documents cited in the SAR, and other relevant publicly available information, including web sites on the internet.

Section 8.4, Basis for Selection of Off-Normal and Accident Conditions, of the SAR describes the basis for selecting off-normal and accident events to ensure all relevant potential scenarios have been considered. The selection of these off-normal and accident event scenarios is based on ANSI/ANS 57.9, (American National Standards Institute/American Nuclear Society, 1992), NUREG–1567 (Nuclear Regulatory Commission, 2000a), and the HI-STORM 100 FSAR (Holtec International, 2000). Design Events II of ANSI/ANS 57.9, as applicable to the Facility, were considered for off-normal conditions and are described in SAR Section 8.1, Off-Normal Operations. Applicable Design Events III and IV of ANSI/ANS 57.9 are described as accident events in SAR Section 8.2, Accidents.

The dry cask storage system to be used at the Facility is the HI-STORM 100 Cask System, which has been reviewed by the NRC and approved for general use under Certificate of Compliance No. 1014 (Nuclear Regulatory Commission, 2000b). As discussed in Chapters 4 and 5 of this SER, the design basis loads considered in the HI-STORM FSAR bound the loading conditions at the PFS Facility site except for the seismic load. Thus, where applicable, the staff relied on the review carried out during the certification process of the cask system, as documented in the NRC's HI-STORM 100 SER (Nuclear Regulatory Commission, 2000c).

The staff reviewed the accident analysis to determine whether the following regulatory requirements have been met:

- 10 CFR 72.90 requires that: (a) site characteristics that may directly affect the safety or environmental impact of the ISFSI be investigated and assessed; (b) proposed sites for the ISFSI be examined with respect to the frequency and severity of external natural and man-induced events that could affect the safe operation of the ISFSI; (c) design basis external events be determined for each combination of proposed site and proposed ISFSI design; (d) the proposed sites with design basis external events for which adequate protection cannot be provided through ISFSI design be deemed unsuitable for the location of the ISFSI; (e) pursuant to Subpart A of Part 51 of Title 10 for each proposed site for an ISFSI, the potential for radiological and other environmental impacts on the region be evaluated with due consideration of the characteristics of the population, including its distribution, and of the regional environs, including its historical and aesthetic values; and (f) the facility to be sited so as to avoid to the extent possible the long-term and short-term adverse impacts associated with the occupancy and modification of floodplains.

- 10 CFR 72.92 requires that: (a) natural phenomena that may exist or that can occur in the region of a proposed site be identified and assessed according to their potential effects on the safe operation of the ISFSI, and that the important

natural phenomena that affect the ISFSI design be identified; (b) records of the occurrence and severity of those important natural phenomena be collected for the region and evaluated for reliability, accuracy, and completeness, and the applicant shall retain these records until the license is issued; and (c) appropriate methods be adopted for evaluating the design basis external natural events based on the characteristics of the region and the current state of knowledge about such events.

- 10 CFR 72.94 requires that (a) the region be examined for both past and present man-made facilities and activities that might endanger the proposed ISFSI, and the important potential man-induced events that affect the ISFSI design must be identified; (b) information concerning the potential occurrence and severity of such events be collected and evaluated for reliability, accuracy, and completeness; and (c) appropriate methods be adopted for evaluating the design basis external man-induced events, based on the current state of knowledge about such events.

- 10 CFR 72.98(a) requires that the regional extent of external phenomena, man-made or natural, that are used as a basis for the design of the ISFSI be identified.

- 10 CFR 72.98(c) requires that those regions identified pursuant to paragraphs 10 CFR 72.98(a) and (b) be investigated as appropriate with respect to: (1) the present and future character and the distribution of population, (2) consideration of present and projected future uses of land and water within the region, and (3) any special characteristics that may influence the potential consequences of a release of radioactive material during the operational lifetime of the ISFSI.

- 10 CFR 72.102(f)(1) requires that the design earthquake for use in the design of structures be determined as follows: (1) for sites that have been evaluated under the criteria of Appendix A of 10 CFR Part 100, the design earthquake must be equivalent to the safe shutdown earthquake for a nuclear power plant; and (2) Regardless of the results of the investigations anywhere in the continental U.S., the design earthquake must have a value for the horizontal ground motion of no less than 0.10 g with the appropriate response spectrum.

- 10 CFR 72.106(b) requires that any individual located on or beyond the nearest boundary of the controlled area not receive from any design basis accident the more limiting of a total effective dose equivalent of 0.05 Sv (5 rem), or the sum of the deep-dose equivalent and the committed dose equivalent to any individual organ or tissue (other than the lens of the eye) of 0.5 Sv (50 rem). The lens of the eye dose equivalent shall not exceed 0.15 Sv (15 rem) and the shallow dose equivalent to skin or to any extremity shall not exceed 0.5 Sv (50 rem). The minimum distance from the spent fuel or high-level radioactive waste handling and storage facilities to the nearest boundary of the controlled area must be at least 100 meters.

- 10 CFR 72.122(b) requires: (1) structures, systems, and components important to safety be designed to accommodate the effects of, and to be compatible with,

site characteristics and environmental conditions associated with normal operation, maintenance, and testing of the ISFSI and to withstand postulated accidents; and (2) structures, systems, and components important to safety be designed to withstand the effects of natural phenomena such as earthquakes, tornadoes, lighting, hurricanes, floods, tsunami, and seiches, without impairing their capability to perform safety functions, and the design bases for these structures, systems, and components must reflect: (i) appropriate consideration of the most severe of the natural phenomena reported for the site and surrounding area, with appropriate margins to take into account the limitations of the data and the period of time in which the data have accumulated, and (ii) appropriate combinations of the effects of normal and accident conditions and the effects of natural phenomena. The ISFSI should also be designed to prevent massive collapse of building structures or the dropping of heavy objects as a result of building structural failure on the spent fuel or high-level radioactive waste or on to structures, systems, and components important to safety.

- 10 CFR 72.122(c) requires that structures, systems, and components important to safety be designed and located so that they can continue to perform their safety functions effectively under credible fire and explosion exposure conditions. Noncombustible and heat-resistant materials must be used wherever practical throughout the ISFSI, particularly in locations vital to the control of radioactive materials and to the maintenance of safety control functions. Explosion and fire detection, alarm, and suppression systems shall be designed and provided with sufficient capacity and capability to minimize the adverse effects of fires and explosions on structures, systems, and components important to safety. The design of the ISFSI must include provisions to protect against adverse effects that might result from either the operation or the failure of the fire suppression system.

- 10 CFR 72.122(h)(1) requires that the spent fuel cladding be protected during storage against degradation that leads to gross ruptures or the fuel be otherwise confined such that degradation of the fuel during storage will not pose operational safety problems with respect to its removal from storage.

- 10 CFR 72.122(h)(4) requires that storage confinement systems have the capability for continuous monitoring in a manner such that the license will be able to determine when corrective action needs to be taken to maintain safe storage conditions.

- 10 CFR 72.122(h)(5) requires that the waste be packaged in a manner that allows handling and retrievability without the release of radioactive materials to the environment or radiation exposures in excess of NRC regulatory limits in 10 CFR Part 20. The package must be designed to confine the high-level radioactive waste for the duration of the license.

- 10 CFR 72.122(i) requires that instrumentation and control systems be provided in accordance with cask design requirements to monitor systems that are important to safety over anticipated ranges for normal and off-normal operations.

- 10 CFR 72.122(l) requires that storage systems must be designed to allow ready-retrieval of spent fuel or high-level radioactive waste for further processing or disposal.

- 10 CFR 72.124(a) requires spent fuel handling, packaging, transfer, and storage systems be designed to be maintained subcritical and to ensure that, before a nuclear criticality accident is possible, at least two unlikely, independent, and concurrent or sequential changes have occurred in the conditions essential to nuclear criticality safety. The design of handling, packaging, transfer, and storage systems must include margins of safety for the nuclear criticality parameters that are commensurate with the uncertainties in the data and methods used in calculations and demonstrate safety for the handling, packaging, transfer and storage conditions and in the nature of the immediate environment under accident conditions.

- 10 CFR 72.128(a)(2) requires that spent fuel storage be designed with suitable shielding for radioactive protection under normal and accident conditions to ensure adequate safety.

The PFS Facility must be sited, designed, constructed, and operated such that public health and safety is adequately protected during all credible off-normal and accident events.

15.1.1 Off-Normal Events

The off-normal events are described in Section 8.1, Off-Normal Operations, of the SAR. This section of the SER discusses results from the review of potential off-normal conditions which are cask drop, partial vent blockage, and operational events. The cask system to be used at the Facility is the HI-STORM 100 Cask System. Where applicable, the staff relied on the analyses in the HI-STORM 100 FSAR and the staff's related evaluation as documented in the HI-STORM 100 SER.

15.1.1.1 Cask Drop Less Than Design Allowable Height

At the Facility, a loaded HI-STORM 100 storage cask will not be lifted over 10 inches. The HI-STORM 100 storage cask was analyzed for a drop from a height of 11 inches (a drop from a lesser height would be bounded). The analysis demonstrated that a drop from this height would not impair the cask's ability to maintain subcriticality, confinement and sufficient shielding of the stored fuel. The analysis and the staff's evaluation are respectively provided in the HI-STORM 100 FSAR and the NRC's related SER. As discussed in Chapter 5 of this SER, drop of a HI-TRAC transfer cask and MPC will not occur due to the design of the lifting devices used in the Canister Transfer Building.

15.1.1.2 Partial Vent Blockage

The HI-STORM 100 storage cask was analyzed for a scenario in which 50 percent of the storage cask's air inlet vents were blocked, in accordance with NUREG-1567 (Nuclear Regulatory Commission, 2000a). The analysis demonstrated that partial vent blockage would not impair the cask's ability to maintain subcriticality, confinement and sufficient shielding of the

stored fuel. The analysis and the staff's evaluation are respectively provided in the HI-STORM 100 FSAR and the NRC's related SER.

15.1.1.3 Operational Events

Failure of Instrumentation

The staff reviewed the information presented in SAR Section 5.1.6.4, Instrumentation; Section 5.4.1, Instrumentation and Control Systems; and Section 7.3.5, Area Radiation and Airborne Radioactivity Monitoring Instrumentation. This off-normal event involves analysis of impact from failure of instruments and control systems. A failure of instrumentation event is postulated to occur when an instrument either is not operational or yields a false reading. The majority of the instrumentation is for temperature monitoring of the storage casks. These casks are designed to operate with convective cooling without significant human involvement. Therefore, an instrument failure does not directly cause an accident but may contribute to or delay detection of another event (e.g., 100 percent blockage of air inlet vents). Furthermore, the Technical Specifications require that the operability of the decay heat removal system be verified every 24 hours.

The canisters containing the spent nuclear fuel will be sealed by welding. Therefore, area radiation and airborne radioactivity monitors are not needed at the cask storage area. The applicant will operate the Facility under a Radiation Protection Program as required in Technical Specification 5.5.3 to assure that radiation fields are continually monitored. External direct radiation dose rates will be monitored along the restricted area and owner controlled area fences with TLDs. Sixteen TLDs will be located along the perimeter of each fence. The TLDs will be used to record dose rates at these locations and provide documentation that radiation levels at these boundaries are within regulatory limits. TLDs will also be placed on the outside of several Facility buildings and other strategic locations inside the Canister Transfer Building and the Security and Health Physics Building to monitor dose rates. The TLDs are retrieved and processed quarterly. Local radiation monitors with audible alarms will be installed inside the Canister Transfer Building to warn personnel about high radiation levels during canister transfer operations. Continuous air monitors will measure the airborne radioactivity concentrations.

Based on the foregoing information, the staff finds that failure of instrumentation will not impair the ability of the structures, systems, and components to maintain subcriticality, confinement and sufficient shielding of the stored fuel.

Vehicular Impact

The staff reviewed the information presented in SAR Chapter 3, Principal Design Criteria; Chapter 4, Facility Design; and Section 8.2.6, Hypothetical Storage Cask Drop/Tip-Over. Vehicular impact is postulated to occur either in the Canister Transfer Building or in the storage area as a result of an interaction between a transportation cask, a storage cask, the transfer facility, a storage pad, or an onsite vehicle and a site locomotive, a site tractor, a trailer, a cask transporter, or a vehicle used by site personnel. Equipment failure, operator error, or a natural event (e.g., tornado) may lead to this off-normal event. Occurrence of this event is easily

identifiable from visual evidence, such as dents or scratches on casks, onsite vehicles, and other Facility structures, systems, and components.

Heavy haul vehicles enter and exit only through the cask load/unload bay of the Canister Transfer Building. Site cask transporters enter a transfer cell only when canister transfer operation is not taking place. The Canister Transfer Building is designed to withstand a tornado missile equivalent to the impact of an automobile weighing 1,800 kg traveling at a speed of 134 ft/s (91 mph) (SAR Table 3.6-1). Onsite vehicles will generally be traveling at a much lower speed, on the order of 15 mph. Therefore, vehicular impact to the Canister Transfer Building is bounded by the tornado missile analysis. Additionally, PFS has committed to install a vehicle barrier around the propane storage tanks.

Potential vehicular impacts in the storage area are limited to site cask transporters, site tractors, and vehicles used by site personnel. As discussed in the HI-STORM FSAR, the storage cask is designed to withstand the impact of an 1,800 kg (an automobile), tornado-generated missile with a velocity of 185 ft/s (126 mph). As previously stated, onsite vehicles will generally be traveling at a much lower speed. Therefore, vehicular impact to the storage cask is bounded by the tornado missile analysis. This tornado missile analysis for the storage cask and the staff's evaluation are respectively provided in the HI-STORM 100 FSAR and the NRC's related SER. This analysis demonstrated that the HI-STORM 100 cask can withstand a tornado missile impact without penetration, permanent deformation, or tipover.

Based on the foregoing information, the staff finds that potential vehicular impact will not impair the ability of the structures, systems, and components to maintain subcriticality, confinement and sufficient shielding of the stored fuel.

Operator Load Handling Event

The staff reviewed information presented in Section 8.1.4 of the SAR, Operator Error. An operator load handling error is postulated to occur when a loaded canister impacts against the inside of a shipping, transfer, or storage cask. A handling error is postulated to occur in four ways: (i) while lifting the canister out of the shipping cask for lowering into the transfer cask, an operator error may cause the canister to impact the top of the transfer cask; (ii) while placing the canister into the storage cask, an operator error with the crane or canister downloader may cause a lateral impact against the inside of the storage cask; (iii) while placing the storage cask onto the storage pad, an operator error may cause a lateral impact against the inside of the storage cask; and (iv) while lowering the canister into the storage cask, an operator error due to a misaligned transfer cask may cause impact on the storage cask edge. Handling events would be detected by operators and personnel either through inspection or audibly. Corrective actions would be taken as necessary, as discussed in Section 8.1.4.4 of the SAR.

The applicant analyzed the effects and consequences of these handling events and demonstrated that the cask components would not exceed their allowable loads or stresses during these events. The canister and its internals would maintain their structural integrity and continue to perform their safety functions.

Based on the foregoing information, the staff finds that handling errors will not impair the ability of the structures, systems, and components to maintain subcriticality, confinement and sufficient shielding of the stored fuel.

Loss of External Electric Power

The staff reviewed the information presented in Section 8.1.1, Loss of External Electric Power, of the SAR. This off-normal event involves a total loss of external alternating current electric power. Loss of external power to the Facility may occur due to a natural phenomenon (e.g., lightning, extreme wind, icy conditions) or as a result of unknown factors affecting the offsite electric grid supplying power to the Facility. A loss of power event in the Canister Transfer Building will be detected by Facility workers through loss of building lighting and functions of the powered equipment. In the storage area, this event will be detected by the start up of the security diesel generator.

Important to safety features of the Facility required to perform their intended functions during a loss of external electric power event include both the cask system and the transfer facility lifting devices. All the safety design features of the cask systems, including shielding, confinement, thermal, and criticality control, are designed to operate passively and without electric power.

As discussed in Section 8.1.1.3 of the SAR, a loss of electrical power event could occur during a canister transfer operation. Three lifting devices to be used in the PFS Facility Canister Transfer Building include a 200-ton overhead bridge crane, a 150-ton semi-gantry crane, and a canister downloader. All three lifting devices meet the criteria for single-failure-proof lifting devices. The overhead bridge and the semi-gantry cranes are designed in accordance with ASME NOG–1 (American Society of Mechanical Engineers, 1989) to hold the lifted load with brakes automatically actuated if a loss of electric power occurs. Similarly, the canister downloader is also designed to fail-as-is in the event of a power loss and is equipped with two redundant sets of anti-drop cam locks. ASME NOG–1 provides the requirements of electrical overhead and gantry cranes with top running bridge and trolley and components of cranes used at nuclear facilities. A loss of electrical power event will delay the canister transfer operation; however, it will not affect the integrity of the canister.

As discussed in Section 8.1.1.3 of the SAR, radiation protection personnel will take necessary measures following a loss of electric power to the Facility, to maintain adequate distance and additional shielding between themselves and the transfer casks to maintain exposures to personnel ALARA until the electric power is restored. Utility repair personnel would be informed and would restore services by conventional means. In case of an interrupted canister transfer operation due to a loss of electrical power event, the operators will take necessary measures to assure adequate distance and/or additional shielding between themselves and the transfer casks to minimize doses until the power is restored to resume the transfer operation.

The staff reviewed the information on potential effects of loss of external electric power on the structures, systems, and components important to safety. Based on the information provided, there is reasonable assurance that no important to safety functions of the Facility will be compromised by this event. The cranes and canister downloader in the Canister Transfer Building are single-failure-proof lifting devices and will be able to hold the load in case of a power interruption. Moreover, additional shielding will be placed between the transfer casks

and the operators until the power is restored to resume the transfer operation. Loss of power will not have any safety significant impact on the Canister Transfer Building. The storage cask system is passive and does not need electric power to perform its safety functions. The staff finds that loss of external power will not impair the ability of the structures, systems, and components to maintain subcriticality, confinement and sufficient shielding of the stored fuel.

15.1.2 Accidents

The SAR includes a discussion of potential accidents resulting from both external natural and man-induced events at the Facility. Natural phenomena events are discussed in Chapter 2, Site Characteristics, of the SAR. The staff evaluation is discussed in Chapter 2 of this SER. The accident analysis review focused on the effects of the natural phenomena and man-induced events on structures, systems, and components important to safety. Analytical techniques, uncertainties, and assumptions were examined. Each event was examined to ensure that it includes: (i) a discussion of the cause of the event, (ii) the means of detection of the event, (iii) an analysis of the consequences and the protection provided by devices or systems designed to limit the extent of the consequences, and (4) any actions required of the operator.

The Facility will use the HI-STORM 100 Cask System. Where applicable, the staff relied on the analyses in the HI-STORM 100 FSAR and the staff’s related evaluation as documented in the HI-STORM 100 SER.

15.1.2.1 Cask Tipover

The staff reviewed the information presented in Section 8.2.6 of the SAR, Hypothetical Storage Cask Drop/Tipover. This accident event involves tipover of a storage cask while on the storage pad or while being transported from the Canister Transfer Building to the storage pad by a cask transporter.

As discussed in Section 8.2.6 of the SAR, the HI-STORM 100 storage cask will not tipover on the storage pad as a result of a credible natural phenomenon, including a design basis seismic event, tornado wind, and tornado-generated missile. However, to demonstrate the defense-in-depth features of the HI-STORM 100 storage cask design, a non-mechanistic tipover scenario was analyzed. The tipover analysis for the storage cask and the staff’s evaluation are respectively provided in the HI-STORM 100 FSAR and the NRC’s related SER. The tipover analysis demonstrated that deformations of the storage cask as a result of a tipover would not impose unacceptable loads on the MPC.

Tipover of the storage cask while on the transporter (due to overturning of a cask transporter) is prevented by the design of the transporter. Cask transporters are considered to be commercially available equipment and are not part of the cask system or ISFSI design. The Technical Specifications require the licensee to use cask transporters that are designed to preclude tipover during a design basis earthquake or if impacted by a design basis tornado missile.

Based on the design of the cask system, the site characteristics, and the equipment to be used at the Facility, the staff agrees that the cask will not tipover. Nevertheless, a tipover would not

impair the cask's ability to maintain subcriticality, confinement and sufficient shielding of the stored fuel.

15.1.2.2 Cask Drop

The staff reviewed the information presented in Section 8.2.6 of the SAR, Hypothetical Storage Cask Drop/Tip Over. This accident event involves dropping a loaded transfer cask, storage cask, or canister in the Canister Transfer Building, storage area, or path from the transfer facility to the storage area.

The storage casks are moved from the Canister Transfer Building to the storage pad using the cask transporter. The Technical Specifications require that the transporter be designed to mechanically limit the storage cask lifting height to 10 inches. The HI-STORM storage cask was analyzed for a drop from a height of 11 inches. For this drop, the maximum acceleration of the loaded storage cask was determined to be less than the design acceleration for the MPC (45 g). Under this postulated accident, all stresses remain within allowable values, thereby assuring that the confinement boundary remains intact. The analysis and the staff's evaluation are respectively provided in the HI-STORM 100 FSAR and the NRC's related SER.

As discussed in Chapter 5 of this SER, drop of a HI-TRAC transfer cask and MPC will not occur due to the design of the lifting devices used in the Canister Transfer Building.

Based on the foregoing information, the staff finds that a cask drop from the maximum allowable height would not impair the cask's ability to maintain subcriticality, confinement and sufficient shielding of the stored fuel.

15.1.2.3 Flood

The staff reviewed the information presented in Section 8.2.3 of the SAR, Flood. The applicant performed a PMF analysis for the proposed site based on state-of-the-art procedures and practices outlined by the U.S. Army Corps of Engineers (1997) to show the cask storage area is flood dry. The PMF analysis is derived from the PMP, or rainfall, that may occur in each of two identified drainage basins (Basin A and Basin B). The PMF analysis comprised delineation of the tributary drainage basins, determination of the appropriate rainfall depths, simulation of the storm and routing of the runoff hydrographs, determination of the flood water surface elevations near and through the PFS Facility site, and evaluation of how the proposed structures affect site safety. Based on this analysis, the proposed location of the Facility was determined to be a flood dry site (i.e., the cask storage pads are positioned above the adjacent flood plain), although the site would be temporarily isolated during a major flood event.

The SAR analysis indicates that the PMF peak discharge water surface elevation for Basin A at the upstream face of the roadway embankment is 4,506.5 ft above mean sea level. The earth berm with top elevation of 4,507.5 ft above mean sea level contains the flood flow. The PMF flood water surface elevation will overtop the low point of the access road embankment (elevation 4,502 ft) by approximately 4.5 ft. The cask storage pad area is located downstream from the embankment at an elevation of 4,462 ft above mean sea level and where the flood water surface elevation will be approximately 4.5 ft lower than the pad elevation. The PMF water surface elevation adjacent to the northeast corner of the Facility for Basin A is

approximately 4,456.8 ft above mean sea level. This is approximately 5 ft below the cask storage area. Therefore, the SAR shows the cask storage area is approximately 5 ft above the PMF water surface elevation for Basin A and will be flood dry.

The SAR analysis indicates that the PMF for Basin B will overtop the railroad embankment (elevation 4,475 ft above mean sea level) by approximately 3.2 ft at an elevation of 4,478.2 ft above mean sea level. The berm constructed immediately upstream of the Facility will have a top elevation of 4,480 ft above mean sea level and will extend above the PMF water surface elevation approximately 1.8 ft (freeboard). Flood waters do not impact the south face of the berm. The PMF water surface elevation at the northeast corner of the site is at an elevation of 4,458 ft above mean sea level. The cask storage pad elevation is 4,462 ft above mean sea level, indicating the pad is approximately 4 ft above the PMF water surface elevation for Basin B. Therefore, the SAR shows the cask storage area is approximately 4 ft above the PMF water surface elevation for Basin B and will be flood dry.

Failure of the railroad embankment will result in the flood waters concentrating through a breach and then resuming their northerly flow in the floodway. The water surface elevation over the embankment will be lowered as the cross-sectional area of the flood flow increases. The flood flow water surface elevation will be a minimum of 4 ft below the cask storage area and the cask storage area will remain flood dry. Although a railroad embankment failure would isolate the site until the embankment is repaired, such failure has no flood impact on the cask storage area.

Failure of the Facility upstream berm is highly unlikely because flood water will not contact the upstream face of the embankment. The only point of flood water contact with the Facility berm is at the interface of the railroad embankment and the west component of the Facility berm. Should the berm fail, the flood water surface elevation could potentially rise approximately 3 ft. However, there will be a minimum 1 ft differential between the water surface elevation and the cask pad top elevation, thereby keeping the casks dry. Therefore, failure of the Facility berm has no flood impact on the cask storage area.

Therefore, the SAR shows that a potential failure of any embankment or combination of embankments resulting from the PMF for Basins A and B does not impact the safety of the cask storage area because it will be flood dry in all scenarios. As a result, these embankments are not important to safety.

The staff reviewed the applicant's information and analysis in connection with a potential flood at the PFS Facility site. The staff found it acceptable because:

- Adequate information has been presented regarding the PMF potential.
- Surface water flooding that may directly affect safety has been sufficiently investigated and assessed.
- Potential flooding from the drainage basins will not submerge the cask storage area.

- Failure of the Facility upstream berm is highly unlikely because flood water will not contact the upstream face of the embankment and any hypothetical failure would not result in flooding of the cask storage area.

The structures, systems, and components important to safety are located above the maximum flood plain and, therefore, available water is insufficient to cause a tipover or overturning, a canister breach, or total submersion of the casks. Based on the information provided, the staff concludes that flooding will not impair the ability of the structures, systems, and components to maintain subcriticality, confinement and sufficient shielding of the stored fuel.

15.1.2.4 Fire and Explosion

Fire

The staff has reviewed the information presented in Section 8.2.5, Fire, of the SAR. Additional information presented in SAR Section 2.3.1.3.6, Thunderstorm and Lightning; Section 4.3.8, Fire Protection System; Section 3.3.6, Fire and Explosion Protection; and Section 7.3.1, Installation Design Features, was also used in this review.

A credible fire accident affecting structures, systems, and components important to safety at the Facility is possible during canister handling at the Canister Transfer Building or cask transportation. A credible fire at the Facility may be initiated by the ignition of diesel fuel from the storage tank, vehicle diesel fuel, or electrical insulation/equipment. Fires from other site-specific sources, such as other materials onsite, grass-fueled wildfires, and accidents on nearby highways or industrial complexes have also been considered. Information regarding the fire design features, fire detection systems, and fire-suppression systems has been evaluated in Chapter 6 of the SER.

No combustible or explosive materials will be stored on or near the storage pads. The restricted area will be completely covered with compacted gravel. The area between the outer edge of the restricted area and outer edge of the perimeter road will also be covered with crushed rock.

Fires within the restricted area may be due to various factors including (SAR Section 8.2.5.1):

- diesel fuel in cask transporters moving storage casks from the Canister Transfer Building to the storage pads,

- diesel fuel in cask transporters spilled inside the canister transfer cells,

- diesel fuel and tires in heavy-haul trucks transporting shipping casks to the cask load/unload bay of the Canister Transfer Building,

- diesel fuel in tanks of locomotives transporting shipping casks to and from the Facility,

- the diesel generator fuel tank inside the Security and Health Physics Building, and

- the diesel fuel storage tank.

The applicant has conducted an analysis of potential fires at the Facility and determined which fires are bounding. The staff has reviewed the applicant's analysis and determined that it is acceptable.

Potential Fires at the Storage Pad

One potential fire at the Facility storage pads involves a diesel-fueled cask transporter with a 50-gallon fuel tank. The tank may rupture, resulting in all 50 gallons of diesel fuel being spilled. The spilled diesel fuel may be ignited, although that is unlikely due to the high flash point of diesel fuel. During storage operations, the only combustible material installed at the storage pads will be the insulation of wiring of temperature monitoring gauges. The amount of insulating material is insufficient to be a major source of fire.

The HI-STORM 100 storage cask has been analyzed for a design basis fire caused by 50 gallons of spilled diesel fuel. This analysis and the staff's evaluation are respectively provided in the HI-STORM 100 FSAR and the NRC's related SER. In this analysis, a pool of diesel fuel is assumed to encircle the storage casks and extend 1 m beyond the cask surface. A fuel consumption rate of 0.15 in./min was assumed in analyzing the fire scenario, which translates to approximately 14 gallons/min. Based on this fuel consumption rate, the 50 gallons of diesel fuel from a cask transporter will be consumed in approximately 3.6 min. The analysis showed that all component temperatures remained below their short-term limits except for the outer one-inch of the concrete in the storage cask, which is acceptable since it does not impair the concrete's shielding function.

Another potential fire at the Facility storage pads involves a locomotive fuel spill. Section 8.2.5.2, Accident Analysis, discusses the effects of a potential rupture of the diesel fuel tanks of the locomotives and associated fire. A postulated worst case fire involves spill of all diesel fuel from two coupled main line locomotives assumed to be positioned at the north rail line nearest to the cask storage area. Distance of the center of the north rail line is 110 ft from the nearest storage pad. PFS has assumed model SD–40–2, Type C-C locomotives in the calculation. These locomotives, manufactured by General Motors Electro-Motive Division, have a rating of 3,000 continuous horsepowers (hp). The length of each locomotive is 68 ft 10 in. The locomotives will be operated at slow speeds (approximately 5 to 10 mph) associated with switching and siding operations. Each locomotive carries 3,200 gallons of diesel fuel in two long tanks, located underneath.

The applicant assumed that both fuel tanks of each locomotive ruptured and spilled a total of 6,400 gallons of diesel fuel under the fuel tanks. The applicant then calculated the heat flux assuming that the pooled diesel fuel ignites and burns. The applicant applied different pool diameters of 50, 75, and 100 ft under each set of fuel tanks of the locomotives (one pool from each locomotive). Although there will be some overlap at 75 and 100 ft diameter pool sizes, the analysis evaluated the heat flux from each pool separately and summed them at the nearest row of storage casks to calculate the total heat flux from both pool fires (SAR Section 8.2.5.2). The integrated radiant heat fluxes from different pool sizes were compared to the fire design and analysis of the HI-STORM 100 storage cask. Based on this analysis, PFS concluded that a fire from 6,400 gallons of diesel fuel spilled from the locomotives is bounded by the design

basis fire analysis of HI-STORM 100 cask system. Because the Canister Transfer Building is further away from the north rail line, it will be able to withstand this hypothetical fire occurring near the storage pads.

The land contour of the Facility site will have a downward slope from the rail lines to the cask storage area. As discussed in Section 8.2.5.2 of the SAR, the licensee will construct an intervening drainage swale that is parallel to the rail siding on its north side. The swale will be designed to retain a hypothetical 6,400-gallon spill from ruptured locomotive fuel tanks and divert the spill from the storage area. The design will account for the unlikely event of a hypothetical tipover (derailment) of the locomotive and complete rupture of all fuel tanks. The nearest edge of the swale will be constructed approximately 10 ft from the rail siding and the other side will be more than 60 ft away from the storage pad. The capacity of the swale will be sufficient to contain a total loss of diesel fuel coincident with a 100-year design rainfall.

Based on the presented information, the staff concluded that a potential locomotive fuel spill near the storage pad area and a subsequent potential fire will not pose a hazard to the Facility such that structures, systems, and components important to safety will fail to perform and release radioactivity.

Potential Fires at the Canister Transfer Building

At the Canister Transfer Building, the diesel fuel tanks of the cask transporters and heavy-haul vehicle tractors are potential sources of fire in the transfer cell and cask load/unload bay, respectively. Locomotives pushing loaded rail cars into the Canister Transfer Building are another source of fuel spills and fires. The heavy-haul vehicles will enter and exit the cask load/unload bay at the south end of the Canister Transfer Building. The heavy-haul vehicle tractors are equipped with 300-gallon diesel fuel tanks.

PFS has assumed use of locomotive model MP-15AC manufactured by General Motors Electro-Motive Division. The basic model of this locomotive has 1,500 hp and carries 1,100 gallons of diesel fuel. PFS proposes to use 150 ton flat rail cars with depressed centers to transport shipping casks by rail. This car has a coupled length of 105 ft. PFS also proposes to use a spacer car, positioned between the shipping cask car and the locomotive, to move the shipping cask in and out of the Canister Transfer Building. The spacer car is approximately 66 ft long. Consequently, the locomotive will be approximately 188 ft away from the car carrying the shipping cask. The rail cars will enter the Canister Transfer Building through the west doorway of the cask load/unload bay. Because the distance of this doorway from the position where the shipping casks would be hoisted is 102.5 ft, the locomotive pushing the shipping cask car would be approximately 16 ft outside the Canister Transfer Building. By administrative procedures of the Facility, train locomotives will be required to stay out of the Canister Transfer Building. Additionally, PFS will install wheel stops onto the rails in the cask load/unload bay east of the bay centerline to physically prevent the locomotive from entering the Canister Transfer Building. Based upon the design, the fuel tank of the locomotive will be an additional 20 ft from the Canister Transfer Building.

PFS (SAR Section 4.3.8.1) has classified the Canister Transfer Building as a Type II Fire Rated construction following the UBC (International Conference of Building Officials, 1997) and a construction Type II structure in accordance with NFPA 220 (National Fire Protection

Association, 1999a). Because nuclear materials will be handled in the Canister Transfer Building, the fire protection systems will be designed in accordance with NFPA 801 (National Fire Protection Association, 1998a). The Canister Transfer Building is designed to limit the potential effects from a diesel fuel fire by providing curbs and sloped floors to contain spilled diesel fuel away from the structures, systems, and components important to safety. The Canister Transfer Building and its surroundings are designed so that any fuel spilled outside the building will not flow into the building.

A foam-water sprinkler system will be installed in the cask load/unload bay in accordance with NFPA 16 (National Fire Protection Association, 1999b). Additionally, the floor of the bay area will be sloped toward one of two sumps located between each bay. One sump will be located at the center of each zone. The sumps will be 9 ft long and 4 ft wide with a floor sloping downward at a rate of 0.25 in./ft for 60 ft to a deep end. NFPA 16 requires that the design discharge of water from the sprinkler system should be no less than 0.16 gallons/min/sq ft. NFPA 801 requires that the drainage system of the building should have adequate size for the suppression system operating for a period of 30 minutes. PFS has calculated the depth of each sump to be 5.6 ft, which will be adequate to accommodate 300 gallons of diesel fuel spill and 30 minutes of discharge of the sprinkler system at the discharge rate allowed. The threshold between the crane bay and load/unload bay will be 1 in. in height to retain any spilled diesel fuel. The rise of the threshold will be gradual to avoid personnel tripping hazard.

The walls of the transfer cells will be 2-hr fire rated, and the sliding doors facing the cask transporter bay area will be 2-hr fire rated to prevent any fire in the transporter bay from affecting an exposed canister during the transfer operation as shown in Figure 4.3-1 of the SAR. The interior walls of the transfer cells are 30 ft high and are made of 1 ft thick concrete. This 1 ft thick concrete provides at least 4-hr fire resistance, based on Table 7-B of the UBC (International Conference of Building Officials, 1997). No sprinklers will be located near the transfer cells to avoid the possibility of spraying a canister and dislodging any contamination (SAR Section 8.2.5.2). The transfer cells will primarily contain the storage, transfer, and shipping casks. The only ignition source in the transfer cells will be the cask transporters used to remove a storage cask for placement on the storage pad. This situation will only occur when the canister is safely contained in the shipping cask or the concrete storage cask. Additionally, the floor of the transfer cells will be sloped away from the cells to ensure that a diesel fuel spill in the transporter bay does not flow into the cells. Moreover, 100-ft long hoses will be installed adjacent to the crane bay and the cask transporter bay exit locations to provide equivalent fire protection in accordance with NFPA 801. These fire hoses will ensure that all areas within the transfer cells are accessible by a water stream in case of a fire.

The transfer cells and crane bay will not store any combustible liquid. One postulated fire scenario in the Canister Transfer Building involves 50 gallons of diesel fuel spilled from the fuel tank of the cask transporter in one of the three canister transfer cells. By PFS Facility administrative procedures, the shield doors on either side of a transfer cell will remain closed when a canister transfer operation is in progress, and the cask transporter is thereby prevented from entering the cell. Additionally, the design of the Canister Transfer Building prevents any diesel fuel spilled outside to enter the transfer cells. A cask transporter with a 50-gallon diesel fuel tank can enter the cell only when the canister is inside the shipping cask with its lid bolted in place or when the canister is inside the storage cask with its lid bolted in place. As discussed previously, a fire involving 50 gallons of diesel fuel will burn for 3.6 min. Analysis presented in the HI-STORM 100 FSAR shows that the storage casks can withstand this type of fire without

compromising its safety functions. This short duration fire would also be bounded by a 1,475 °F, 30 min fire, which shipping casks approved under 10 CFR Part 71 are required to withstand. Because the cask transporter, the only significant source of ignition in a transfer cell, cannot enter the transfer cell while the canister transfer operation is in progress, a fire when the canister is in a transfer cask is precluded.

A fire in the cask load/unload bay involving 300 gallons of diesel fuel in heavy-haul trucks transporting shipping casks has been postulated. The cask load/unload bay is approximately 200 ft long and 50 ft wide. A 300-gallon diesel fuel spill will result in a pool 36 ft long and 6 ft wide with a depth of 2.23 in. At a burning rate of 0.15 in./min, the fuel in this pool will be burned in approximately 15 min. The deep ends of each sump will be located approximately 60 ft away from the center of the load/unload bay, where a shipping cask would be placed for preparation of transferring into a canister transfer cell. The temperature of the fire near the shipping cask would be substantially lower than a 1,475 °F, 30 min fire. Additionally, the cranes will be in the high bay area whereas the sumps are located in the low bay areas. Consequently, a fire in the sumps will not affect any structures, systems, and components so as to cause a radioactive release.

A fire in the low bay areas would produce upper hot layer temperatures. The cranes would be exposed to these high temperatures. Therefore, PFS evaluated the effects of a postulated fire on the cask involving the heavy-haul trailer. To determine a bounding fire scenario for the Canister Transfer Building, PFS has evaluated four credible fire scenarios:

- a diesel fuel spill fire of 300 gallons being consumed in 30 min, assuming a leak rate of the tanks of the heavy-haul trailers equal to 10 gallons/min, which results in a fire of duration 30 min;
- a diesel fuel spill of 300 gallons spread over an area of 200 sq ft (2.4 in. fuel depth) consumed in 16 min;
- a double axle of tires of the heavy-haul trailers (a total of 16 tires) assumed to burn for 30 min; and
- a combined 200 sq ft diesel fuel spill of 300 gallons and a tire fire lasting 30 min.

Details of the analyses are given in Stone & Webster Engineering Corporation (2000a,b).

In scenarios involving a 200 sq ft diesel fuel pool fire, it has been assumed that the sumps at each end of the cask load/unload bay do not exist and 300 gallons of diesel fuel forms a pool, centered at the trailer's fuel tanks, that extends to the nearest set of tires of the trailer. These scenarios were evaluated using the software FPEtool to determine the fire plume temperatures in the low bay area (30-ft high ceiling), hot layer temperatures in the high bay area (90-ft high ceiling), and release rate of heat from each fire. An area of the load/unload bay equal to 10,200 sq ft and height of the ceiling equal to 30 ft were used in plume calculations. Concrete walls and ceiling heat loss area of the high bay area, equal to 80,545 sq ft, were used in calculating the temperatures of hot layers. A vent to the low bay area, having height equal to 30 ft and

width equal to 20 ft, was assumed because the hot layer calculations require a vent. These analyses do not consider the automatic fire-suppression system to be installed in the Canister Transfer Building and any manual actions to extinguish the fire. The results are given in Table 15-1.

Table 15-1. Results from analysis of different fire scenarios (SAR Section 8.2.5.2)

Fire Scenario	Plume Temperature at Low Bay (°F)	Hot Layer Temperature at High Bay (°F)	Heat Release Rate (kW)
(i) Diesel fuel pool, consumed in 30 min	834	324	21,100
(ii) Diesel fuel pool, consumed in 16 min	1200	408	38,000
(iii) Tire fire, duration 30 min	503	214	9,000
(iv) Combined 16 min diesel fuel pool and 30 min tire fire	1372	459	47,000/9,000†

†47,000 kW heat release rate (combined diesel pool and tire fire) lasts for first 16 min and 9,000 kW heat release rate from tire fire continues for an additional 14 min.

Results given in Table 15-1 show that the bounding fire is a 300-gallon diesel fuel spill, which burns in 16 min, combined with a 30 min tire fire.

A substantial ignition source is necessary to create a self-sustaining fire of the tires of the heavy-haul vehicles. The analysis presented by PFS (Stone & Webster Engineering Corporation, 2000b) considered fire involving a set of tires on the vehicle. Because the floor is sloping toward the sump and the sump is sloping away from the shipping cask, it was considered a non-credible event for a fire involving 300 gallons of diesel fuel spilled from the vehicle tank to spread more than 60 ft to affect the shipping cask. It is also extremely unlikely for the tires on the adjacent axle, separated by 12 ft, to catch fire as the peak radiant heat flux to the adjacent axle was calculated to be 8.0 kW/m^2. A significantly larger heat flux (more than two and a half times) is necessary to ignite vulcanized rubber.

As a worst case scenario, PFS assumed tires on the double axle closest to the shipping cask (total of 16 tires) would burn. The calculated peak radiant heat flux at the middle of the flame was 10.7 kW/m^2. However, shipping casks approved under 10 CFR Part 71 must be designed to withstand a fire burning at 1,475 °F for 30 min, yielding a radiant heat flux of 68 kW/m^2. Therefore, there is reasonable assurance that a fire involving tires of the heavy-haul vehicles would not affect the safety functions of a shipping cask.

Canister transfer operations may take place in the transfer cells while a heavy-haul vehicle is in the cask load/unload bay. The reinforced concrete barrier walls, 30 ft in height, of the transfer

cells protect the equipment within the cells from radiant heat caused by a fire in the cask load/unload bay. Additionally, the smoke layer temperatures over the transfer cells from the bounding fire will not create a significant hazard to the equipment within the transfer cells due to the 90 ft high ceiling in the high bay area and the large heat loss surface area of the reinforced concrete walls and ceiling. The highest calculated average upper layer temperature was 459 °F for the bounding fire scenario, with somewhat higher temperatures near the ceiling and lower temperatures near the bottom of the upper layer. These temperatures would not affect the structural integrity of the canisters or the transfer casks based on the design and fire analysis presented in the HI-STORM 100 FSAR. Moreover, the upper layer temperature from the bounding fire scenario is low and will not affect the Canister Transfer Building structure. Upper layer temperatures were half of those needed to cause flashover of the contents of the Canister Transfer Building. Flashover occurs when the upper layer temperature is high enough to cause most of the combustibles within the fire area to auto-ignite. Although components associated with the electric power supplies and motors for the crane and canister downloader may fail at these temperatures, the cranes and the canister downloader are designed to safely maintain their loads in case of loss of electric power.

The Canister Transfer Building is constructed of reinforced concrete, which meets the non-combustible criteria and can withstand the effect of large fires for long periods of time. This plume temperature analysis showed that the concrete structure of the Canister Transfer Building can withstand the postulated fires without collapse. Because the plume temperatures obtained at the low bay ceiling in these fire scenarios are below the exposure conditions of an ASTM E–119 fire resistance test (American Society for Testing and Materials, 1998), there is reasonable assurance that the postulated fires will not pose any hazard to the structural integrity of the Canister Transfer Building.

The size of the Facility is also beneficial, in that the heat from a fire would dissipate in the high bay, allowing more time before the building becomes untenable for workers to egress and emergency response personnel to suppress the fire. The segregation of the transfer cells with concrete walls is beneficial because it shields the transfer operation from a fire in the load/unload bay. The cask transporter will also be segregated from the transfer cells during transfer operations with a 2-hr fire rated barrier.

The applicant’s analysis was conservative since it did not take into effect the benefits of the smoke removal system, load/unload bay drainage, foam-water deluge, and manual efforts to mitigate the fire before these high temperatures are reached. Fire detection, alarm, and suppression systems will be designed according to applicable NFPA Standards and provided with sufficient capacity and capability to minimize the adverse effects of fires on structures, systems, and components important to safety. As discussed above, a foam-water deluge system will be used in the load/unload bay. The foam-water deluge provides superior suppression of Class B fires (applicable here), around the heavy haul vehicle. Fire hoses and portable extinguishers will be provided for quick deployment. Hydrants will be located near the buildings to support manual fire suppression using the fire trucks. Two fire pumps, one electric and one diesel, and two water tanks are provided for redundancy. A fire brigade is provided during hours of operation, when fires having the potential for radiological release could occur. Additional details are given in Chapter 6 of this SER.

The SAR also describes the smoke detection, fire alarms, and a smoke removal system for the Canister Transfer Building. Photo-sensitive smoke detectors will be provided for early warning

to the building occupants. The fire alarm annunciates within the building and at a central alarm panel in the Security and Health Physics Building for continuous 24 hour a day monitoring. Smoke removal is provided by the building's exhaust ventilation fans and should reduce the smoke level and upper layer temperature of the transfer bay during a fire. These systems provide adequate mitigation of the Canister Transfer Building fire risk to reduce the impact on structures, systems, and components important to safety. Detailed discussion of the fire detection, alarm, and suppression systems is given in Chapter 6 of this SER.

Potential for Wildfires

Based on information from the National Oceanic and Atmospheric Administration, PFS has estimated that approximately 20 severe thunderstorms took place in Tooele County from 1975 through 1995, with two reported instances of lightning strikes causing injuries (SAR Section 2.3.1.3.6). PFS has also provided information on potential wildfires that may affect the Facility (SAR Section 8.2.5.1), based on Britton (Parkyn, 1999). This document analyzed the possibility and characteristics of a wildfire reaching the PFS Facility site boundary. According to Britton, the valley does not have continuous fuels due to the dry climate and the presence of alkaline and salty soils. Cheatgrass is the dominant fuel for wildfires in Skull Valley. Although cheatgrass does not have a significant influence on frequency of occurrence of wildfires, fires can spread easily in cheatgrass compared to a typical bunch grass site if cheatgrass is available in sufficient quantity.

During the last 18 years, 71.6 percent of the 109 fires of record in the area were less than 100 acres in size. This indicates marginal fuel continuity for large fire development and the intensity of the initial firefighting efforts by the Bureau of Land Management and other agencies (Parkyn, 1999). PFS has concluded the following:

- The average number of fires in Skull Valley is approximately six per year over a large area.

- The probability of a worst case fire encountering the perimeter of the Facility is well below 1 percent in a given year.

- Planning (fuel modification and fuel breaks) and current fire fighting methods (aerial slurry drops) will significantly reduce the probability of a fire reaching the PFS Facility site.

- The fuel load in Skull Valley is approximately 5,000 lb/acre.

- With this fuel loading, a flame length reaching a maximum of 28 ft is possible for very short time periods.

- A temperature of above 200°F will last 5.4–9 min at the soil surface and less than 1 min at approximately 10 ft above the soil surface.

- The temperature may reach approximately 1,466°F close to the soil surface, based on investigations at the Horse Haven study site near Ely, Nevada, which may be considered as the upper limit for Skull Valley.

- The rate of spread of wildfire is highly variable and where heavy fuel is available, the rate of spread of a fire can be as high as 590 ft/min for short runs.

- The fuel load can be easily reduced by planting a crested wheatgrass barrier around all areas susceptible to wildfire.

- With a 100-ft fuel break (a zone containing no significant combustible vegetation), no heat damage is possible for structures, systems, and components important to safety at the Facility.

The Facility will be located on an open gravel surface (SAR Section 3.3.6). Figure 1.2-1 of the SAR gives the layout of the restricted area of the Facility. Concrete storage pads will be separated from the inner fence of the Facility surrounding the restricted area by a minimum distance of 150 ft (Cooper, 1999). The restricted area not covered by the storage pads will have crushed rock 12 in. deep. The outer fence is separated from the inner fence by a distance of 20 ft. The isolation zone (i.e., the region between the fences) will also be covered 12 in. deep with crushed rock. The 20-ft wide perimeter road, located at a distance of 10 ft from the outer fence, will also be covered 12 in. deep with crushed rock. The 10-ft wide zone between the perimeter road and the outer fence will also have a 12-in. deep crushed rock surface (Cooper, 1999). This results in a 200-ft gravel barrier between the outer-most concrete storage pad and the outer edge of the perimeter road. A maintenance program will control any significant growth of vegetation through the crushed rock. Therefore, the surface of the restricted area, including the region up to the perimeter road, will be noncombustible (Cooper, 1999).

PFS will plant a 300 ft crested wheatgrass barrier around the restricted area. Based on the previous information, the site has more than 100 ft of fuel break between the outside edge of the perimeter road and any storage cask or site structure important to safety. Crested wheatgrass barrier provides another 300 ft of buffer. By comparison, the U.S. Fire Administration (1993) suggests a 100-ft fuel break for wildfires in pine forests.

A group of four tanks with an individual capacity of 5,000 gallons will store propane for heating the Canister Transfer Building and the Security and Health Physics Building. These tanks will be located at least 1,800 ft from the nearest cask storage area and the Canister Transfer Building. The group of tanks will be separated by missile barrier walls to ensure that more than one tank will not rupture at any given time. To prevent any damage from wildfires, PFS will place crushed rock on the ground at least 100 ft radially outward from the tanks. As discussed before, a 100 ft fire break provides adequate protection from wildfires. One or two propane tanks, with a capacity less than 5,000 gallons, will also be located at least 1,800 ft away from the Canister Transfer Building and the storage pads. These tanks will be used for heating the Operations and Maintenance Building and the Administration Building.

Fires - Conclusion

The staff has reviewed the information provided by the applicant regarding potential wildfires and onsite fires at the Facility. The staff found the applicant's analysis acceptable because:

- Adequate design details have been provided regarding the fire detection, alarm, and suppression systems to be installed at the Facility. These systems will be designed in accordance with acceptable codes and standards. Moreover, these systems have sufficient capacity and capability to minimize the adverse effects of a postulated fire on structures, systems, and components important to safety. The suppression systems and fire fighting brigade are discussed in Section 6.1.5.1 of this SER.

- Noncombustible and heat-resistant materials will be used to construct important to safety structures, systems, and components, wherever practical.

- Through design and administrative procedures, sources of ignition (e.g., spill of diesel fuel) will be kept out of the canister transfer cells, especially when the canisters are outside the protection of either a shipping cask or a storage cask.

- A restricted area with designed fire barriers to prevent wildfires from affecting the Facility has been adequately described.

- The storage casks are designed to withstand a fire from 50 gallons of diesel fuel from the fuel tank of the cask transporters.

- Hypothetical fires involving the fuel tanks of the two main line locomotives will not pose any radiological hazards to the storage casks on the storage pads or the Canister Transfer Building.

- Switching locomotives will be prevented from entering the Canister Transfer Building by administrative procedures. Additionally, wheel stops will be installed to physically prevent a locomotive from entering the Canister Transfer Building.

- A foam-water sprinkler will be installed at the cask load/unload bay sufficient to suppress any fire from 300 gallons of diesel fuel spilled from the tanks of heavy-haul trucks.

- Cask transporters (the only ignition source in the transfer cells), are prevented from entering the cells when a canister transfer operation is in progress.

- Plume temperature calculated at the low bay ceiling or upper layer temperature at the high bay area will not affect the structural integrity of the Canister Transfer Building.

The applicant has assessed the site conditions, such as availability of cheatgrass and ground topography near the rail lines, that may affect the safety of the Facility. It has also assessed the frequency and severity of wildfires. Additionally, the applicant has appropriately designed the systems, structures, and components important to safety and located them within the Facility so that they can continue to perform their safety functions under credible fire scenarios. Moreover, the design of the Facility includes barriers (e.g. crested wheat grass, crushed gravel) to protect against adverse effects that might result from either the operation or the failure of the fire-suppression system.

Based on the foregoing evaluation, there is reasonable assurance that onsite fires and wildfires will not create a significant hazard to the Facility. The staff finds that the Facility is sited, designed, and operated to minimize the potential for fires and any onsite fires or wildfires would not impair the ability of the structures, systems and components to maintain subcriticality, confinement, sufficient shielding, and retrievability of the stored fuel. The applicant's description of its means and equipment to fight fires onsite provides a defense-in-depth approach and is adequate to assure the health and safety of its workers, the public, and the environment.

Onsite Explosion

The staff has reviewed the information presented in SAR Section 8.2.4, Explosion, and Section 3.3.6, Fire and Explosion Protection. Areas within the Facility where a potentially explosive agent can be found include:

- the backup power generator diesel fuel tank;
- the propane gas storage tanks for heating the Canister Transfer Building and the Security and Health Physics Building; and
- the propane gas storage tanks for heating the Administration Building and Operation and Maintenance Building.

Important to safety structures, systems, and components that are required to function after an explosion event include both the storage casks and the Canister Transfer Building. Regulatory Guide 1.91 (Nuclear Regulatory Commission, 1978) sets 1 psi as the peak positive incident overpressure below which no significant damage to the structures would be expected to result from an explosion. Blast-induced ground motions are bounded by the earthquake criteria, and blast-generated missiles are bounded by the tornado missile criteria established for the Facility. For the explosion sources present in the Facility, air overpressure from an explosion presents the most critical consideration.

A diesel fuel oil storage tank will be located within the restricted area fence for refueling onsite vehicles, including the cask transporter. The tank will be placed approximately 200 ft from the Canister Transfer Building and approximately 700 ft from any storage cask located on a concrete pad. The capacity of the diesel storage tank will be approximately 1,000 gallons A regional bulk fueling service will supply the fuel to the tank. This aboveground tank will have a double wall to satisfy the primary and secondary spill containment requirements of NFPA 30 (National Fire Protection Association, 1996b). The tank will be surrounded with dikes to contain fuel in the event of a leak or spillage. The tank will be designed in accordance with the requirements of UL-142, Steel Aboveground Tanks for Flammable and Combustible Liquids (Underwriters Laboratories Inc., 1993) and UL-2085, UL Insulated Aboveground Tanks for Flammable and Combustible Liquids (Underwriters Laboratories Inc., 1997). Another double-wall subbase diesel tank will be in the Security and Health Physics Building to provide fuel for the backup diesel generator. The anticipated capacity of the diesel tank in the Security and Health Physics Building for providing fuel for the backup diesel generator is 350 gallons, which exceeds the exempt amount of 120 gallons for Class II combustible liquid. Therefore, a water sprinkler will be installed in the diesel generator room in accordance with NFPA 13 (National

Fire Protection Association, 1999c) (SAR Section 8.2.4.2). The diesel generator room will be separated from all other adjacent interior spaces by a 1-hr rated fire barrier.

The outdoor diesel storage tank may rupture from a collision or tornado-driven missile impact resulting in spillage of diesel fuel. However, spilled diesel fuel does not create the potential for an explosion because of its low volatility and high flash point.

A group of four centralized tanks, with maximum individual capacities of 5,000 gallons, will store a maximum of 20,000 gallons of propane for heating the Canister Transfer Building and the Security and Health Physics Building. The storage tanks will be located outside the restricted area, at least 1,800 ft south or southwest of the Canister Transfer Building and at least 1,800 ft from the nearest cask storage pads. The distance between the storage tanks and the Operations and Maintenance Building will be approximately 1,000 ft. The four propane tanks will be separated by missile walls designed to ensure that a single tornado missile cannot rupture more than one tank. One or two small size tanks with capacities less than 5,000 gallons will be located near the Administration Building and the Operations and Maintenance Building to supply propane for heating these buildings. These tanks also will be at least 1,800 ft away from the nearest storage pad and the Canister Transfer Building. Consequently, the blast from a vapor-cloud explosion caused by release of propane from one tank will not develop air overpressure larger than 1 psi.

The aboveground propane storage tanks will be designed in accordance with the requirements of NFPA 58 (National Fire Protection Association, 1998b). The propane heating system will be installed on the roof of the Canister Transfer Building. Outdoor pipelines supplying propane will be below ground and coated or wrapped. An excess flow control feature will be installed at the storage tanks that will isolate a distribution line if the flow detector senses an abnormally high flow rate, indicating a leak of propane. Propane is classified as a flammable and liquefiable gas. Propane will be stored as a liquefied petroleum gas with the tank pressurized to the vapor pressure of the propane liquid, whose temperature will be close to the average ambient daily temperature. Relief valves on the tanks will be set at approximately 275 psig.

The propane from the storage tanks will be distributed to the Canister Transfer Building and the Security and Health Physics Building using 2 in. schedule 80 steel pipe. Use of buried and all-welded piping system will minimize the possibility of propane leakage. A compressor, located near the storage tanks, will provide the motive force necessary to move the propane to these buildings. Excess flow control features, installed at the storage tanks, will isolate propane flowing to the affected distribution line in case of an abnormally large flow rate. An abnormally large flow rate would be an indication of a large leak or rupture of the pipe. Additionally, a single excess flow shutoff valve will be located on the 2 in. pipe header downstream of the connection points of the distribution lines from the four propane storage tanks. This valve will close automatically if a high flow rate is detected. This system of automatic isolation valves will isolate ruptured pipelines. Therefore, the potential for significant leak of propane in the vicinity of the Canister Transfer Building or Security and Health Physics Building is minimized.

The Canister Transfer Building is designed to withstand a pressure differential of 1.5 psi from a design basis tornado (SAR Section 3.2.8.1). Moreover, the design of the proposed storage cask systems shows at least 5 psi pressure differential is needed before any damage takes place.

Although unlikely, it is hypothesized that the propane tanks will rupture when struck by a projectile, such as a tornado missile. Because of vehicle barriers, a vehicle is not expected to collide with the propane storage tanks.

PFS carried out an atmospheric dispersion analysis to determine the maximum downwind distance from the storage tanks in which the propane concentration in the plume could be above the lower explosive limit (SAR Section 8.2.4). Additionally, PFS determined the air overpressure developed by delayed ignition of the resulting propane vapor cloud. PFS analyzed four possible scenarios:

- Scenario 1: A 2-in diameter hole at the top of the tank, allowing only propane vapor to be released.

- Scenario 2: A 2-in diameter hole at the bottom of the tank, allowing only liquid propane to be released.

- Scenario 3: An instantaneous release of 20,000 gallons of propane from one tank.

- Scenario 4: An instantaneous release of 5,000 gallons of propane from one tank.

The objective of this study was to determine whether release and dispersion of the entire propane from a 20,000-gallon tank and later ignition of the vapor cloud would produce acceptable air overpressure at the storage casks and the Canister Transfer Building. If the calculated air overpressure was found to be unacceptable, four smaller storage tanks, each with a 5,000-gallon capacity, would be used instead of one 20,000-gallon tank, if similar analysis with a 5,000-gallon storage tank produced acceptable air overpressure at the storage pads and the Canister Transfer Building.

The tanks would be located at a minimum distance of 1,800 ft from the Canister Transfer Building and the nearest storage casks. The tank was assumed to be full at a temperature of 20 °C (68 °F) and at a pressure of 8.4 atm in each case. Atmospheric conditions assumed are night time with very stable condition (Stability Class F), and an ambient temperature of 20 °C. These characteristics produce worst case conditions for dispersion. A wind speed between 1 to 5 m/s, that produced the largest predicted propane concentration at 549 m (1,800 ft) distance from the tanks, was used in the analysis. The wind speed is consistent with site measured data, reported in Section 2.3.2.1.3, Wind Direction and Speed, of the SAR.

To analyze the first two scenarios, PFS used the TSCREEN model, developed by the U.S. Environmental Protection Agency, to predict the release rate of two-phase propane from pressurized tanks with holes. Additionally, the SLAB model (Ermak, 1990) was used to predict the dispersion of large scale release of two-phase, denser than air plumes resulting from tank spills.

The distance at which the air overpressure resulted from the vapor-cloud explosion in each scenario would be equal to one psi was calculated with the methodology of Regulatory Guide 1.91 (Nuclear Regulatory Commission, 1978). An explosive yield factor of 3 percent was assumed in determining the TNT equivalent weight of propane.

Regulatory Guide 1.91 (Nuclear Regulatory Commission, 1978) estimates that, in most cases, less than 1 percent of the calorific energy will be released as blast energy. Additionally, Industrial Risk Insurers (1992) states that analyses of actual chemical plant vapor-cloud explosions indicate an explosion yield factor of 1 to 5 percent. Industrial Risk Insurers suggest a value of 2 percent for the explosion yield factor to be used in maximum and catastrophic loss estimates. Based on the Society of Fire Protection Engineers' (SFPE) Handbook of Fire Protection Engineering (Society of Fire Protection Engineers, 1995), the presence of a large structure within the vapor cloud is a necessary but not sufficient condition for an explosion, since approximately 22 percent of reported ignitions resulted in deflagration and not an explosion. The explosion yield factor is approximately 1 percent for releases of 1,000 to 10,000 kg of vapor and is in the range of 1 to 10 percent for larger than 10,000 kg releases (Society of Fire Protection Engineers, 1995). The Federal Emergency Management Agency (FEMA) specifies the explosion yield factor for propane to be equal to 3 percent (Federal Emergency Management Agency, 1989). Based on the FEMA Handbook, a number higher than 3 percent will correspond to other more explosive substances, such as certain alkenes and fuels containing oxygen, which are expected to have higher fractions of total energy contributing to the blast from a vapor-cloud explosion. Based on all the previous information, the staff accepts 3 percent as a reasonable value for the explosion yield factor for propane to calculate the amount of energy released in a hypothetical onsite propane vapor-cloud explosion following a release from a storage tank.

In Scenario (1), propane in gaseous phase will initially exit the tank at a pressure of 8.4 atm. As the pressure drops, liquid propane will transform into vapor until the liquid is cooled to its boiling point of $-42°C$. If the tank initially was at $20°C$, approximately 37 percent of total propane will vaporize leaving 67 percent in the liquid state. Results from the TSCREEN analysis show that propane would be released from the tank at a rate of 3.69 kg/s for about 67 min. A wind velocity of 3 m/s produced the furthest extension of the vapor-cloud at a lower explosive limit from the tank. The mass of the cloud was estimated to be 234 kg (515 lb). It was assumed that ignition would occur at a point near the center of the plume, which was estimated by taking one-half the distance from the tank to the edge of the cloud where the concentration was equal to the lower explosive limit. The 1 psi overpressure would occur from this plume at a distance of 175 m (580 ft) from the tank based on an analysis using TNT equivalency and methodology of Regulatory Guide 1.91.

In Scenario (2), liquid propane will flash to vapor as it exits the tank. TSCREEN results predicted that it would take 19 min to empty a 20,000-gallon propane tank. The propane release was modeled as 37 percent vapor and 63 percent droplets. The rate of emission was calculated to be 33.2 kg/s. The model predicted that ground level concentration of propane exceeding lower explosive limit would be up to a distance of 450 m from the tanks. Based on a worst case wind speed of 3 m/s, the mass of cloud was estimated to be 4,980 kg (10,956 lb). An overpressure of 1 psi would occur at a distance of 438 m (1,445 ft) from the tanks.

In Scenario (3), 20,000 gallons of propane is instantaneously released due to rupture of one storage tank. The liquid propane would flash to vapor and aerosol droplets as it exits the tank. The release was modeled using the SLAB code at 37 percent vapor and 63 percent aerosol droplets. The propane vapor-cloud was modeled as being transported in a downwind direction by the worst case wind speed of 3 m/s. A terrain roughness value of 0.0003 m was used as characteristics of "level desert" following Ermak (1990). The ignition point was assumed to coincide with the center of the cloud when the concentration at the center of the cloud had

decreased to just below the upper explosion limit, while the bulk of the cloud was still in the explosive range. At this point, the center of the cloud was 210 m (690 ft) from the tanks and the 1 psi overpressure contour was located 418 m (1,371 ft) from the cloud center. Hence, the 1 psi overpressure extended 628 m (2,061 ft) from the tanks.

In Scenario (4), 5,000 gallons of propane are released instantaneously from one storage tank. The release was modeled as 37 percent vapor and 63 percent aerosol droplets of propane at −42°C. The SLAB model predicted a maximum concentration of propane at the lower explosive limit at a distance of 400 m from the tank. For this scenario, the cloud again ignited at the point where the maximum concentration reached the upper explosive limit and all the tank contents participated in the explosion. The model yielded a 1 psi overpressure at 383 m (1,192 ft) from the tanks.

The staff determined that it would have been desirable to use the same ignition criterion and explosion for all four scenarios, i.e., ignition occurs at the point where the cloud center concentration decreases to just below the upper explosive limit and all the contents of the released propane (not just the fraction initially vaporized) participates in the explosion. However, since both criteria gave approximately the same distances to the 1 psi overpressure contour for Scenarios (3) and (4), it can reasonably be assumed that both criteria would have given approximately the same 1 psi overpressure distances for Scenarios (1) and (2) as well.

The applicant's assumption that the ambient temperature is 20°C was examined by the staff. SLAB simulations were conducted when the ambient temperature was assumed to be −9°C (15 °F), which is a realistic temperature for a winter night at the Facility location. Assuming that the tanks contained the same mass of propane, the downwind distance to the point where the cloud center concentration had just decreased to the upper explosive limit for Scenario (4) was found to be within several meters of the downwind distance for the 20°C ambient temperature distribution. This is a result of the fact that the vaporized propane has a temperature initially of −42°C, and so both ambient temperatures are well above the propane boiling temperature. There could, however, be somewhat more mass of propane in the tanks at this ambient temperature if the tanks were filled when the ambient temperature was below 20°C. If so, the downstream distance to the upper explosive limit would be slightly greater than for the case examined by PFS. However, the difference is not substantial enough to pose a hazard to the Facility.

Based on the results of these four scenarios, only a rupture of a single 20,000-gallon propane tank would result in a explosive concentration of propane vapor traveling to the Canister Transfer Building and the nearest storage casks under the worst atmospheric conditions (with a potential to generate an air overpressure in excess of 1 psi at the Canister Transfer Building or storage pad area). Consequently, PFS has selected to use four propane storage tanks with maximum individual capacity of 5,000 gallons instead of the single 20,000-gallon tank. These tanks would be separated by missile walls to ensure that a single tornado missile cannot rupture more than one tank. Therefore, the analysis with one 5,000-gallon storage tank would be bounding.

PFS also carried out an analysis to determine the potential effects of a rupture of the propane distribution line next to the Canister Transfer Building. A large leak of propane would cause a low-pressure indication at the heaters resulting in shutting off the fuel supply to the heaters and isolation of the distribution line at the storage tank. The rupture has been assumed to be large

enough to allow the remaining propane in the pipe downstream of the shutoff valve at the tank to escape. The propane was assumed to form a vapor cloud next to the Canister Transfer Building without being dispersed.

The propane distribution line will be approximately 2,200 ft long from the shutoff valve to the 1.5 in. branch lines leading to each of the roof-mounted propane heaters. PFS has estimated the total branch length to be approximately 100 ft. Assuming that the propane is at the maximum design pressure of 125 psi for vapor liquified petroleum-gas service, the worst case mass of propane cloud to escape from the isolated pipe would be 45.5 lb (20.6 kg). The amount of propane escaped may cause a fire of a few seconds duration, however, the mass of the propane released from the postulated pipe rupture is insignificant to develop an explosion, based on the SFPE handbook (National Fire Protection Association, 1995).

The HI-STORM 100 storage cask is designed to withstand an explosion that generates an external differential pressure of 5 psi. Therefore, the storage cask will not be adversely affected by potential propane explosions at the site.

The staff reviewed the information provided by the applicant regarding potential hazards from accidental onsite explosion at the Facility. The staff found the analysis acceptable because:

- Adequate design details of the propane and diesel storage tanks have been provided.

- Potential air overpressure from ignition of a propane vapor-cloud has been analyzed using acceptable methodologies. The analysis assumed the worst case scenario where all 20,000 gallons of propane vapor ignites and a source of ignition is present nearby.

- Vapor-cloud dispersion and delayed ignition have been analyzed using acceptable methodologies.

- Results of the analyses (with and without atmospheric dispersion) show that four 5,000-gallon propane tanks will be located sufficient distances away from any structures, systems, and components important to safety so that the hazards associated with air overpressure are negligible.

- Missile walls will separate four 5,000-gallon propane storage tanks to prevent simultaneous rupture of more than one tank from a tornado missile.

- The amount of propane in the pipeline delivering propane from the tanks to the Canister Transfer Building is too small to cause an explosion.

The applicant has appropriately designed the structures, systems, and components important to safety and located them within the Facility so that they can continue to perform their safety functions under potential onsite explosion scenarios. Based on the foregoing evaluation, the staff finds that potential onsite explosions would not impair the ability of the structures, systems, and components to maintain subcriticality, confinement and sufficient shielding of the store fuel.

15.1.2.5 Lightning

The staff reviewed the information presented in SAR Section 8.2.9, Lightning, Section 3.2.12, Lightning, and Section 4.7.1.5.1.H, Lightning. Lightning is a large-scale, high-tension natural electrical discharge in the atmosphere. It is a natural event associated with thunderstorms in which one or more cloud-to-ground strikes could affect Facility structures, systems, and components exposed to the environment. A lightning event would be caused by meteorological conditions at the site. Its frequency is dependent on the time of day, geographic location, and elevation. Certain areas of the country are also prone to greater occurrences of thunderstorms, particularly the warmer and more humid locations.

The general effects of a lightning strike depend on the structures affected and the number of lightning strikes. Specific effects may include a localized temperature increase, a loss of power, or a short circuit of electrical components. A lightning strike on the Canister Transfer Building or a storage cask may be detected visually at the location of the site by discoloration, typically a blackened area at the point of impact. The occurrence of the lightning strike may be observed by individuals at the time of the event, or it may not be observed until a later time during routine surveillance inspection.

In SAR Section 8.2.9, lightning is classified as a natural phenomenon Design Event III, which is defined in ANSI/ANS 57.9–1992 (American National Standards Institute/American Nuclear Society, 1992). A Design Event III is an infrequent event that could reasonably be expected to occur during the lifetime of the proposed ISFSI. The staff concurs with the classification of a lightning event at the Facility as a Design Event III. The Facility has a moderate to severe risk of a lightning strike based on an assessment performed in accordance with NFPA 780 (National Fire Protection Association, 1997a). Mean annual number of days with thunderstorms for the site, based on the U.S. Meteorological Service isoceraunic map in NFPA 780, is between 31 and 40 (SAR page 4.7-8a).

Both the Canister Transfer Building and cask system are important safety features of the PFS Facility that may be affected by a lightning strike. The Canister Transfer Building superstructure will be provided with lightning protection in accordance with NFPA 780 (National Fire Protection Association, 1997a) to protect the important to safety features found inside the transfer facility from a direct lightning strike (SAR Section 3.2.12). NFPA 780 provides for the protection of people, buildings, special occupancies, structures containing flammable liquids and gases, and other entities against lightning damage. An air terminal lightning protection system will be installed on the Canister Transfer Building to protect it from a lightning strike. Air terminals will be installed on the ridge and perimeter of the upper roof and along the perimeter and interior of the lower roof areas. These terminals will be interconnected to a main conductor cable that will be connected to ground rods around the perimeter of the building. As the Canister Transfer Building exceeds 75 ft in height, all lightning-protection materials will be NFPA 780 Class II materials (SAR Section 4.7.1.5.1.H). The perimeter fences will be connected to the Facility grounding system for safety of personnel in the event of lightning strikes.

Section 8.2.9 of the SAR states that lightning poles will be installed in the vicinity of the storage pads. These poles are grounded metal light fixtures and are approximately 120-ft high. NFPA 780 (National Fire Protection Association, 1997b) specifies the zone of protection for a 20-ft

high structure (e.g., a storage cask) as a circular area with a radius of 75 ft around the light pole. However, the light poles are approximately 500 ft apart. It is possible that lightning may strike a cask not within the zones of protection offered by two consecutive poles. As discussed in Section 11.2.12 of the HI-STORM 100 FSAR, any lightning strike on the overpack will discharge through the steel shell of the overpack to the ground. Such an occurrence will not have any adverse effect on the overpack. The HI-STORM 100 lightning analysis and the staff's evaluation are respectively provided in the HI-STORM 100 FSAR and the NRC's related SER.

A lightning strike may initiate an offsite grass fire. As discussed in the evaluation of potential fires (SER Section 15.1.2.4) the restricted area of the Facility that is not covered by the storage pads will have crushed rock 12 in. deep. The 20-ft wide perimeter road, located 10 ft from the outer fence, will also be covered 12 in. deep with crushed rock. A maintenance program will control any significant growth of vegetation through the crushed rock. Therefore, the surface of the restricted area, including the region up to the perimeter road, will be noncombustible. Also a fire break of approximately 300 ft will be provided by the crested wheatgrass barrier. Additional details of fire hazard evaluation are in Section 15.1.2.4 of this SER. The staff has concluded there is reasonable assurance that lightning-induced wildfires will not produce a significant hazard to the Facility.

The staff reviewed the information provided by the applicant with respect to potential hazards from a lightning strike to the Facility. The staff found it acceptable because:

- The applicant has adequately described the potential for a lightning hazard to the Facility.

- Adequate lightning protection systems will be installed in the Canister Transfer Building. The protection system will be designed in accordance with appropriate standard.

- The potential hazard of a lightning strike to the storage pad area has been adequately analyzed. The cask system is designed to perform its safety functions in event of a lightning strike.

- Any open space in the restricted area will be covered with crushed rock. Additionally, there will be an adequate fire barrier to protect structures, systems, and components important to safety from lightning-induced wildfires.

The applicant has adequately examined the possible frequency of lightning potential at the proposed site. The staff finds that the structures, systems, and components important to safety are designed to accommodate the effects of lightning. The Canister Transfer Building will continue to function in the event of a lightning strike and is protected from any lightning-induced wildfires by the designed fire barriers. The information on potential effects of a lightning strike at the Facility provides reasonable assurance that lightning would not cause a hazard to the Facility. Based on the foregoing evaluation, the staff finds that a lightning strike would not impair the ability of the structures, systems, and components to maintain subcriticality, confinement, and sufficient shielding of the stored fuel.

15.1.2.6 Earthquake

The staff has reviewed the information presented in the following SAR sections: Section 8.2.1, Earthquake; Section 2.6, Geology and Seismology; Section 3.2.10, Seismic Design; Section 4.2.3, Cask Storage Pads; Section 4.7.1.4.1, Seismic Support Struts; Section 4.7.1.5.1.F, Earthquake; Section 4.7.1.5.3, Structural Analysis; Section 4.7.2, Canister Transfer Cranes; and Section 4.7.5, Cask Transporter. The staff also reviewed the information in Appendix 2G of the SAR, which provided an additional seismic evaluation on co-seismic rupturing of the Stansbury and East or East/West faults.

A seismic event can occur at any time during any stage of a transfer or storage operation involving a cask or a canister. At a specific site, earthquake potential is often described by annual probability of exceeding certain ground motion levels or seismic hazard curves. Section 3.4 of the SAR classifies the structures, systems, and components important to safety into three categories: A, B, and C, based on the QA procedures. All structures, systems, and components important to safety should be able to function during a seismic event. These important to safety features of the Facility include the (i) canister (Category A), (ii) concrete storage cask (Category B), (iii) transfer cask (Category B), (iv) lifting devices (Category B), (v) Canister Transfer Building (Category B), (vi) canister transfer overhead bridge crane (Category B), (vii) canister transfer semi-gantry crane (Category B), (viii) seismic struts (Category B), and (ix) cask storage pads (Category C).

The PFS Facility design earthquake was originally described by the site-specific 84^{th}-percentile response spectrum curves anchored at a peak horizontal acceleration of 0.67g and a peak vertical acceleration of 0.69g, based on an earlier DSHA study conducted by Geomatrix Consultants, Inc. (1997). A recent detailed geological survey conducted by Geomatrix Consultants, Inc. (1999a) has identified additional faults in the vicinity of the site. After taking into account these newly discovered faults in the DSHA (Geomatrix Consultants, Inc. 1999b), the 84^{th} percentile peak horizontal acceleration and peak vertical acceleration values rose to 0.72 and 0.80g, respectively, exceeding the originally proposed design values. Subsequently, PFS proposed to use PSHA for design (Parkyn, 1999) and submitted to the NRC a request for exemption from the seismic design requirement of 10 CFR 72.102(f)(1). Based on the site-specific PSHA conducted by Geomatrix Consultants, Inc. (1999a), 2,000-year return period earthquake produces a peak horizontal acceleration of 0.53g and a peak vertical acceleration of 0.53g at the proposed PFS site. These ground motion levels are not expected to increase due to co-seismic rupturing of the Stansbury fault with East or East/West faults. The design of the Facility is based on a design response spectrum that envelops the 2,000-year return period hazard spectra. Section 2.1.6 of this SER provides additional information on the seismic ground motion hazard and the staff's review of the PFS request for exemption at the Facility.

The Canister Transfer Building provides physical protection of the canisters during transfer from the transportation cask to the storage cask. This building was analyzed using a lumped mass model (Stone & Webster Engineering Corporation, 1998a) and a three-dimensional finite element model (Stone & Webster Engineering Corporation, 1998b) using the ANSYS computer code. Results of these analyses indicated that the available design strength exceeds that required for the factored design loads. Detailed evaluation of the design of the Canister Transfer Building is given in Chapter 5 of this SER.

The overhead bridge crane, the semi-gantry crane, and the canister downloader are all single-failure-proof lifting devices, as discussed in Chapter 4 of the SAR. A 200-ton overhead bridge crane and a 150-ton semi-gantry crane will be used for loading and unloading shipping casks and transferring spent nuclear fuel canisters between the shipping and storage casks. The overhead bridge crane lifts the shipping casks from a heavy-haul trailer or rail car and places it upright into one of the transfer cells. These cranes utilize a patented hoisting safety system called X–SAM. The cranes are designed in accordance with ASME NOG–1 (American Society of Mechanical Engineers, 1989) and are single-failure-proof in accordance with NUREG–0554 (Nuclear Regulatory Commission, 1979). ASME NOG–1 provides the requirements of electrical overhead and gantry cranes with top running bridge and trolley and components of cranes used at nuclear facilities. NUREG-0554 identifies the design features, fabrication, installation, inspection, testing, and operation of the hoisting system and braking systems for trolley and bridge of a single-failure-proof overhead crane handling system. The Facility lifting devices are designed with single-failure-proof features so that any potential failure of a single component will not result in the crane losing capability to stop and hold the load (SAR Section 4.7.2.5.4). The cranes are provided with suitable restraints to prevent any uplift during an earthquake. The crane design will not allow any part to become detached and fall in a design earthquake. Additionally, the cranes will not lower the load in an uncontrolled manner during or as a result of a design earthquake. Moreover, design specification of the cranes include manual release capability to release the brakes for hoist, emergency, bridge, gantry, and trolley for controlled lowering and positioning of the load in case of an emergency (SAR Section 4.7.2.5).

Additionally, the shipping cask will be secured prior to disconnecting the crane and unbolting the lid, by attaching seismic support struts between the cask and the transfer cell building columns (SAR Section 4.7.1.4.1). The seismic support struts are designed to resist the forces generated by the PFS Facility design basis ground motion and maintain the shipping cask secured in the upright position. The HI-TRAC transfer cask can remain connected to either the overhead bridge crane or the semi-gantry crane throughout the transfer operation. Continuous connection with the crane assures that the transfer cask cannot topple under PFS Facility design basis ground motion. Seismic support struts will be attached to the transfer cask prior to disconnecting the crane to assure cask stability under PFS Facility design basis ground motion.

Cask transporters will be used to move the loaded storage cask between the canister building and the storage pad. The Technical Specifications require that the transporter be designed to limit the lifting height of a canister to a maximum of 10 in and to prevent overturning or tipover under a design basis ground motion.

The cask storage pads have been designed in accordance with ANSI/ANS-57.9–1992 (American National Standards Institute/American Nuclear Society, 1992) and ACI 349-90 (American Concrete Institute, 1990). Each pad is an independent reinforced concrete structure of dimensions 30 ft wide, 64 ft long, and 3 ft thick. Eight loaded proposed storage casks will be placed on each pad. The design of the storage pads accounts for the weight of the loaded storage casks and the design earthquake for the site. The design of the storage pads would provide an adequate safety factor against bearing failure under static and earthquake loadings. Additionally, the storage pad is not susceptible to subsurface failures associated with liquefaction (SAR Section 2.6.4.8). The staff's evaluation of the storage pads is discussed in Sections 2.1.6.3 and 5.1.3 of this SER.

The generic cask stability analysis, presented in the FSAR for the HI-STORM 100 Cask System does not bound the PFS Facility site-specific ground motion. Therefore, Holtec International (1999) carried out additional analysis to demonstrate that the HI-STORM 100 storage casks will not tip over in a PFS Facility design basis ground motion, characterized by the response curves with a zero period acceleration of 0.53 g in both horizontal directions and 0.53 g in the vertical direction. This supplemental analysis has been reviewed in Chapter 5, Installation and Structural Evaluation, of this SER. This supplemental analysis of the stability of the HI-STORM 100 storage cask considered soil-structure interaction, actual storage pad site, and a variety of cask placement configurations on the storage pad. Two bounding coefficients of friction for the cask-pad interface were analyzed: (1) coefficient of friction equal to 0.2 emphasizing sliding and (2) coefficient of friction equal to 0.8 emphasizing tipover. For the case with coefficient of friction equal to 0.2, a cask will slide less than 3 in. For the other case, the lateral motion of the cask top center point from its initial position is less than 4 in.

The staff has reviewed the information and analyses provided by PFS for potential hazards from earthquake ground motion at the Facility as discussed in Section 2.1.6.2 of this SER. The staff found that the PSHA methodology with a 2,000-year return period value used to determine the design earthquake for accident analyses to be acceptable because:

- There are sufficient regulatory and technical bases to accept the PSHA methodology for seismic design of the Facility, as detailed in Section 2.1.6, Geology and Seismology, of this SER and in Stamatakos et al. (1999)

- The PFS PSHA is based on adequate characterization of potential seismic sources, ground motion attenuation, and associated uncertainties; and the PSHA results are conservative, as detailed in Section 2.1.6, Geology and Seismology, of this SER and in Stamatakos et al. (1999).

- The design spectra were developed based on the procedures outlined in Regulatory Guide 1.165 (Nuclear Regulatory Commission, 1997) and sufficiently incorporated near-source effects, as detailed in Section 2.1.6, Geology and Seismology, of this SER and in Stamatakos et al. (1999).

- Co-seismic rupturing of the Stansbury fault with the East or East/West fault would not significantly affect the 2,000-year return period ground motion level at the proposed PFS site, as detailed in Section 2.1.6,Geology and Seismology, of this SER and in Stamatakos et al. (1999).

The staff also reviewed the information presented by the applicant on stability analyses of structures, systems, and components important to safety. The staff's evaluation is discussed in Chapter 5 of this SER. The staff found PFS's stability analyses acceptable because:

- The applicant has demonstrated that the HI-STORM 100 storage casks will not tipover or slide while stored on the concrete pads from site-specific ground motion.

- Single-failure-proof lifting devices, designed to withstand the site-specific ground motion without toppling or dropping the load, will be used in the Facility.

- Seismic support struts, designed to resist the forces generated by site-specific design basis ground motion, will secure the shipping, storage, and transfer casks during transfer operations.

PFS has adequately determined design basis earthquake events for the Facility design. The methods adopted by the PFS for evaluating the design basis ground motion are appropriate as evaluated in Section 2.1.6 of this SER. Also, as discussed in Section 2.1.6 of this SER, the regional extent of earthquakes and subsequent ground motion are identified. The applicant submitted a request for an exemption from the seismic design requirements of 10 CFR 72.102(f)(1) (Donnell, 2000) and supporting documents (Donnell, 2000). The staff found the exemption request is acceptable with a 2,000-year return period earthquake. PFS has conducted accident analyses using 2,000-year return period ground motions and demonstrated the adequacy of design of structures, systems, and components important to safety.

Based on the foregoing evaluation, the staff finds that a design earthquake event would not impair the ability of the structures, systems, and components to maintain subcriticality, confinement, and sufficient shielding of the stored fuel.

15.1.2.7 Loss of Shielding

Chapter 8 of the SAR discusses the dose consequences for the identified design basis accidents and natural phenomena events. The applicant determined that the confinement system is not adversely affected during a design basis accident. Also, no design basis accident would significantly degrade the shielding capability of the storage cask or the Canister Transfer Building. Based on the results of the accident analysis, there is reasonable assurance that the dose to any individual beyond the owner controlled area will not exceed the limits in 10 CFR 72.106(b) and occupational exposures from accident recovery will not exceed the limits in 10 CFR Part 20.

15.1.2.8 Adiabatic Heatup/Full Blockage of Air Inlets and Outlets

The HI-STORM 100 storage cask was analyzed for 100-percent blockage of the storage cask's air inlet vents. The analysis and the staff's evaluation are respectively provided in the HI-STORM 100 FSAR and the NRC's related SER. This analysis indicated that the MPC confinement boundary and fuel cladding temperatures remain below their short-term temperature limits at 72 hours into the event. Based on this result, the HI-STORM 100 Technical Specifications (Appendix A, Certificate of Compliance 1014) require a 24-hour periodic surveillance to verify that the overpack inlet and outlet ducts are free of blockage. This surveillance requirement is also in the PFS Facility Technical Specifications.

Based on these surveillance requirements, the staff finds that 100 percent vent blockage is unlikely to occur over an extended period of time and, therefore, would not impair the cask's ability to maintain subcriticality, confinement, and sufficient shielding of the stored fuel.

15.1.2.9 Tornadoes and Missiles Generated by Natural Phenomena

The staff reviewed the information presented in SAR Section 2.3.1.3.3, Tornadoes; Section 3.2.8, Tornado and Wind Loadings; Section 4.7.1.5.1.E, Tornado Winds and Missiles; and Section 8.2.2, Extreme Wind. This evaluation assumed that site personnel would not have any prior warning before the Facility structures, systems, and components are impacted by a potential design basis tornado and a tornado missile.

The State of Utah experiences on average two tornadoes each year based on National Oceanic and Atmospheric Administration data for the period 1950–1995 (http://www.ncdc.noaa.gov/ol/climate/severeweather/small/avgt5095.gif). Table 2.3-1 of the SAR lists four tornadoes during the period 1975–1995 that occurred within a 1° latitude-longitude square, approximately 3,641 sq mi, centered at the proposed site. All four tornadoes occurred in Tooele County. However, no information is available for one of these tornadoes, that was reported on September 23, 1992. Based on data for the other three tornadoes, PFS estimated the mean number of tornados per year in the square to be 0.14 with a geometric mean tornado path area of 0.035 sq mi. The estimated probability of a tornado striking anywhere in the square that includes the PFS Facility site is 1.37×10^{-6} per year or a recurrence interval of 728,200 years.

Characteristics of the design basis tornado and tornado missile are given in Section 3.2.8 of the SAR. The SAR developed the characteristics of the design basis tornado in accordance with Regulatory Guide 1.76, Design Basis Tornado for Nuclear Power Plants (Nuclear Regulatory Commission, 1974). The proposed site is located in Region III, as defined in Regulatory Guide 1.76. The characteristic of the design basis tornado for Region III is defined as a tornado with a maximum wind speed of 240 mph, a rotational speed of 190 mph, a translational speed of 50 mph, a radius of maximum rotational speed of 150 ft, and a 1.5-psi pressure drop at a rate of 0.6 psi/s.

Three design basis tornado missiles are based on Spectrum I missiles of Section 3.5.1.4, Missiles Generated by Natural Phenomena, of NUREG–0800 (Nuclear Regulatory Commission, 1981c). These missiles include an automobile with a weight of 1,800 kg (3,600 lb) (a massive kinetic energy missile that will deform on impact), an 8-in. 125-kg armor-piercing artillery shell (a rigid missile to test penetration resistance), and a 1-in. solid steel sphere (a small rigid missile of a size sufficient to pass through openings in protective barriers). It is assumed, based on Section 3.5.1.4 of NUREG–0800, that all three missiles will impact at 35 percent of the maximum horizontal wind speed of the design basis tornado, that is, at 84 mph. The first two missiles are assumed to impact at normal incidence. The last missile impinges on the barrier openings in the most damaging directions. These objects are postulated to be picked up and transported by the winds of a design basis tornado.

Important to safety structures, systems, and components that may be affected by design basis tornado missiles are (i) canister transfer facility superstructures, (ii) site transporters, and (iii) storage casks. These structures, systems, and components are required to function during this design basis event.

The HI-STORM 100 storage cask is designed to withstand a 360 mph tornado with a 3.0 psi pressure drop, and a 1800 kg lb tornado-generated missile with a velocity of 126 mph. These

parameters bound the PFS Facility design basis tornado. The tornado analysis for the HI-STORM 100 and the staff's evaluation are respectively provided in the HI-STORM 100 FSAR and the NRC's related SER. This analysis demonstrated that the HI-STORM 100 cask can withstand a design basis tornado and tornado missile impact without penetration, permanent deformation, or tipover.

The structure of the Canister Transfer Building is expected to function during an extreme wind event. Tornado wind with associated pressure drop is considered to act simultaneously. The tornado wind speed converted to wind pressure following ASCE 7-95 (American Society of Civil Engineers, 1996). This methodology is acceptable to the staff. The structure will be designed to protect all structures, systems, and components within the building by withstanding the tornado wind and associated pressure drop by means of its static strength without requiring any venting (SAR Section 4.7.1.5.1). The Canister Transfer Building walls and superstructure are designed to structurally withstand both horizontal and vertical components of the impact of the spectrum of tornado missiles. The transfer facility superstructure provides tornado missile protection for the entire transfer facility through reinforced concrete walls and roof. Components of this building will be of sufficient strength and size to resist the missile impact without compromising the strength and stability of the structure and to prevent penetration of the missile and associated spalling of concrete interior to the point of impact. The layout of the building (SAR Figure 4.7-8) and specially designed labyrinths will prevent tornado missiles from entering through the doors or ventilation openings in the walls and roof, and impacting the fuel canisters, single-failure-proof cranes and their supports, and any other structures, systems, and components in the building (SAR Section 4.7.1.5.1).

The applicant's discussion of the design of cask transporters in Section 4.7.5 of the SAR does not discuss resistance to overturning on impact by a design basis tornado missile. Cask transporters are commercially available equipment and are not considered to be part of the cask system or ISFSI design. The Technical Specifications require the licensee to use cask transporters that are designed to preclude tipover if impacted by a design basis tornado-driven missile.

The staff reviewed the information provided by the applicant and evaluated the analyses of potential hazards from design basis tornadoes and tornado missiles at the Facility. The staff found it acceptable because:

- The frequency and characteristics of tornadoes and tornado missiles for the proposed site have been adequately assessed.

- Acceptable methodologies have been used to characterize the design basis tornadoes and tornado missiles for the proposed site.

- Structures, systems, and components important to safety that may be affected by the design basis tornados and tornado missiles have been identified.

- The storage cask and Canister Transfer Building are adequately designed to withstand postulated tornado wind loads and loads imparted by the postulated tornado missiles.

- The Technical Specifications require the licensee to use cask transporters that are designed to preclude tipover if impacted by a design basis tornado-driven missile.

The information presented in the SAR demonstrates that appropriate methodologies have been adopted to investigate the potential tornado severity and frequency at the proposed site along with the associated missile hazards. PFS has identified the severity of hazards associated with a design basis tornado for the proposed site and incorporated it into the design of the Canister Transfer Building using appropriate design loads and layout of the building. The design of the Canister Transfer Building has adequately considered the appropriate design basis tornado loadings and the associated hazards so that the important to safety structures, systems, and components in the building will be protected. The information presented is sufficient to conclude that the design of the Canister Transfer Building is adequate to withstand the design basis tornado loadings and the associated tornado missiles so that the important to structures, systems, and components will be protected.

Based on the foregoing evaluation, the staff finds that a tornado or tornado-generated missile would not impair the ability of the structures, systems, and components to maintain subcriticality, confinement, and sufficient shielding of the stored fuel.

15.1.2.10 Accidents at Nearby Sites - Offsite Explosion Hazards

The staff reviewed the information presented in SAR Section 2.2, Nearby Industrial, Transportation, and Military Facilities. Supplemental information presented by Brunsdon (1999), Bureau of Indian Affairs (1975), and Davis (1999) was also used in this review. An explosion is classified as a human-induced Design Event IV following ANSI/ANS 57.9–1992 (American National Standards Institute/American Nuclear Society, 1992). ANSI/ANS 57.9–1992, which gives the design criteria for an ISFSI, defines Design Event IV as “events that are postulated because their consequences may result in the maximum potential impact on the immediate environs.” This accident event involves an offsite or onsite explosion that may damage important to safety structures, systems, and components of the Facility, namely the casks and the transfer facility superstructure. The effects produced by an explosion may be an incident or reflected overpressure, blast-induced ground motion, or blast-generated missiles. The onsite explosion hazard has been evaluated in Section 15.1.2.4, Fire and Explosion, of this SER.

The potential scenarios at the Facility that can result from an offsite explosion include:

- an accident at the Tekoi Rocket Engine Test Facility,
- an accidental explosion of a rocket engine on the access road to the Tekoi Rocket Engine Test Facility or on Skull Valley Road,
- an accident at the Dugway Proving Ground or the Tooele Army Depot, and
- a transportation accident involving a trailer or rail car shipping explosives on a nearby transportation route.

Accidental Explosion at Tekoi Rocket Engine Test Facility

Note: The Tekoi Rocket Engine Test Facility does not currently have a lessee and is not presently in operation. However, the Tekoi facility was in operation when the staff initiated its review of the PFS Facility application. Therefore, the potential impact of the operations at the Tekoi facility is considered in this SER. The information below is based on the actual usage of the facility by the last lessee, Alliant Techsystems, Inc.

The Tekoi Rocket Engine Test Facility was leased by Alliant Techsystems Inc. and was located approximately 2.5 miles south-southeast of the Facility on the Reservation of the Skull Valley Band of Goshute Indians (SAR Section 8.2.4.1). This test facility was used periodically for experimenting with high explosives and to test rocket engines mounted on stationary bases in the static test range. Hickman Knolls, a rock formation with an elevation of approximately 4,800 ft above mean sea level, lies directly between the PFS Facility (approximate elevation 4,465 ft above mean sea level) and the Tekoi test facility (elevation approximately 4,600 ft above mean sea level). Hickman Knolls is approximately 200 ft taller than the Tekoi test facility and approximately 335 ft higher in elevation than the PFS Facility site.

The Tekoi Rocket Engine Test Facility had two operational areas: (i) high hazard explosive test area and (ii) static test range. The high hazard explosive test area had an explosive limit of 200 lb of Class 1.1 explosives and was used to test all classes of explosives (SAR Section 8.2.4.1). Class 1.1 includes bulk explosives and some propellants with mass explosion hazard, based on the U.S. Department of Defense (DOD) Contractors' Safety Manual for Ammunition and Explosives (DOD 4145.26-M) (U.S. Department of Defense, 1997). The static test range had three bays. Bay 3 of the static test range had the highest explosive limit of 1,200,000 lb of Class 1.1 propellants (SAR Section 8.2.4.1). Additionally, the facility was equipped for testing a Space Shuttle Rocket Motor (solid rocket boosters), which contains 1,100,000 lb of propellant (http://www.ksc.nasa.gov/shuttle/technology/sts-newsref/srb.html). Therefore, 1,200,000 lb of propellant would bound the Space Shuttle rocket motors.

PFS (SAR Section 8.2.4.2) estimates that an air overpressure of 1 psi would be developed at a distance of 4,782 ft (0.91 mile) from an explosion of 1.2 million pounds of explosive. The overpressure would be less at greater distances from the Tekoi facility. Alliant Techsystems Inc., had established a buffer zone of 1.5 miles from the Tekoi Test facility (Brunsdon, 1999).

Regulatory Guide 1.91 (Nuclear Regulatory Commission, 1978) recommends a safe distance R in ft from an explosion of W lb of TNT at which conservatively selected 1 psi overpressure would develop. According to Regulatory Guide 1.91, an overpressure level of 1 psi is conservative for structures, systems, and components of concern. The recommended equation is:

$$R \geq 45\, W^{\frac{1}{3}} \qquad (15\text{-}1)$$

Based on this equation, 1,200,000 lb of TNT will produce an overpressure of 1 psi at a distance of 4,782 ft (0.91 mi) and 10,000,000 lb of TNT (maximum quantity of explosive that can be transported on a river vessel and by any transportation mode) will produce 1 psi overpressure at a distance of 9,898 ft (1.8 mi). Further assuming that the propellants will behave like an

explosion of confined vapor clouds, which is not credible, *W* is increased by 240 percent, in accordance with Regulatory Guide 1.91. The minimum distance of separation necessary for this accident scenario, estimated from Eq. (15-1), is 1.2 mi.

Because the restricted area of the PFS Facility is over 12,000 ft (2.3 mi) from the Tekoi test facility, the estimated air overpressure at the PFS Facility would be less than 1 psi. It is extremely unlikely that any structures, systems, and components important to safety will sustain any damage from air overpressure from explosive and rocket engine testing. Table 3.6-1 of the SAR states that the Canister Transfer Building is designed to withstand an air overpressure of at least 1 psi. The HI-STORM 100 storage cask is designed to withstand a explosion overpressure of 5 psi. Moreover, it is expected that the actual overpressure at the PFS Facility site would be substantially less than that predicted using the previous equation due to the natural terrain, in that Hickman Knolls will significantly deflect and disperse the air overpressure.

The previous analysis does not consider any enhancement of air overpressure due to possible temperature inversion at the proposed site. The PFS Facility site will experience temperature inversion approximately 50 percent of total hours during winter and fall. Inversion frequency decreases to approximately 35 to 40 percent during summer and spring (SAR Section 2.3.1.3.9). If an inversion exists, an increase in noise level by a factor of 2 to 3 is not uncommon (E.I. du Pont de Nemours & Company, Inc., 1977).

The SAR did not consider any inversion effects to estimate an air overpressure that may be damaging to any structures, systems, and components important to safety. However, the staff performed an independent calculation to verify the PFS analysis. Equation (15-1) cannot be used, however, to predict the air overpressure at a given distance from a given amount of explosive. To estimate the effect of temperature inversion on possible air overpressure, the staff used an equation given in E.I. du Pont de Nemours & Company, Inc. (1977):

$$P = 82\left(\frac{R}{W^{\frac{1}{3}}}\right)^{-1.2} \qquad (15\text{-}2)$$

where *P* = air overpressure. For an air overpressure of 1 psi, Eq. (15-2) gives

$$R = 39.3\ W^{\frac{1}{3}} \qquad (15\text{-}3)$$

which is approximately 15 percent less than Eq. (15-1).

Assuming *W* equal to 1,200,000 lb and *R* equal to 12,144 ft (2.3 mi), estimated air overpressure with a temperature inversion increase factor of 3 is 0.83 psi. The difference between Eq. (15-2) and Eq. (15-1) has been taken into account by increasing the calculated air overpressure using Eq. (15-2) by 15 percent. The adjusted estimated air overpressure becomes 0.95 psi. It should be noted that the estimated air overpressure is conservative. It is unlikely that an explosion with the maximum amount of propellant will take place when the worst temperature inversion

conditions exist, which will focus the blast energy to the PFS Facility site. Moreover, the structures, systems, and components important to safety are designed to withstand this pressure differential. Therefore, there is reasonable assurance that an explosion with the maximum amount of propellant at the Tekoi Rocket Engine Test Facility under the worst atmospheric conditions will not pose a hazard to the PFS Facility.

In May 1974, a partially fired rocket motor containing 12,000 lb of propellant exploded in place while being tested at the Bacchus Works (Davis, 1999; Brunsdon, 1999; Bureau of Indian Affairs, 1975). The motor did not escape the test pod; however, 90 percent of all test stand hardware, motor fragments, and facility debris were projected up to 6,000 ft from the pad. The Bureau of Indian Affairs (1975) stated, “a rocket engine is capable of exploding only when an ignition device is installed.” The Trident First Stage rocket contains approximately 44,000 lb of the same propellant. Assuming no consumption of propellant before explosion, the Bureau of Indian Affairs (1975) stated, “90 percent of all fragments would fall within 7,400 ft and 96 percent of all fragments would fall within 7,920 ft (1.5 mi).” This calculation was performed using documentation from “General Safety Engineering Design Criteria, Chemical Rocket Propellant Hazards, Chemical Propulsion Information Agency (CPIA) Publication No. 194, October 1971.” CPIA Publication No. 194 provides general guidance, safety criteria, procedures, instructions, precautions, and other related guidelines for minimizing hazards associated with the handling, storage, transportation, and use of liquid and solid propellants. As the PFS Facility is at least 1.9 miles from the Skull Valley Road, there is reasonable assurance that flying objects from an explosion during transport of a Trident rocket engine containing 44,000 lb of propellants will not pose a hazard to the PFS Facility.

Another postulated accident scenario is that a rocket motor may potentially escape from a test stand and hit structures, systems, and components important to safety at the PFS Facility. The Tekoi test facility was designed to prevent rocket motors from escaping the test bay during testing (Brunsdon, 1999; Davis, 1999; Bureau of Indian Affairs, 1975). The rocket motors were restrained to the test stand. The steel restraining members would retain large fragments in an explosion of the rocket motor (Brunsdon, 1999). The thrust block absorbs the forward thrust of the rocket motor being tested, and instruments measure the thrust produced by the motor.

Static testing of the rocket motors was generally conducted in a horizontal configuration. Occasionally, motors were tested vertically with the nozzle upward. Motors tested horizontally in Bays 2 and 3 had their nozzles pointed in the west and southeast directions, respectively (Davis, 1999). If a rocket motor comes loose from the thrust block and attachment points, it would normally strike the test stand structure, causing motor case rupture. This process renders the motor incapable of flight and reduces the possibility of a motor escaping the stand. Some test stands incorporated special devices that would rupture the motor in case of a restraint system failure (Davis, 1999).

Safety procedures had been adopted at the Tekoi test facility to minimize the potential for a motor failure during static testing (Davis, 1999; Brunsdon, 1999; Bureau of Indian Affairs, 1975). Every motor was x-rayed, its manufacturing and inspection records were reviewed, and any deviation from the motor design specifications was evaluated. Only motors expected to perform successfully were tested at the Tekoi test facility.

No rocket motor has ever escaped from the test stands at the Tekoi test facility. However, one rocket motor escaped from the harness at the Bacchus Works facility in Magna, Utah, in the

early 1960s before installation of modern safety features (Brunsdon, 1999; Bureau of Indian Affairs, 1975). The Bacchus Works facility was used prior to transferring the operations to the Tekoi test facility in 1975 (Bureau of Indian Affairs, 1975).

In the unlikely event of a motor escaping the test bay, there would be significantly less than a 2.6 percent chance of striking the PFS Facility assuming uniform probability in any direction, and ignoring distance considerations. Further, Hickman Knolls will reduce the likelihood of an escaping motor or any flying debris impacting the PFS Facility site because of the higher elevations of the Hickman Knolls. Moreover, as the rockets were tested in directions away from the PFS Facility site, it is unlikely that a rocket motor would fly toward the PFS Facility. Therefore, there is reasonable assurance that an escaping rocket motor from the Tekoi test facility will not pose any hazard to the PFS Facility site.

Accidental Explosion of a Rocket Engine in Transit

A hypothetical rocket engine explosion may take place on the access road to the Tekoi test facility or on Skull Valley Road. The access road runs due east from the test facility and intersects Skull Valley Road. At its closest point, the access road is 2.0 miles (10,560 ft) away from the PFS Facility restricted area. Similarly, Skull Valley Road is at least 1.9 miles (10,000 ft) from the PFS Facility site (Brunsdon, 1999; Private Fuel Storage Limited Liability Company, 2000a). Therefore, an accidental explosion of the largest rocket motor tested at the Tekoi test facility (1,200,000 lb of propellants) on Skull Valley Road or the access road would produce an air overpressure less than 1 psi. Consequently, there is reasonable assurance that an accidental explosion of a rocket motor during transit through Skull Valley and the access roads to the Tekoi test facility will not pose a hazard to the PFS Facility.

Accidental Explosion at Dugway Proving Ground and Tooele Army Depot

The northern perimeter of the Dugway Proving Ground is approximately 9 miles from the PFS Facility. The Tooele Army Depot is approximately 17–22 miles from the PFS Facility. Additionally, the Dugway Proving Ground has a mean elevation of 4,350 ft and is surrounded on three sides by mountain ranges. The Cedar Mountains, with an elevation of at least 5,300 ft above mean sea level lie between the Dugway Proving Ground and the Facility. The Stansbury Mountains, with an elevation of approximately 8,000 ft above mean sea level, lie between the Tooele Army Depot and the Facility. Consequently, the Dugway Proving Ground and the Tooele Army Depot present no explosion hazard to the Facility due to the large distances from the proposed site and intervening mountain ranges.

Accidental Explosion at a Nearby Transit Route

The Dugway Proving Ground receives and ships conventional army weapons approximately 95 times in a year (SAR Section 2.2). Some of these shipments could travel on the Skull Valley Road. This road presents the only potential for an explosion occurring in transportation near the Facility. This scenario would be in association with transportation of explosives with no obstacles intervening between the road and the Facility. The Skull Valley Road runs north-south through the Skull Valley Indian Reservation east of the Facility and provides entrance to the site access road. The road is 1.9 miles from the Canister Transfer Building and 2.0 miles from the nearest storage pads. As discussed previously, it requires more than

10,000,000 lb of TNT detonating simultaneously to create an air overpressure of 1 psi. Therefore, transport of conventional army weapons through Skull Valley Road does not pose a hazard to the Facility.

Summary of Review of Offsite Explosion Hazards

The staff reviewed the information provided by the applicant and evaluated the applicant's analyses of potential hazards from offsite explosions at the PFS Facility site. The staff found it acceptable because:

- The Tekoi Rocket Engine Test Facility is no longer in operation, and in any event the Tekoi facility was adequately described with adequate information about its distance from the Facility. Design and safety procedures adopted at the Tekoi test facility were sufficiently described.

- Surface topography between the Tekoi test facility and the PFS Facility that directly affects the air overpressure and potential for debris in case of an accidental explosion of a rocket engine being tested were sufficiently investigated and assessed.

- Historical data on rocket motor explosion was adequately described, and any potential impact on the Facility was sufficiently assessed.

- Potential effects of a rocket explosion or explosion of army weapons while in transit through Skull Valley were sufficiently described and assessed.

- Information on natural topography and the distance between the Facility and Dugway Proving Ground or Tooele Army Depots were adequately described. Potential effects of accidental explosions at either site were adequately described and assessed.

- Information on potential temperature inversion near the Facility has been presented in the SAR. While the applicant did not consider it in estimating the air overpressure from any potential explosion, the staff's independent analysis using established methodology provides reasonable assurance that, even in the worst-case scenario, the potential effects will not produce a hazard to the Facility.

The applicant has examined, collected, and evaluated information of potential offsite explosions at the Tekoi Rocket Engine Test Facility, Dugway Proving Ground, Tooele Army Depot, and accidental explosion while transporting conventional army weapons and Trident rockets through Skull Valley Road. The applicant used acceptable methods to evaluate the potential explosions at these nearby facilities. Evaluation of the potential effects show that offsite explosions will not pose a hazard to the Facility.

Based on the foregoing evaluation, the staff finds that potential offsite explosions at nearby facilities would not impair the ability of the structures, systems, and components to maintain subcriticality, confinement, and sufficient shielding of the stored fuel.

15.1.2.11 Accidents at Nearby Sites - Aircraft Crash Hazards

The staff has reviewed the information presented in SAR Section 2.2 (Private Storage Limited Liability Company, 2000a) and the report, Aircraft Crash Impact Hazard at the Private Fuel Storage Facility (Private Fuel Storage Limited Liability Company, 2000b). The staff review also included a crash hazard analysis for the X-33, a suborbital demonstrator vehicle. The purpose of this review is to ensure that the risk to the Facility due to aircraft hazards has been appropriately estimated and is acceptable.

The staff reviewed the aircraft crash hazard analysis in accordance with NUREG–0800, Section 3.5.1.6, Aircraft Hazards (Nuclear Regulatory Commission, 1981a). The staff accepts the methodology in NUREG-0800, as applicable, for reviewing the aircraft crash probability for the Facility site. Acceptance criterion no.1 of NUREG–0800, Section 3.5.1.6, Aircraft Hazards provides three screening criteria that have to be satisfied to conclude, by inspection, that the aircraft hazards are less than 10^{-7} per year for accidents that could result in radiological consequences greater than 10 CFR Part 100 exposure guidelines. The staff's review indicates that the Facility site does not satisfy screening criterion 1(b) which states, "The plant is at least 5 statute miles from the edge of military training routes, including low-level training routes, except for those associated with a usage greater than 1,000 flights per year, or where activities (such as practice bombing) may create an unusual stress situation." The number of flights to the Utah Test and Training Range (UTTR) transiting Skull Valley was 3,871 in 1998. Therefore, screening criterion 1(b) is exceeded. According to NUREG–0800 review guidance, a detailed review is therefore needed to assess the aircraft crash hazards to the site .

Estimating the total probability of an aircraft crash onto the Facility site requires an evaluation of crash probabilities due to several sources:

- aircraft taking off and landing at Salt Lake City International Airport
- aircraft flying high altitude jet route J-56 (commercial airway)
- aircraft flying low altitude route Victor 257 (commercial airway)
- aircraft taking off and landing at other municipal airports located close to the site
- general aviation aircraft flying in the vicinity of the Private Fuel Storage Facility site
- aircraft taking off and landing at Michael Army Airfield at Dugway Proving Ground
- aircraft flying military airway IR-420
- military aircraft from Hill Air Force Base flying to and from the UTTR
    - aircraft transiting Skull Valley en route to the UTTR South Area

- aircraft conducting training in the restricted air space on the UTTR South Area

- aircraft departing the UTTR via the Moser Recovery en route to Hill Air Force Base

• military helicopters flying near the Private Fuel Storage Facility site

• jettisoned ordnance

• X-33 suborbital demonstrator vehicle

Aircraft Taking Off and Landing at Salt Lake City International Airport

Salt Lake City International Airport (SLCIA) is about 50 statute miles northeast of the Private Fuel Storage Facility site (Cole, 1999a). The North-South alignment of the runways at SLCIA places the Facility away from the takeoff and landing segments of flights departing from and arriving at SLCIA. In 1998, a total of about 365,000 takeoffs and landings took place at SLCIA (Cole, 1999a,b). The web site of the Federal Aviation Administration (FAA) (http://www.faa.gov/ats/asc/Airport_Data/SLC_Data.html) indicates that the number of operations (that is, number of take offs and landings) was 385,000 in fiscal year (FY) 1997. The FAA web site further indicates that the number of operations (that is, number of take offs and landings) will increase from 385,000 in FY1997 by a factor of 43.4 percent in FY2021 to 552,000. According to screening criterion 1(a) of Section 3.5.1.6 of NUREG–0800 (Nuclear Regulatory Commission, 1981a), an airport located a distance D of more than 10 miles from a site presents an acceptably low risk if the annual number of operations at the airport is less than $1{,}000 \times D^2$. Prassinos and Kimura (1998) also specify this criterion. The above current and projected annual number of airport operations for SLCIA are well below the $1000 \times D^2$ criterion. The SLCIA produces a probability of aircraft crash to the Private Fuel Storage Facility site significantly smaller than 10^{-7} because the annual number of operations is significantly less than $1{,}000 \times D^2$ or 2,500,000 (Nuclear Regulatory Commission, 1981a). Additionally, the number of takeoffs and landings at Salt Lake City International Airport would have to increase by more than 650 percent to exceed the NUREG-0800, Section 3.5.1.6 acceptance criterion.

An aircraft may be in the ascending or descending mode significantly far away from the runway. However, historical data on crash locations suggest that the crash probability of an aircraft during landing or take off from an airport becomes negligible more than 10 miles from the end of the runway (Nuclear Regulatory Commission, 1981a).

The staff reviewed the information and PFS analysis with respect to the potential hazard of aircraft taking off and landing at Salt Lake City International Airport. The staff found the hazards acceptable because:

• Adequate information has been presented to describe the potential hazard.

• Acceptable methodology has been used to screen the potential hazard.

• Other acceptable methodology corroborates the conclusions.

- An appropriate air traffic growth factor suggested by the FAA has been taken into account to estimate the effects of future traffic growth at Salt Lake City International Airport.

- The acceptance criteria of NUREG-0800 Section 3.5.1.6 are met with respect to current and projected airport operations.

Based on the above information, the staff has concluded that aircraft taking off and landing at Salt Lake City International Airport would not pose any undue hazard to the Facility.

Aircraft Flying High Altitude Jet Route J-56

A high altitude jet route J-56 passes 11.5 statute miles north of the Private Fuel Storage Facility site. It has a maximum en route altitude of 33,000 ft above mean sea level with traffic consisting of commercial airlines and private business jets. Although J-56 does not have a specified width assigned to it, it is reasonable to assume a width of 8 nautical miles (9.2 statute miles) given the practice followed by the pilots (Cole, 1999a). Fewer than 12 aircraft use the J-56 route each day (Private Fuel Storage Limited Liability Company, 2000b).

The probability of an aircraft flying J-56 crashing onto the Private Fuel Storage Facility site has been calculated in Private Fuel Storage Limited Liability Company (2000b) following methodology presented in NUREG–0800, Section 3.5.1.6, Aircraft Hazards (Nuclear Regulatory Commission, 1981a). The width of the airway plus twice the distance from the airway edge to the site, W, is 23 statute miles (the site is outside the airway). The effective site crash area has been calculated as the sum of the effective fly-in area A_f, including the footprint area and the shadow area, and effective skid area A_s. These effective areas were calculated using formulas given in DOE Standard DOE–STD–3014–96 (U.S. Department of Energy, 1996). The DOE Standard for estimating the effective target area is within the NRC guidelines given in NUREG-0800, Section 3.5.1.6, Aircraft Hazards. Taking into consideration both the cask storage area and the Canister Transfer Building, the effective area of the Facility for commercial aviation is estimated to be 0.26 mi^2 (Private Fuel Storage Limited Liability Company, 2000b). Using C, the in-flight crash rate, equal to 4×10^{-10} crashes/aircraft/mile, following NUREG–0800 (Nuclear Regulatory Commission, 1981a), the probability of an aircraft flying J-56 crashing onto the Private Fuel Storage Facility site is about 1.9×10^{-8} per year.

The staff reviewed the information and analysis presented by the applicant with respect to potential hazards of aircraft flying the Jet Route J-56. The staff found them acceptable because:

- Adequate information has been presented to describe the potential hazards.

- Acceptable methodologies have been used to estimate the potential crash probability at the Facility.

Based on the presented information, there is reasonable assurance that the aircraft flying the Jet Route J-56 would not pose a hazard to the Facility.

Aircraft Flying Low Altitude Route Victor 257 (V-257)

A low altitude route Victor 257 (V-257) passes 19.5 statute miles east of the Private Fuel Storage Facility. It has a minimum en route altitude of 12,300 ft above mean sea level and runs north-south. V-257 has a width of 13.8 statute miles. Consequently, the Private Fuel Storage Facility site is 12.6 statute miles from the edge of V-257 airway with *W* equal to about 39 statute miles. Fewer than 12 aircraft use V-257 per day. The effective area and in-flight crash rate *C* are the same as used in the J-56 route analysis. The probability of an aircraft flying V-257 and crashing onto the Private Fuel Storage Facility site is estimated to be about 1.2×10^{-8} per year on the basis of the methodology presented in NUREG–0800 (Nuclear Regulatory Commission, 1981a).

The staff reviewed the information and analysis presented by the applicant with respect to potential hazards of aircraft flying the Victor Route V-257. The staff found them acceptable because:

- Adequate information has been presented to describe the potential hazards.

- Acceptable methodologies have been used to estimate the potential crash probability at the Facility.

Based on the presented information, there is reasonable assurance that aircraft flying Route V-257 would not pose a hazard to the Facility.

Aircraft Taking off and Landing at Other Municipal Airports Located Close to the Site

There are several smaller municipal airports in the vicinity of the Private Fuel Storage Facility site; however, all airports are beyond 5 statute miles of the site. Provo Municipal Airport is located 55 statute miles east-southeast of the Facility. Its main runway also places takeoff and landing traffic away from the Private Fuel Storage Facility site. General aviation aircraft can take off and land at Salt Lake City International Airport, Tooele Airport (26 statute miles east-northeast of the Facility), Bolinder/Tooele Valley Airport (27 statute miles northeast of the Facility), Cedar Valley Airport (40 statute miles east of the Facility), and Salt Lake City No. 2 Airport (45 statute miles east-northeast of the Facility) (Cole, 1999a). On the basis of the criteria of Section 3.5.1.6 of NUREG–0800 (Nuclear Regulatory Commission, 1981a), the probability of crash is significantly less than 10^{-7} crash per year from aircraft flying into or out of these airports and need not be considered further.

General Aviation Aircraft Flying in the Vicinity of the Private Fuel Storage Facility Site

The Private Fuel Storage Facility site is located in the Sevier B Military Operating Area (MOA), which is adjacent to the airspace of restricted areas R6406 and R6402. Civilian aircraft are prohibited from flying through the restricted air space. Despite the restrictions, some general aviation aircraft occasionally may transit the MOA; however, the U.S. Air Force does not keep records of civilian general aviation aircraft flying around the UTTR (Cole, 1999a).

Because the U.S. Air Force does not record the traffic of general aviation aircraft around the UTTR (Cole, 1999a), it is difficult to estimate the probability of a crash of such aircraft onto the

Private Fuel Storage Facility site following NUREG-0800 methodology (Nuclear Regulatory Commission, 1981a). Hence, PFS estimated the crash probability on the basis of data derived from United States national aviation statistics.

FAA reported 412 fatal crashes of general aviation aircraft in the United States in 1995 (Private Fuel Storage Limited Liability Company, 2000b). FAA data indicate that 15 percent of all general aviation fatal accidents in 1995 occurred in cruise mode of flight. Therefore, PFS has multiplied the national average crash probability by 15 percent to estimate the cruise mode crash rate. To take into account the relatively low General Aviation traffic density in Utah, a further adjustment was made by considering the number of General Aviation aircraft in the state versus the total for the United States. On the basis of the Aviation and Aerospace Almanac, the State of Utah had 1,218 general aviation aircraft in 1995 compared to 182,600 aircraft in the United States (Private Fuel Storage Limited Liability Company, 2000b). Hence, the reduction factor due to lower traffic density is 1,218/182,600, or about 0.0066. In addition, the General Aviation crash rate was adjusted to exclude business jets, which have been accounted for in the crash probability estimates for the designated airways, such as J-56 or V-257. Since business jets account for about 7.85 percent of all General Aviation fatal accidents, their exclusion represents a reduction factor of (1.00 − 0.0785), or about 0.92. Finally, an adjustment was made to account for the tornado missile protection provided in the design of the Facility. This design feature excludes about 55 percent of the General Aviation aircraft crashes from consideration, because these aircraft would result in less momentum and kinetic energy at impact than a design basis tornado missile, for which Facility has sufficient protection[1]. The reduction factor for excluding the lighter aircraft is (1.00 - 0.55), or 0.45. With the above adjustments, the state-wide crash probability density has been estimated to be about 2.0×10^{-6} per yr/mi^2.

PFS (Private Fuel Storage Limited Liability Company, 2000b) has estimated the effective area of the Facility by combining the effective areas of both the Canister Transfer Building and the cask storage pad area. The effective area was estimated to be 0.1173 mi^2. Therefore, the probability of a general aviation aircraft crash onto the Facility is $2.0 \times 10^{-6} \times 0.1173$, or 2.36×10^{-7} per year.

The inherent assumption of this approach is that the probability of a crash is uniform over the State of Utah. It is quite likely that major populated areas, such as Salt Lake City, Ogden, or

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[1]The spent fuel canister will always be inside the storage or shipping cask inside the Canister Transfer Building except during the canister transfer operation. The canister will be inside a transfer cask during the transfer operation. The transfer operation will take about 3.4 hr per canister (Private Fuel Storage Limited Liability Company, 2000a). As PFS will receive approximately 200 canisters in each year, spent fuel would be inside the transfer cask for a period of 680 hr per year or about 8 percent of the time (Private Fuel Storage Limited Liability Company, 2000b). As the estimated effective area of the Canister Transfer Building is about 10 percent of the cask storage area, the annual probability that the Canister Transfer Building would be hit by a general aviation aircraft during a canister transfer operation is about 2×10^{-9}. Additionally, the canister transfer operation will take place only in a small part of the building. The overhead bridge crane and the semi-gantry crane are of robust construction and designed to withstand a design-basis ground motion. Therefore, any adjustment to the estimated vulnerability will be significantly small and PFS did not adjust the probability.

Provo, will have significantly higher concentration of general aviation aircraft traffic than sparsely populated areas such as Skull Valley. Moreover, the proposed site is within the Sevier B Military Operating Area (MOA). Generally, pilots flying general aviation aircraft will tend to avoid a MOA because they have to obtain clearances to fly through it. The expectation of a low General Aviation traffic density is supported further by personal observation and experience of Col. Ronald Fly and Lt. Col. Dan Phillips, who have flight experience in the vicinity of the proposed PSF Facility and who stated they never had any indication of such aircraft in Skull Valley (Private Fuel Storage Limited Liability Company, 2000b). Therefore, the staff concludes that PFS has analyzed the potential risk of a general aviation aircraft crashing on the proposed site conservatively.

The staff reviewed the data and analyses presented by PFS with respect to crash potential of general aviation aircraft onto the Facility. The staff found them acceptable because:

- PFS made a reasonable estimate of the General Aviation crash probability using available national crash data which were adjusted for conditions reflecting local and regional air traffic conditions.

- PFS took into account the effect of the Facility's design-basis tornado missile protection on the risk of an on-site aircraft crash.

- State-wide crash probability is biased by areas with a large number of general aviation aircraft. The proposed site, however is located within a MOA and is only 2 miles from a restricted air space. Also, it is located at a distance from major population areas that may have higher densities of general aviation aircraft operations. Consequently, the number of general aviation aircraft flying through the area will be significantly reduced.

- PFS used the methodology of the DOE Standard (Department of Energy, 1996) to estimate the effective area of the Facility.

Based on the presented information and analysis, there is reasonable assurance that the general aviation aircraft would not pose a hazard to the Facility

Aircraft Taking Off and Landing at Michael Army Airfield at Dugway Proving Ground

The Facility is located 17.25 statute miles from the Michael Army Airfield runway at Dugway Proving Ground. The approach toward the Facility is located nearly at right angles from the direction of the runway. This orientation puts the Facility in a low risk quadrant, since aircraft crashes associated with airport landings and takeoffs occur predominantly along or near the direction of the runway.

As indicated above in the discussion of the SLCIA aircraft crash probabilities, NUREG-0800, Section 3.5.1.6, Aircraft Hazards (Nuclear Regulatory Commission, 1981a) specifies that an airport located a distance D of more than 10 miles from a site presents an acceptably low risk if the annual number of operations at the airport is less than $1{,}000 \times D^2$. For a distance of 17.25 miles, this proximity criterion results in a threshold number of operations of at least 289,000 per year to have a crash probability larger than 10^{-7} per year. The U.S. Army has indicated,

however, that only a total of approximately 414 flights per year occur along IR-420 to and from Michael Army Airfield (Private Fuel Storage Limited Liability Company, 2000b).

The staff reviewed the information presented with respect to potential hazards of aircraft landing and taking off at Michael Army Airfield. The staff found the information acceptable because:

- NUREG-0800 (Nuclear Regulatory Commission, 1981a) methodology and criteria were used in determining that the aircraft hazards due to Michael Army Airfield operations could be screened out on the basis of airfield proximity and the number of operations per year.

- Information from the DOE Standard DOE-STD-3014-96 (Department of Energy, 1996), and Kimura et al. (1996), was used as additional indication that landing and taking off from Michael Army Airfield will not pose a hazard to the Facility. The DOE Standard and Kimura et al. (1996) for estimating the crash probabilities of aircraft landing and taking off from an airfield are within the NRC guidelines given in NUREG-0800, Section 3.5.1.6, Aircraft Hazards.

Based on the information discussed above, there is reasonable assurance that Michael Army Airfield would not pose a hazard to the Facility. The crash probability from military aircraft using the Michael Army Air Field will be significantly less than 10^{-7} crashes/year, and its contribution to the cumulative overall crash probability can be neglected.

Aircraft Flying Military Airway IR-420

Military Airway IR-420 runs northeast to southwest over the Private Fuel Storage Facility site to Michael Army Airfield on Dugway Proving Ground. It is 11.5 statute miles (10 nautical miles) wide. Large transport aircraft (e.g., C-5s, C-141s, C-17s) fly to and from Michael Army Airfield using this airway. The airspace over Dugway Proving Ground is a restricted airspace, and the flow of traffic is radar controlled either by Salt Lake City Air Traffic Control Center or Clover Control (Private Fuel Storage Limited Liability Company, 2000b).

PFS has indicated that large transport aircraft flying to Michael Army Airfield include C-5, C-17, C-141, and KC-10 (Private Fuel Limited Liability Company, 2000b). These large multi-engine cargo aircraft are similar to commercial airliners. PFS has concluded that data for crashes with destroyed military cargo aircraft compare “very favorably” to civilian commercial aircraft.

PFS analyzed U.S. Air Force accident reports for mishaps involving C-5, KC-10, C-17, and C-141 aircraft during FY1989 through FY1998. PFS concluded that none of the destroyed aircraft mishaps took place under circumstances representative of flying in airway IR-420 (Private Fuel Limited Liability Company, 2000b). Some of the factors involved in the cause of these crashes included an air refueling operation, an on-ground (parked aircraft) destruction by another aircraft, and a foreign site with lack of radar coverage or flight control services. Hence, according to Maj. Gen. Wayne O. Jefferson, USAF (Ret.), a former B-52 wing commander, none of the destroyed aircraft were destroyed under conditions that would be associated with IR-420 flights (Private Fuel Storage Limited Liability Company, 2000b, Tab Z). Consequently, PFS used the crash rate of 4×10^{-10} per mile for commercial airliners in flight, as suggested in

NUREG-0800, Section 3.5.1.6 (Nuclear Regulatory Commission, 1981a). The staff considers using the commercial airliner crash rate for estimating crash probability of large cargo aircraft to be a reasonable approximation.

PFS argued that a Class A or Class B mishap can easily occur in a large multi-engine aircraft without resulting in a crash due to redundancies in the aircraft systems. The most notable redundancy is the extra engine(s) that allow the aircraft to land in the event of a problem. As the pilot(s) remains in control of the aircraft in such events, the aircraft does not pose a significant threat to a surface Facility. Even in rare circumstances, where the pilot cannot land the aircraft because he is too far away from an airport, the pilot can attempt to guide the aircraft away from a large Facility such as the PFS Facility. Consequently, using Class A and Class B mishaps would significantly overstate the crash rate for multi-engine cargo aircraft. Based on this argument, the staff finds PFS' use of destroyed aircraft class for calculating the crash probability of multi-engine cargo aircraft acceptable.

Using DOE Standard DOE-STD-3014-96 (Department of Energy, 1996), PFS estimated the total effective area of the Facility to be equal to 0.21 mi^2, using the formula specified in NUREG-0800, Section 3.5.1.6 (Nuclear Regulatory Commission, 1981a). On the basis of approximately 414 flights per year along airway IR-420 to and from Michael Army Airfield and an airway width of 11.5 miles, the probability of crash is estimated by PFS to be 3×10^{-9} per year.

The staff carried out a confirmatory analysis using crash data of destroyed large military cargo aircraft. There were 6 crashes with destroyed aircraft from FY1989 to FY1998 in 3,525,061 flight hours, or a crash rate of 1.702×10^{-6} per hour of flight (Private Fuel Storage Limited Liability Company, 2000b). Based on the DOE ACRAM Study (Kimura et al., 1996), PFS stated that large cargo aircraft flew approximately 3.6×10^{9} miles in 7.738×10^{6} hr in both normal and special in-flight modes from 1967 to 1993. Consequently, these aircraft flew on average 465 miles in every hour of flight in this period. Assuming that the average speed of these cargo aircraft do not change in FY1989 to FY1998, the estimated crash rate is 3.66×10^{-9} per flight mile.

Assuming a specific crash rate of 3.66×10^{-9} per flight mile would result in an onsite crash probability of about 2.8×10^{-8} crashes per year. However, the staff notes that this is an exceptionally conservative estimate, since it is based on crash data corresponding to flight conditions not applicable to IR-420 (Private Fuel Storage Limited Liability Company, 2000b, Tab Z). Specifically, PFS indicates that all of the crashes in the reported data above involved flight conditions not found in IR-420. Therefore, the actual specific crash rate is much less than 3.66×10^{-9} per flight mile. Given this, the staff finds that the use of the NUREG-800 value of 4×10^{-10} crashes per mile is appropriate. Therefore, the staff accepts the onsite crash probability of 3×10^{-9} crashes per year as an reasonable estimate.

The staff reviewed the data and analysis presented by PFS with respect to potential hazards of large transport aircraft flights on military airway IR-420 to and from Michael Army Airfield. The staff found them acceptable because:

- PFS used the NRC methodology to estimate the crash probability onto the Facility.

- The use of the commercial aircraft crash rate in NUREG-0800 (Nuclear Regulatory Commission, 1981a) to approximate military cargo aircraft crash rates along IR-420 is reasonable.

- PFS analyzed the accident reports of these aircraft from the U.S. Air Force to justify the crash rate used in the analysis.

- PFS used the methodology of the DOE Standard (Department of Energy, 1996) to estimate the effective area of the Facility. As discussed in connection with aircraft flying jet route J-56, the DOE Standard for estimating the effective target area is within the NRC guidelines given in NUREG-0800, Section 3.5.1.6, Aircraft Hazards.

On the basis of NUREG-0800 (Nuclear Regulatory Commission, 1981a), the DOE Standard DOE-STD-3014-96 (Department of Energy, 1996), and Kimura et al. (1996), aircraft using IR-420 for flying to and from Michael Army Airfield will not pose a hazard to the Facility.

Military Aircraft From Hill Air Force Base Flying to and from the UTTR

Military training flights are conducted in the UTTR. The training range is divided into a North Area, located north of Interstate 80, and a South Area, located west of the Cedar Mountains and South of Interstate 80. The UTTR North Area is over 30 miles north of the Facility. At this distance, ground strikes from aircraft mishaps in the UTTR North Area would not pose a hazard to the Facility.

Military aircraft flying in or around the UTTR South Area comprise three groups:

- aircraft transiting Skull Valley en route to the UTTR South Area,

- aircraft conducting training in the restricted air space on the UTTR South Area, and

- aircraft departing the UTTR via the Moser Recovery en route to Hill Air Force Base.

Information presented for each of these groups and estimated probability of crash of an aircraft onto the proposed site is described below.

Aircraft Transiting Skull Valley En Route to the UTTR South Area

Based on U.S. Air Force data, almost all of the 3,871 military aircraft that transited Skull Valley in 1998 were F-16s. The predominant route of F-16s is through the east side of Skull Valley along the edge of the Stansbury Mountains, which are approximately 5 statute miles east of the Facility. The Private Fuel Storage Facility site is located in the Sevier B MOA. At the Facility location, the Sevier B MOA extends approximately 2 miles to the west of the site and 10 miles to the east. The Sevier B MOA has a ceiling of 9,500 ft above mean sea level, approximately 5,000 ft above ground level at the Facility. The U.S. Air Force has indicated that the planes in the UTTR generally fly at an altitude of 3,000 to 4,000 above ground level at speeds of 350 to

400 knots. According to Private Fuel Storage Limited Liability Company (2000b), pilots only fly in Skull Valley under visual meteorological conditions, that is, clear of clouds with at least 5 miles of visibility (Private Fuel Storage Limited Liability Company, 2000b).

The crash rate for F-16s transiting Skull Valley would be representative of aircraft in "normal" flight phase, defined in DOE Standard DOE-STD-3014-96 (Department of Energy, 1996) since the F-16s do not engage in any special operations involving high-stress maneuvering in Skull Valley. F-16s transiting through Skull Valley engage in low-stress maneuvers consisting of clearing turns, G-awareness, and terrain masking (Private Fuel Storage Limited Liability Company, 2000b). PFS has adequately described the activities involved in these maneuvers to show that they appropriately belong to "normal" flight phase conditions.

The DOE ACRAM study (Kimura et al., 1996) provides the crash rates for F-16s for 1975 through 1993. PFS used the crash rate for the parameter C (crash rate per mile of flight) in Equation (15-4) after updating it using recent data from the U.S. Air Force.

The U.S. Air Force maintains mishap rates for each type of aircraft. The mishap rate is defined as number of crashes per 100,000 hr of flight. The crash rate on a per mile basis was estimated by PFS by dividing the time rate (i.e., crashes per hour) by the average speed of aircraft (i.e., miles per hour) (Private Fuel Storage Limited Liability Company, 2000b, Tab D). On the basis of the U.S. Air Force data, PFS modified the normal crash rate developed in the DOE ACRAM study by updating the data from FY1975 to FY1993 with data from FY1994 to FY1998. Hence PFS used the crash rate based on the last 10 year data, i.e., from FY1989 to FY1998.

Using the updated F-16 accident rate in normal in-flight mode, PFS estimated the crash probability to be 2.736×10^{-8} per mile. PFS used the more recent 10-year average crash rate in the calculations. This is acceptable because, given the trend toward lower crash rate, use of the lifetime (1975 through 1998) average crash rate would be overly conservative.

PFS used the formula given in NUREG-0800, Section 2.5.1.6 Aircraft Hazards (Nuclear Regulatory Commission, 1981a) to estimate the crash probability, P, at the Private Fuel Storage Facility site from F-16s transiting through Skull Valley. In order to separate the evaluation of F-16 crashes due to engine failures from those due to other causes, the formula was resolved into two components, as follows:

$$
\begin{aligned}
P &= P_1 + P_2 \\
&= NC\frac{A}{W}R_1 + NC\frac{A}{W}R_2 \qquad (15\text{-}4)
\end{aligned}
$$

where,

P_1	=	probability of an F-16 crashing on the Facility as a result of engine failure or other malfunctions with the pilot retaining control of the aircraft.
P_2	=	probability of an F-16 crashing on the Facility due to engine failure or other malfunctions with the pilot not retaining control of the aircraft.
N	=	number of aircraft flying near the site in a year.
C	=	crash rate per mile of flight.
A	=	effective area of the Facility.

W = width of the air space through which the F-16s fly.

R_1 = probability that the crash is of the type such that the pilot retains control of the aircraft but is unable to guide the aircraft away from the Facility. This is the product of the probability that the pilot retains control of the aircraft for a time that is sufficient to guide the aircraft away from the Facility, $P_{Able\text{-}to\text{-}Avoid}$, and the probability that such a pilot will still not be able to guide the aircraft away from the Facility, P_{hit}. In other words, R_1 is equal to $P_{Able\text{-}to\text{-}Avoid} \times P_{hit}$.

R_2 = probability that the crash is of the type such that the pilot does not retain control of the aircraft and is unable to guide the aircraft away from the Facility before ejecting.

PFS estimated both R_1 and R_2 based on the data and analyses presented in Tab H of Private Fuel Storage Limited Liability Company (2000b). PFS used accident investigation reports from the U.S. Air Force in these analyses. For R_1 and R_2, PFS focused on F-16 mishaps involving a destroyed aircraft as these analyses estimated the hazards to the Canister Transfer Building and the spent fuel storage casks. The Canister Transfer Building is made of reinforced concrete. The spent fuel storage casks have a concrete overpack. Kimura et al. (1996) state that for facilities with hardened structures, a more appropriate estimate of the crash frequency may be based on mishaps with destroyed aircraft only, i.e., the mishaps in which it was uneconomical to repair the aircraft. The staff finds this to be reasonable. Hence, the use of the data set consisting of mishaps with destroyed aircraft in the analyses is appropriate. Additionally, use of the data set with mishaps with destroyed aircraft is appropriate since military aircraft such as the F-16 normally are destroyed in a crash landing on terrain other than an airfield runway.

PFS estimated the effective area of the Facility assuming a full load of 4,000 casks. The effective areas of the Canister Transfer Building and the cask storage area were estimated separately using the formulas and information given in DOE Standard DOE STD–3014–96 (Department of Energy, 1996). As discussed in connection with aircraft flying jet route J-56, the DOE Standard for estimating the effective target area is within the NRC guidelines given in NUREG-0800, Section 3.5.1.6, Aircraft Hazards. Total effective area of the Facility is the sum of effective areas of the Canister Transfer Building and the cask storage area. The estimated effective area of the cask storage area at full capacity is 0.1222 sq miles and that of the Canister Transfer Building is 0.0126 sq miles. Consequently, for the F-16 analysis, the total effective area of the Facility at full capacity, A of Equation (15-4), is 0.1337 mi^2.

At the latitude of the Facility, the Sevier B MOA east-west width is about 12 miles. However, the F-16s are required to fly higher than 1,000 ft above ground level and below 9,500 ft mean sea level. Consequently, the F-16s could not fly in a small portion of the easternmost 2 miles of the Sevier B MOA due to the presence of the Stansbury Mountains (Private Fuel Storage Limited Liability Company, 2000b, Figure 1). Therefore, PFS has used the width of the airway equal to 10 miles for estimating the crash probability, or in other words, *W*, of Equation (15-4) is equal to 10 miles.

PFS obtained 126 F-16 aircraft accident investigation reports, conducted under Air Force Instruction (AFI) 51–503, (Private Fuel Storage Limited Liability Company, 2000b). Of these, 117 reports included mishaps with 121 of the 139 destroyed aircraft. The accident reports focused on mishaps with destroyed aircraft; as discussed above, it is appropriate to use the

data of mishaps with destroyed aircraft since military aircraft such as the F-16 normally are destroyed in a crash landing on terrain other than an airfield runway.

PFS analyzed the F-16 accident reports using three different approaches to develop three subsets of the original data set to estimate the fraction of accidents while transiting Skull Valley in which the pilot would be able to avoid the Private Fuel Storage Facility site. Each data subset provided a different perspective of the data. The three different approaches to analyze the original data set are:

(1) All accidents caused by events that could have occurred in Skull Valley, irrespective of the phase of flight (normal in-flight, special in-flight, takeoff and landing). PFS has referred to this data subset as Skull Valley Type Events (Private Fuel Storage Limited Liability Company, 2000b).

PFS applied the evaluation parameters or the screening criteria to the entire accident data set of 121 destroyed F-16 aircraft to determine the population of mishaps that could have occurred in Skull Valley, regardless of the flight phase (i.e., takeoff/landing, normal, and special)(Private Fuel Storage Limited Liability Company, 2000b). PFS found that most of the mishaps in the original accident data set did not occur under Skull Valley type flight conditions . Hence, PFS excluded those events that could not occur in Skull Valley near the PFS Facility, such as midair collisions or G-induced loss of consciousness. These types of mishaps may occur during high-stress, aggressive maneuvering of special operations in restricted air spaces of the UTTR. As discussed before, F-16s transit Skull Valley en route to the UTTR South Area in normal in-flight mode without any high-stress, aggressive maneuvering.

PFS included in this data set F-16 mishaps that occurred in special operations that were not directly caused by collisions or high-stress maneuvering. For example, engine failure, such as turbine blade failure, is essentially a random event. Therefore, although a given engine failure had occurred in the training ranges, it may be equally likely to occur in Skull Valley. PFS also included in this population those mishaps that occurred during take off and landing but were not attributable to the unique circumstances during these phases.

(2) All accidents caused by events that could have occurred in Skull Valley during the normal in-flight phase of operation. PFS has referred to this data subset as ACRAM flight phase (Private Fuel Storage Limited Liability Company, 2000b).

(3) All accidents in normal in-flight phase that occurred under flight environments in which F-16s transit the Sevier B MOA near the Facility. PFS has referred to this subset of data as Sevier B MOA Flight Conditions (Private Fuel Storage Limited Liability Company, 2000b).

Conditions encountered by all F-16s transiting the Sevier B MOA near the Facility evaluated in this group include altitude (between 1,000 to 5,000 ft above ground level), speed, weather (typically visual meteorological conditions clear of clouds and visibility at least 5 miles), time of day, and flight activity.

PFS used a team of experts to evaluate the accident reports. The team was comprised of Brigadier General James L. Cole, U.S. Air Force (ret.); Major General Wayne O. Jefferson, U.S. Air Force (ret.), and Colonel Ronald E. Fly, U.S. Air Force (ret.). The expert panel jointly identified the evaluation parameters and independently evaluated each accident report to assess:

- ACRAM Flight Phase: phase of flight in which the aircraft was flying when it was destroyed (i.e., takeoff and landing, normal in-flight, and special in-flight).

- Cause of the Accident: whether the accident was caused by an engine failure due to a mechanical problem or damage to the engine. If the accident was due to an engine failure, it could result in either complete loss of power, loss of useable power, or loss of control over the engine, as identified in the accident report.

- Ability to Avoid a Fixed Ground Site: whether the pilot had enough time and would have been able to avoid a fixed site on the ground. This assessment by the expert panel considered the following (Private Fuel Storage Limited Liability Company, 2000b):

  - nature of the initiating event such as engine or other mechanical failure, G-induced loss of consciousness, spatial disorientation etc,

  - altitude of the aircraft at which the initiating event occurred,

  - weather at the time of initiating event,

  - speed of the aircraft at the time of initiating event, and

  - control available to the pilot based on the initiating event.

On the basis of the results of the evaluation, the PFS expert panel identified the fraction of mishaps in which the pilot would have been able to avoid a surface site, such as the Facility, using those three data sets. The details are given in Table 15-2.

Information presented in Table 15-2 shows that 58 mishaps out of a total of 121 or 48 percent were caused by failure of F-16 engines. The PFS expert panel determined that all engine failures, including catastrophic ones, left the pilots with ample time and capability to avoid a fixed site on the surface such as the Facility.

Table 15-2. Results of analyses to estimate fraction of mishaps in which the pilot would have been able to avoid the Private Fuel Storage Facility (Private Fuel Storage Limited Liability Company, 2000b, Tab H).

Flight Phase				
	Normal	Special	Take-off/Landing	Total
Accidents	27	62	32	121
Engine Failure	16	26	16	58
Able to Avoid Facility	21	27	21	69
Total Skull Valley Type Events	19	25	17	61
Sevier B MOA Flight Conditions	9	0	0	9

Additionally, there were 11 mishaps, caused by reasons other than engine failure, which would have allowed the pilot sufficient time and capability to avoid a fixed surface Facility. Consequently, PFS concluded that in 69 out of 121 mishaps, the pilot would have been able to avoid the Private Fuel Storage Facility site.

Eight mishaps in normal in-flight phase were assessed by the PFS expert panel as not relevant to Skull Valley. In four of these mishaps, the pilots were in control and, consequently, had sufficient time to avoid a fixed surface site. In another four mishaps, the pilots were not in control and, therefore, would not have been able to avoid the Facility.

It should be noted that "Able to Avoid" mishaps are not all Skull Valley Type Events. Only 61 out 121 destroyed aircraft mishaps were assessed as Skull Valley Type Events by the PFS expert panel (Private Fuel Storage Limited Liability Company, 2000b). Using only Skull Valley Type Events (61 out of a total 121 destroyed aircraft), PFS estimated the fraction of mishaps in which the pilot would have had sufficient time and capability to avoid a surface site like the Facility. The results are given in Table 15-3.

Table 15-3. Estimation of fraction of mishaps in which the pilot would have been able to avoid the Private Fuel Storage Facility using the data set of Skull Valley Type Events (Based on Private Fuel Storage Limited Liability Company, 2000b, Tab H).

Flight Phase				
	Normal	Special	Take-off/Landing	Total
Total Skull Valley Type Events	19	25	17	61
Able to Avoid	17	25	17	59
Not Able to Avoid	2	0	0	2

As stated in Table 15-3, there were 61 Skull Valley Type accidents that took place between FY1989 and FY1998. On the basis of the analysis conducted for these events by the expert panel, PFS estimated that with the exception of two mishaps (May 25, 1990 and April 4, 1991), the rest involved situations where the pilots remained in control and had sufficient time to

avoid the Private Fuel Storage Facility site. On the basis of the information presented in Table 15-3, PFS estimated that in 59 mishaps out of 61 Skull Valley Type Events (i.e., 97 percent) the pilots had sufficient control and time to avoid a fixed surface site.

An additional factor associated with F-16 aircraft flying in Skull Valley is that they are in normal in-flight phase of operation. By eliminating mishaps occurring in other flight phases the number of mishaps relevant to Skull Valley is 19. In 17 of these mishaps, the pilot was able to exercise avoidance procedures. Hence, on this basis, the probability of avoiding the Facility is estimated to be 17/19, or 89 percent.

Additionally, the PFS expert panel concluded that only 9 mishaps fell under the strict guidelines of Skull Valley flight environment that includes not only the normal flight mode but also specified speed and altitude restrictions (Private Fuel Storage Limited Liability Company, 2000b, Tab H). Of these, only one mishap involved loss of avoidance ability according to the assessment of the panel. Hence, in 8 out of 9 mishaps (89 percent), the pilot was able to control the aircraft.

The staff reviewed the information and analysis, presented by PFS in Tab H of Private Fuel Storage Limited Liability Company (2000b), on the fraction of potential mishaps in which the pilot would have sufficient control and time to steer an aircraft experiencing trouble while transiting Skull Valley. On the basis of its review, the staff considers that the data subset representing mishaps that took place in normal in-flight mode or the data subset referred by PFS as ACRAM flight phase is representative of Skull Valley conditions.

As discussed before, using these three different data subsets PFS has estimated the avoidance probability, (i.e., the probability that a pilot experiencing trouble with the F-16 aircraft while transiting Skull Valley would have sufficient control and time to avoid a surface site like the Facility). PFS concluded that a pilot having trouble with the aircraft would be able to avoid the Facility in approximately 90 percent of the time. This is based on the mishaps histories for ACRAM Flight Phase and Sevier B MOA Flight Conditions data subsets. Similarly, it is estimated that avoidance would be achieved 97 percent of the time if one were to use the Skull Valley Type Events data subset. Based on the above discussion and since the ACRAM Flight Phase data subset produces the lower bound estimate, the staff has used in its review a value of 90 percent for the avoidance probability for F-16 pilots involved in aircraft malfunctions while transiting Skull Valley. Therefore, the probability $P_{Able\text{-}to\text{-}Avoid}$, in Equation (15-4), is 0.90.

PFS calculated the probability, P_{hit} in Equation (15-4), that a pilot, with time and opportunity to direct a crashing F-16 away from the Facility, would fail to do so. This evaluation is based on standard procedures followed by F-16 pilots in emergencies at 5,000 ft above ground level or lower, actions that would be required by the pilot to avoid the site, the time that a pilot would have to direct the aircraft away, analysis of accident reports from the U.S. Air Force by the expert panel, and other factors that may affect a pilot's capability to avoid the site (Private Fuel Storage Limited Liability Company, 2000b).

PFS has judged that a pilot with sufficient control and time available would be able to avoid striking the Facility at least 95 percent of the time. This assumption is based on consideration of factors such as pilot training and procedure, experience, the flight control computer, and the terrain and visibility characteristics of Skull Valley. Consequently, the probability that the pilot would not be able to avoid the Facility with sufficient control and time, P_{hit} in Equation (15-4), is

equal to 0.05. In accordance with the definitions presented in Equation (15-4), this leads to an estimated value of 0.045 for R_1.

Factor R_2 in Equation (15-4) is the probability that the initiating event leading to a crash will force a pilot to eject immediately from the aircraft. Consequently, a pilot would not have control of the aircraft and would not be able to guide it away from the Facility. A pilot would retain control of the aircraft with sufficient time to steer the plane away for 90 percent of F-16 crashes. Therefore, in only 10 percent of all F-16 crashes would the pilot have to eject immediately. Hence, the factor R_2 is estimated to be 0.1.

PFS estimated the probability of F-16s transiting Skull Valley impacting the Facility, P, using Equation (15-4) based on the estimated values of N, C, A, W, R_1, and R_2, as discussed previously:

N = 3871
C = 2.736×10^{-8} per mile
A = 0.1337 mi^2
W = 10 mi
R_1 = 0.045
R_2 = 0.1

$$P = 3871 \times 2.736 \times 10^{-8} \times \frac{0.1337}{10} \times (0.045 + 0.1) = 2.05 \times 10^{-7}$$

Therefore, PFS estimated the crash probability of F-16s transiting Skull Valley to be 2.05×10^{-7} per year for the Facility. The estimated probability is conservative because:

- the estimation is based on crash rate C for Equation (15-4) for Class A and Class B mishaps which include mishaps in which the aircraft was partially damaged but not destroyed or did not crash.

- the estimation methodology assumed that flight paths of F-16s transiting Skull Valley are uniformly distributed across the valley, when the predominant route of choice is to fly along the eastern side of the valley, away from the proposed site.

It should be noted that estimation of P_{hit} has to be qualitative because of lack of quantitative information. No information exists on the fraction of F-16 mishaps where a pilot had adequate control of the aircraft in addition to sufficient time to direct the crashing aircraft away from a fixed surface Facility, yet failed to avoid the surface structure. It should also be noted that in all these accidents the pilot had control of the aircraft. Events in which the pilot lost control of the aircraft due to major damage, such as in a midair collision, are excluded from this discussion. The pilot in such cases would immediately eject from the aircraft. PFS has conservatively classified those mishaps in the list of historical accidents as cases where the pilot would not be able to avoid a surface Facility like the Facility.

The staff carried out a sensitivity analysis to determine the effect of variation of P_{hit} on the overall probability of crash using Equation (15-4). The results are given in Table 15-4.

Table 15-4. Sensitivity analysis of P_{hit} on overall crash probability.

$P_{Able\text{-}to\text{-}Avoid}$	P_{hit}	R_1	R_2	P_1	P_2	$P = P_1 + P_2$ (crash/yr)
0.90	0.01	0.009	0.1	1.3×10^{-8}	1.4×10^{-7}	1.5×10^{-7}
0.90	0.05	0.045	0.1	6.4×10^{-8}	1.4×10^{-7}	2.1×10^{-7}
0.90	0.10	0.090	0.1	1.3×10^{-7}	1.4×10^{-7}	2.7×10^{-7}
0.90	0.15	0.135	0.1	1.9×10^{-7}	1.4×10^{-7}	3.3×10^{-7}
0.90	0.20	0.180	0.1	2.5×10^{-7}	1.4×10^{-7}	3.9×10^{-7}

Results presented in Table 15-4 show that a 20 times increase of P_{hit} value (from 0.01 to 0.20) increases the overall crash probability by approximately 2.5 times. Consequently, the overall probability of crash of F-16s transiting Skull Valley is not highly sensitive to the particular value of P_{hit} used in the calculation. Results of this analysis illustrate that the P_{hit} value, developed in a qualitative manner, has negligible influence on the estimated crash probability, and that use of 0.05 as P_{hit} is acceptable. Therefore, the staff accepts the PFS crash probability of 2.05×10^{-7} per year for F-16s as reasonable. However, the staff conservatively used a crash value of 2.7×10^{-7} per year in Table 15-7, assuming a P_{hit} value of 0.10 as shown in the sensitivity analysis in Table 15-4.

The staff reviewed the data, information, and analyses presented by PFS with respect to potential hazards of F-16 aircraft flying through Skull Valley to reach the UTTR South Area. The staff found them acceptable because:

- PFS used the DOE ACRAM Study crash data for Class A and Class B mishaps for normal operations and updated the crash rate with recent (after FY1993) information on mishaps from the U.S. Air Force. This crash rate will be higher than the crash rate considering only the mishaps with destroyed aircraft.

- PFS used the methodology suggested by the DOE Standard to estimate the effective area of the Facility. As discussed in connection with aircraft flying jet route J-56, the DOE Standard for estimating the effective target area is within the NRC guidelines given in NUREG-0800, Section 3.5.1.6, Aircraft Hazards.

- PFS used the basic NRC methodology to estimate the crash probability onto the Facility.

- PFS used relevant accident reports from the U.S. Air Force to estimate the above fraction of mishaps. PFS used expert judgment appropriately to arrive at the fraction of mishaps where the pilot would be able to divert the aircraft away from the Facility.

- PFS used appropriate Air Force Manuals to carry out the analysis to conclude that a pilot with control and time available would be able to divert the aircraft in most circumstances.

- The ultimate crash probability is not very sensitive to the P_{hit} value used in the estimation. P_{hit} value has been estimated qualitatively. However, the value used for P_{hit} is acceptable as the overall crash probability is not highly sensitive to the value selected for P_{hit}.

On the basis of the information, data, and analyses presented, the staff concludes that F-16 aircraft transiting Skull Valley on the way to the UTTR South Area will not pose a significant risk to the Facility.

Aircraft Conducting Training in the Restricted Air Space on the UTTR South Area

The U.S. Air Force uses the UTTR for air-to-ground combat and air-to-air combat training. The UTTR is divided into the North Area and the South Area. The air space over the UTTR extends beyond the land boundaries of the range and is divided into restricted areas and MOAs. MOAs on the UTTR are located on the edges of the range adjacent to the restricted areas. The air space over the restricted areas extends from the surface up to 58,000 ft. Activities within the restricted airspace are entirely military when the range is open. Civilian aircraft may transit to MOAs only with permission from the military air traffic controllers at Clover Control.

As indicated previously, the UTTR North Area is over 30 miles north of the Private Fuel Storage Facility site, so that activities in the North Area do not pose a hazard to the Facility. The UTTR South Area is comprised of four restricted areas and two MOAs. The restricted areas are R-6402, R-6405, R-6406, and R-6407. The MOAs are subdivided into Sevier A and B areas. The proposed site for the Facility lies within the Sevier B MOA. Restricted air spaces R-6402 and R-6406 are also subdivided into R-6402A and B, and R-6406A and B, respectively. Restricted air spaces closest to the Facility are R-6402B and R-6406B. The Facility is 2 statute miles from the eastern edge of restricted areas R-6402B and R-6406B. The site is over 18 statute miles east of the eastern land boundaries of the UTTR South Area and 8.5 statute miles northeast of the northeastern boundary of Dugway Proving Ground.

As discussed previously, the U.S. Air Force carries out air-to-ground attack and air-to-air combat training in the UTTR South Area. Fighter aircraft, attack aircraft, and bombers on the UTTR South Area conduct air-to-ground attack training in the vicinity of targets located at least 20 miles from the Facility.

According to the U.S. Air Force (1999), a Weapons System Evaluation Program (WSEP), nicknamed “Combat Hammer”, is held annually at the UTTR to evaluate weapons system performance. Weapon systems evaluated by type and average number in each year are (U.S. Air Force, 1999):

- GBU-10/12/24/27 4 to 60 (inert warhead)
- GBU-15 6 to 12 (inert warhead)
- AGM-142 2 (inert and live warhead)
- AGM-65 40 to 60 (live warhead)

•	AGM-130	2 to 6	(inert warhead)
•	AGM-88	2 to 21	(inert warhead)

AGM-65 (Maverick), is an air-to-surface guided missile with a range up to 14 miles (Donnell, 1999a). Mavericks are fired in directions away from the Private Fuel Storage Facility site with a solid propellant rocket motor provided with enough fuel to fly 5 miles (Donnell, 1999a). In addition, 7 to 10 cruise missiles (AGM-86, AGM-86C, and AGM-129) are tested annually in the UTTR (U.S. Air Force, 1999); these cruise missiles are discussed separately in Section 15.1.2.18 of this SER.

Any weapon systems capable of crossing the range boundaries are fitted with a Flight Termination System (FTS) installed prior to testing on the UTTR (U.S. Air Force, 1999; Private Fuel Storage Limited Liability, 2000b). The FTSs are designed to destroy the weapon on command and terminate the weapon flight path from the Mission Control Room at Hill Air Force Base in case a weapon anomaly is detected. According to the Hill Air Force Base (U.S. Air Force, 1999), "the UTTR has never experienced a FTS failure."

Air-to-ground ordnance delivery is carried out at several target complexes within the UTTR South Area (Private Fuel Storage Limited Liability Company, 2000b, Tabs A and B). The distance of these target complexes from the Facility range from about 21 to more than 40 miles.

Run-in headings (i.e., headings used by aircraft to reach a target for weapons delivery) for air-to-ground weapon delivery are established at each of these target complexes on the basis of individual test requirements and safety reviews (Private Fuel Storage Limited Liability Company, 2000b, Tab B). None of these run-in headings ever transit over Skull Valley (Private Fuel Storage Limited Liability Company, 2000b, Tab J). Therefore, aircraft using the run-ins would not pose a hazard to the Facility.

Large multi-engine bomber aircraft may conduct air-to-ground weapons delivery training on the UTTR South Area at altitudes more than 20,000 ft above ground level. These aircraft would not pose a hazard to the Facility. In the event of simultaneous failure of all engines, the aircraft would crash to the ground close to the point where the emergency developed. Otherwise, attempts would be made to land at Michael Army Airfield or select a terrain suitable for emergency landing. Because of the nature of the terrain, the Cedar Mountains area would not be good for an emergency landing or a bail out. Consequently, air-to-ground training activities carried out at the UTTR South Area do not pose a significant risk to the Facility.

Cargo aircraft and some combat aircraft practice air refueling training on the far western side of the UTTR South Area (Private Fuel Storage Limited Liability Company, 2000b) at locations more than 50 miles from the Private Storage Facility site. Aircraft mishaps at such distances would not pose a hazard to the Facility.

PFS has estimated the probability of a crash onto the Facility for an aircraft engaged in air-to-air combat training on the UTTR South Area Private Fuel Storage Facility site on the basis of (Private Fuel Storage Limited Liability Company, 2000b):

- density of air-to-air combat training operations over the UTTR South Area sectors closest to the Facility,

- expected crash rate per hour of fighter aircraft training,
- areas of the range sectors from which a crash can possibly impact the Private Fuel Storage Facility site,
- size of the footprint area in which a crashing aircraft could hit the ground, and
- effective area of the Private Fuel Storage Facility site.

In its calculation of the potential hazards, PFS assumed the following:

- Density of training operations out to within 3 miles of the edge of the UTTR South Area near the Facility is the same as the density in the center of the range.
- Aircraft becoming disabled up to 10 miles from the Facility would fly the distance to the Facility while out of control and impact the site.
- Aircraft are uniformly distributed from ground to 35,000 ft above ground level within the cut-out area for each restricted area, defined by an arc with 10 miles radius and a 3 miles wide buffer zone.

On the basis of the information from the U.S. Air Force, the total number of sorties flown on the UTTR (North and South Areas) in 1998 was 13,367. Of these, 8,284 were flown over the UTTR South Area, as shown in Table 15-5.

Table 15-5. Number of sorties on the UTTR South Area for different aircraft (Based on Private Fuel Storage Limited Liability Company, 2000b)

Aircraft Type	**Sorties**	
	Number	Percentage of Total
F-16	5,726	69
F-14, F-15, F-18	634	8
Attack Aircraft	51	0.06
Bombers	1,175	14
Cargo and Other Aircraft	607	7
Helicopters	91	1
Total for UTTR South Area	8,284	100

On the basis of the DOE ACRAM Study (Kimura et al., 1996), the single engine F-16 has the highest crash rate, except for A-7 attack aircraft. The percentage of attack aircraft, which includes A-10 aircraft, is less than 0.1 percent of the total number of aircraft used in the UTTR

South Area. All other aircraft using the area have lower crash rates. Therefore, use of single engine F-16 crash rates or, equivalently, assuming all fighter planes used in the UTTR South Area are F-16s, conservatively bounds the military aircraft crash rate. PFS used the single-engine F-16 crash rate in estimating the potential hazard to the Facility.

PFS estimated the annual number of crashes in the UTTR South Area using a modified version of the formula of Kimura et al. (1998):

$$H = C \times A_c \times A_{eff} / A_p \times R \qquad (15\text{-}5)$$

where,

H	=	number of impacts per year
C	=	crash rate of the aircraft/mi^2/yr
A_c	=	cut-out area
A_{eff}	=	effective area of the Facility
A_p	=	footprint area
R	=	factor representing potential ability of the pilot to avoid the Facility in the event of a crash precipitated by an engine failure or some other event that left the pilot in control of the aircraft.

This methodology for estimating the crash probability of aircraft is within the NRC guidelines given in NUREG-0800, Section 3.5.1.6, Aircraft Hazards.

Referring to Table 15-5, fighter aircraft (F-14, F-15, F-16, and F-18) flew a total of 6,360 sorties to the UTTR South Area in 1998. According to PFS and information provided by the Vice Commander of the 388th Fighter Wing at Hill Air Force Base, about one third of these (2,120) were air-to-air combat sorties. PFS estimated that the number of hours spent in air-to-air combat training also was about one-third of the total number of flight hours. Fighter aircraft spent 7,404 hr on the UTTR South Area in 1998. Hence, the number of hours spent in air-to-air combat training is estimated to be 2,468.

PFS calculated the expected distribution of F-16 crashes on the basis of the level of activity, i.e., number of air operations, in each restricted range area and MOA in the UTTR South Area. The U.S. Air force has information on the number of air operations in each range area during FY1998. The U.S. Air Force defines one air operation as an aircraft flying into or through a range area (includes both Sevier A and Sevier B MOA). Therefore, a single sortie may represent more than one operation depending on the number of range areas the aircraft flew through.

PFS assumed that, on the average, the total number of hours spent by fighter aircraft on air-to-air combat training sorties in each area would be proportional to the number of operations conducted in each area.

On the basis of the U.S. Air Force data, a total of 27,229 air operations took place in 1998 in restricted areas R-6402, R-6405, R-6406, R-6407, and Sevier A and B MOAs. Out of 27,229 operations, 909 and 6,679 operations took place in R-6402 and R-6406, respectively. In other words, a fraction of 0.0334 of the total 27,229 operations took place in restricted area R-6402 and a fraction of 0.2453 of the total number occurred in R-6406. Consequently, the estimated

annual number of hours spent by fighter aircraft in restricted areas R-6402 and R-6406 are 82.4 and 605.4 hr, respectively.

PFS estimated the crash rate of F-16s engaged in air-to-air combat training on the basis of information from the DOE ACRAM Study (Kimura et al., 1996) and U.S. Air Force (website http://www-afsc.saia.af.mil/AFSC/RDBMS/Flight/Stats/F-16mds.html). On the basis of the number of special in-flight operations and the associated flight hours reported in the DOE ACRAM study, PFS estimated the crash rate for F-16s in special in-flight mode to be 5.58×10^{-5} per hour. PFS updated the crash rate derived from the DOE ACRAM study using more recent data. The updated crash rate per flight hour data results in an estimate for special operations equal to 79/(4,016,311/2) or 3.96×10^{-5} per hour.

PFS estimated the expected number of crashes in each area by multiplying the number of annual air-to-air combat training flight hours spent in the area by the crash rate per hour for F-16s (estimated to be 3.96×10^{-5}/hr). Therefore, the expected number of crashes in R-6402 and R-6406 is 3.26×10^{-3} and 2.40×10^{-2} per year respectively.

The ground areas are 1,295 mi^2 and 11,742 mi^2 for R-6402 and R-6406, respectively. Therefore, the expected crash density in R-6402 is 2.52×10^{-6} and in R-6406 is 2.05×10^{-5} per sq miles per year. The inherent assumption in estimating this crash density is that the crash rate or the number of crashes per square mile per year is uniform. This is a conservative assumption since PFS has determined that military aircraft activity within the restricted airspaces are concentrated toward the center. PFS used these crash rates to estimate the crash probability for aircraft engaged in UTTR training, in relation to the Facility.

PFS also concluded that air-to-air combat training missions conducted more than 10 miles from the Facility would not pose a credible crash hazard to the Facility for the following reasons (Private Fuel Storage Limited Liability Company, 2000b):

- Disabled F-16s (e.g., engine failure) would take about 1.5 minutes to glide 10 miles. This estimated time provides ample opportunity to direct the aircraft away from the Facility.

- Out-of-control aircraft (e.g., aircraft undergoing structural damage or experiencing a deep stall) would impact the ground within a few miles from the point where they became uncontrollable.

- If the pilot loses situational awareness, the aircraft would most likely go out of control quickly and crash within a short distance.

- If the pilot suffers G-induced loss of consciousness, he will remain incapacitated for about 20 to 30 sec, based on centrifuge tests on pilots. The accident report for the February 28, 1994, mishap stated that average time of total G-induced loss of consciousness is 24 sec (Private Fuel Storage Limited Liability Company, 2000b, Tab Y). An aircraft traveling at the speed of sound on a level flight would travel approximately 5 miles in that time. Accident reports for all six G-induced loss of consciousness mishaps (Private Fuel Storage Limited Liability Company, 2000b, Tab Y) indicate this type of mishap occurs during steep descents, thereby significantly reducing the horizontal travel distance of a crashing aircraft.

- If the mishap is due to collision with the ground during low-level maneuvering, the aircraft will impact the ground virtually at the point of misjudgement by the pilot.

Additionally, PFS analyzed the reports of accidents on restricted area ranges during combat training in which the pilot was not able to control the aircraft (Private Fuel Storage Limited Liability Company, 2000b, Tab Y). PFS indicates that in such accidents the aircraft impacted the ground well within 10 miles from the point of the initiating event. Moreover, PFS argues that any crashing aircraft able to reach the proposed site from more than 10 miles away would be under the control of the pilot (Private Fuel Storage Limited Liability Company, 2000b). In such cases, the pilot would guide the aircraft to a controlled bailout area, an open area of the UTTR, or toward Michael Army Airfield for a forced landing.

Based on the above factors, PFS assumed that in some instances aircraft flying within 10 miles of the Facility could experience situations in which the aircraft would not be under the control of the pilot (Private Fuel Storage Limited Liability Company, 2000b). Hence, some air activities in the restricted areas were assumed to pose a potential hazard to the Facility. To account for this, a cut-out area, A_c, is defined by a 10 miles radius arc, centered on the Facility, through these restricted areas and the 3-mile buffer zone on the edge of the restricted areas (Private Fuel Storage Limited Liability Company, 2000b, Tab A).

The distance a crashing aircraft will be able to glide is dependent on the altitude at which it was flying when the emergency initiated. Some crashing aircraft flying within 10 miles of the PFS but at low altitudes may not reach the Private Storage Facility site as it would be further away than their glide distances. To account for altitude dependent glide distances for aircraft , PFS (Private Fuel Storage Limited Liability Company 2000b) divided the vertical air space into four altitude bands. Crash hazards from aircraft flying in these altitude bands were assessed separately to estimate the total crash hazard to the proposed site. Within each restricted area, the annual crash rate per square mile area for each altitude band, C_a, is calculated by multiplying the crash rate C per square mile per year by the fraction of aircraft in each band.

PFS assumed that the aircraft are uniformly distributed over the vertical airspace of 0 to 35,000 ft above ground level, although they generally spend more time at medium or lower altitudes (Private Fuel Storage Limited Liability Company, 2000b). Values of C for R-6402 and R-6406, and C_a for each altitude band are given in Table 15-6.

PFS used a glide ratio of 5:1, which is lower than the maximum straight-ahead glide ratio of F-16s since most aircraft would have to turn in order to reach the Facility (Private Fuel Storage Limited Liability Company, 2000b). As set forth below, this difference does not have a significant effect in the results. Turning results in the aircraft losing energy and effectively reduces the glide ratio from the straight-ahead value.

PFS calculated the cut-out area, A_c of Equation (15-5), for each altitude band within restricted areas R-6402 and R-6406 (Private Fuel Storage Limited Liability Company, 2000b). The results are shown in Table 15-6.

PFS also calculated the footprint area, A_p of Equation (15-5), which is equal to the area of a circle around the point at which the initiating event leading to a crash would begin (Private Fuel

Storage Limited Liability Company, 2000b). PFS calculated A_p separately for each of the altitude bands. These results are also given in Table 15-6.

Table 15-6. Estimation of cut-out area, footprint area, and crash rate for each altitude band (Based on Private Fuel Storage Limited Liability Company, 2000b)

Range Area	Altitude Band (Above Ground Level) (ft)	Arc Radius (mi)	Cut-out Area A_c (mi^2)	Footprint Area A_p (mi^2)	Crash Rate C ($crash/mi^2/yr$)	Crash Rate for Altitude Band C_a ($crash/mi^2/yr$)
R-6402	0 to 3,333	1.58	0.0	7.8	2.52×10^{-6}	2.40×10^{-7}
	3,333 to 6,667	4.73	0.0	70.4	2.52×10^{-6}	2.40×10^{-7}
	6,667 to 10,000	7.89	24.5	195.6	2.52×10^{-6}	2.40×10^{-7}
	10,000 to 35,000	10.00	53.0	314.2	2.52×10^{-6}	1.80×10^{-6}
R-6406	0 to 3,333	1.58	0.0	7.8	2.05×10^{-5}	1.95×10^{-6}
	3,333 to 6,667	4.73	0.0	70.4	2.05×10^{-5}	1.95×10^{-6}
	6,667 to 10,000	7.89	4.5	195.6	2.05×10^{-5}	1.95×10^{-6}
	10,000 to 35,000	10.00	12.5	314.2	2.05×10^{-5}	1.46×10^{-5}

PFS estimated the probability of crash onto the proposed site by taking into account that pilots with control of the aircraft and sufficient time would avoid the Facility. The factor R in Equation 15-5 is quantified based upon the data and analysis presented in Tabs H and Y of Private Fuel Storage Limited Liability Company (2000b) following methodology similar to that adopted for analyzing the potential risk from F-16s transiting Skull Valley. R is again resolved into two parts: R_1 and R_2. Values for R_1 and R_2 were estimated from analyzing the accident reports (Private Fuel Storage Limited Liability Company, 2000b, Tab Y).

Based upon the data presented in Table 15-2, the PFS expert panel concluded that in 27 out of 62 (44 percent) mishaps during special operations from FY1989 to FY1998 the pilot would have sufficient time and control of the aircraft to avoid a fixed surface site, such as the Facility. Therefore, in 56 percent of the mishaps the pilot did not have control of the aircraft; R_2 is equal to 0.56. PFS assumed that a pilot, given control of the crashing aircraft and time to avoid the Facility, would actually be able to avoid it in 95 percent of the cases. Only in 5 percent of the cases the pilot would not be able to avoid it, that is, P_{hit} is 0.05. This assumption is based on the same rationale discussed in connection with the estimation of potential risk from F-16s transiting Skull Valley and considers factors such as pilot training and procedure, experience, the flight computer, and the terrain. Therefore, PFS calculated R_1 is 0.44 × 0.05 or 0.02 and R is (0.56 + 0.02) or 0.58.

Based on the estimated values of the parameters C_a, A_c, A_p, and R, PFS estimated the crash probability onto the Facility from air-to-air combat training operations in each of the restricted areas R-6402 and R-6406 using Equation (15-5). The effective area of the Facility, as

calculated in connection with F-16s transiting Skull Valley, remains the same. The estimated crash probabilities for restricted areas R-6402 and R-6406 are 2.6×10^{-8} and 4.8×10^{-8} per year, respectively. Therefore, PFS calculated the total crash probability at the Private Storage Facility site from air-to-air combat training in the UTTR South Area is 7.35×10^{-8} per year.

PFS' analysis of the potential risk of aircraft crash from air-to-air training operations in the UTTR South Area includes some conservative assumptions. PFS used a crash rate for Class A and Class B mishaps during special operations, rather than for destroyed aircraft. PFS used the DOE ACRAM study crash data for Class A and Class B mishaps during special operations and updated it with recent information (after FY1993) from the U.S. Air Force. Additionally, aircraft in air-to-air combat training require space for maneuvering. The shape of the cut-out area for R-6406 near the Facility is quite narrow (Private Fuel Storage Limited Liability Company, 2000b, Tab A). Therefore, aircraft on air-to-air combat training missions most likely will use both areas R-6402 and R-6406. Based on the information from the U.S. Air Force (Private Fuel Storage Limited Liability Company, 2000b), the level of operations in R-6406 is approximately six times that in R-6402. In 1998, there were 6,670 operations in R-6406 compared to 909 operations in R-6402. The low-level of operations in R-6402 reflects that pilots generally do not conduct air-to-air combat training over Dugway Proving Ground. Therefore, it is likely that the number of operations in the cut-out area of R-6406 near the Facility will be substantially lower than used in the analysis. Consequently, the crash probability from air combat training in R-6406 will be lower.

As discussed above, the probability that a pilot with control of the crashing aircraft and time would fail to avoid the Facility is based on qualitative rationale. PFS assumed a probability of 5 percent for such scenarios. The staff carried out a sensitivity analysis with a probability of 10 percent for such scenarios. The resulting estimated crash probability is 7.7×10^{-8} per year using Equation (15-5); this is not a significant change in the estimated crash probability. Therefore, PFS' use of a crash probability of 7.35×10^{-8} per year is acceptable.

As discussed above, PFS calculated the potential crash probability based on the assumption of a glide ratio of 5:1 rather than of the maximum straight-ahead glide ratio for the F-16 of 7 nautical miles per 5,000 ft. The staff carried out a sensitivity analysis to estimate the effect of this assumption on crash probability. As discussed above, increasing the glide ratio will allow more aircraft to reach the Facility. Consequently, the cut-out area from which an aircraft would be able to reach the Facility, A_c, will increase. However, higher glide ratio will also give a larger footprint area, A_p, leading to a lower value of A_{eff}/A_p. Consequently, increasing the glide ratio has two effects that tend to cancel.

PFS estimated the cut-out area from the map for each arc radius. The staff approximated the cut-out area for each altitude band by taking the cut-out area value calculated by PFS for the nearest-matching arc radius. The difference in arc radius is less than 0.15 miles. The estimated probability of crash for both restricted areas R-6402 and R-6406 using Equation (15-5) is 8.3×10^{-8} per year, compared to 7.35×10^{-8} per year estimated by PFS. Therefore, the staff used a crash probability of 8.3×10^{-8} per year as shown in Table 15-7.

The staff reviewed the data, information, and analyses presented by PFS with respect to potential hazards of aircraft conducting air-to air combat training operations in the UTTR South Area. The staff found them acceptable because:

- Based on the U.S. Air Force data, no run-in headings for weapons delivery transit Skull Valley Area. Additionally, the target locations for air-to-ground weapons delivery are more than 20 miles from the Facility.

- PFS used the DOE ACRAM Study Crash data for Class A and Class B mishaps for special operations (Kimura et al., 1996) and updated the crash rate with recent information (FY1994 through FY1998) on mishaps from the U.S. Air Force.

- PFS used the methodology suggested by the DOE Standard (Department of Energy, 1996) to estimate the effective area of the Facility.

- PFS used the basic methodology suggested by Kimura et al. (1998) to estimate the crash probability onto the Facility, modified to exclude mishaps in which the pilot would have sufficient time and control to divert the aircraft away from the Facility.

- PFS used accident reports from the U.S. Air Force to estimate the fraction of mishaps in which the pilot would be able to avoid impacting the Facility. PFS used expert judgment to arrive at the fraction of mishaps where the pilot would be able to divert the aircraft away from the Facility.

- PFS used appropriate Air Force Manuals to carry out the analysis to conclude that a pilot with control and time available would be able to divert the aircraft in most circumstances. The ultimate crash probability is not very sensitive to this probability value, which has been estimated quantitatively.

- PFS used the crash rate of single engine F-16 aircraft as the basis for calculating the probability of crash for all aircraft. As discussed above, this type of aircraft has one of the highest crash rates among military aircraft using the UTTR. Consequently, use of the single engine F-16 crash rates is conservative.

On the basis of PFS' data, information, and analyses, as well as the staff's sensitivity calculations, the staff concluded that air combat training at the UTTR South Area will not pose a hazard to the Facility. Additionally, air-to-ground weapons delivery will not pose a significant risk to the Facility as the targets are more than 20 miles away. Moreover, no run-in headings for delivery of weapons transit Skull Valley.

Aircraft Departing the UTTR via the Moser Recovery En Route to Hill Air Force Base

Military aircraft exiting the UTTR North Area generally proceed east and request radar vectors from Hill Air Force Base Approach Control or use the Causeway 4 Recovery route to return to Hill Air Force Base (Private Fuel Storage Limited Liability Company, 2000b). Aircraft using the Causeway 4 Recovery route fly across the Great Salt Lake. The closest distance between these aircraft and the Private Storage Facility site is at least 57 statute miles (Private Fuel Storage Limited Liability Company, 2000b). Aircraft returning from the UTTR North Area use the Stansbury Recovery route only at night or in marginal weather conditions and when Runway

32 at Hill Air Force is active. The distance between the Private Storage Facility site and this recovery route is 29 miles (Private Fuel Storage Limited Liability Company, 2000b).

Most aircraft returning to Hill Air Force Base from the UTTR South Area exit the northern edge of the range in coordination with Clover Control. They proceed north for radar vectors or fly the Causeway 4 Recovery route for landing at Hill Air Force Base.

The Moser Recovery route may also be used by aircraft returning to Hill Air Force Base. The Moser Recovery route passes within about 2 to 3 miles north of the proposed site at an altitude of 15,000 ft above mean sea level and is an instrument recovery route. This recovery route is used only at night or in marginal weather conditions at Hill Air Force Base and when Runway 32 at Hill Air Force Base is active (Private Fuel Storage Limited Liability Company, 2000b). Runway 32 is oriented in the northwest direction.

Pilots train on the UTTR South Area mostly during daytime and in good weather conditions (Private Fuel Storage Limited Liability Company, 2000b). Consequently, the Moser Recovery route is seldom used. On the basis of information from air traffic controllers, less than 5 percent of aircraft returning to Hill Air Force Base from the UTTR South Area use the Moser Recovery route. Therefore, the number of flights using the Moser Recover route annually is $0.05 \times 5{,}726$, where 5,726 is the number of flights of F-16s to the UTTR South Area per year. This amounts to 286 aircraft per year.

Since F-16s returning to Hill Air Force Base via the Moser Recovery route do not engage in any high-stress maneuvers, the aircraft are in normal in-flight mode. The crash rate for F-16s in normal in-flight mode during FY1989 to FY1998 has been determined to be 2.736×10^{-8} crash per flight mile (Private Fuel Storage Limited Liability Company, 2000b). PFS has assumed that the width of this airway is 10 nautical miles or 11.5 statute miles (Private Fuel Storage Limited Liability Company, 2000b).

PFS (Private Fuel Storage Limited Company, 2000b) has modified the formula of NUREG–0800, Section 3.5.1.6. Aircraft Hazards (Nuclear Regulatory Commission, 1981a) to estimate the annual probability of crash by incorporating a factor R. The factor R accounts for catastrophic events in which the pilot ejects after avoiding the site. The factor R is the summation of factors R_1 and R_2 used in connection with the analysis of potential impact of F-16s transiting through Skull Valley (Eq. 15-4). A similar analysis was performed by PFS for F-16 flights along the Moser Recovery route. On the basis of that analysis, the factor R was estimated to be 0.145.

Using the estimated annual number of aircraft flying along the Moser Recovery route, the probability of a crash per mile, the Facility effective area, and the air route width, PFS estimated the annual probability of a crash onto the Private Storage Facility site to be 1.32×10^{-8}.

The above probability is based on the assumption that a pilot who retained control of a crashing F-16 flying on the Moser Recovery route, would be able to direct the aircraft away from the Facility at least 95 percent of the time. The staff reviewed the information presented on the potential hazard to the Facility. The staff found it acceptable because:

- Appropriate methodologies have been used to estimate the crash probability of F-16 flights returning to Hill Air Force Base using the Moser Recovery route.

- Qualitative judgments specific to the Moser Recovery route, in addition to that given for F-16s transiting through Skull Valley, have been provided to support the assumption that a pilot of a crashing F-16 would be able to avoid the proposed site in 95 percent of the cases.

On the basis of the information and analysis presented, the staff concludes that aircraft returning to Hill Air Force via the Moser Recovery route will not pose a significant risk to the Facility.

Military Helicopters Flying Near the Private Fuel Storage Facility Site

Most of the helicopter flights in the UTTR are in the North Area. PFS indicated that in FY1998, only 91 helicopter flights took place in the UTTR South Area. There are no scheduled helicopter flights transiting Skull Valley (Private Fuel Storage, 2000b).

According to DOE Standard DOE-STD-3014-96 (Department of Energy, 1996), impact frequencies associated with helicopter flights away from the immediate vicinity of their home sites are insignificant. The standard assumes that the lateral variation of helicopter crashes on the average is bounded by 0.25 miles from the centerline of the flight path.

Because there are no regularly scheduled flights through Skull Valley and the site is 2 miles outside the UTTR restricted airspace, the staff concludes that the probability of crash of a military helicopter on the Facility is negligible.

Jettisoned Ordnance from Crashing Military Aircraft

On the basis of the information provided by the U.S. Air Force, almost all of the aircraft that transit through Skull Valley on the way to the UTTR South Area are F-16s. F-16 pilots experiencing engine trouble may intentionally jettison the onboard ordnance and/or other external stores, such as external fuel tanks, in order to lighten the aircraft and reduce drag so as to gain altitude (Private Fuel Storage Limited Liability Company, 2000b). The U.S. Air Force (1999) notes that the ordnance would be in ‘safe’ (unarmed) mode while transiting Skull Valley. The arming sequence for the onboard ordnance starts within the Department of Defense (DOD) land boundaries (Private Fuel Storage Limited Liability Company, 2000b). F-16s carry several different types of ordnance that include inert and live bombs. Inert ordnance does not contain any explosive and will not explode. The U.S. Air Force noted that the possibility of explosion of an unarmed ordnance carried onboard by a crashing aircraft is remote (Private Fuel Storage Limited Liability Company, 2000b). Therefore, the potential hazard to the Facility from inert and unarmed live ordnance is generally from dead weight impact of the ordnance. However, PFS has evaluated this scenario in its analysis. The staff’s evaluation of the analysis is presented below.

PFS has conservatively assumed for this analysis that F-16 flights are uniformly distributed across Skull Valley, although the predominant flight path is along the eastern edge of the valley, away from the proposed site. It is also likely that a pilot would take steps to avoid striking a populated site with jettisoned ordnance. However, the PFS analysis conservatively assumes no such steps have been taken by the pilot (Private Fuel Storage Limited Liability Company, 2000b).

The probability $P_○$ of jettisoned ordnance striking the Private Storage Facility site is calculated using a modified version of NUREG-0800 formula (Nuclear Regulatory Commission, 1981a). Probability of jettisoned ordnance striking both the Canister Transfer Building and the cask storage area are summed to calculate the probability of impacting the Facility. The probability $P_○$ is defined as

$$P_○ = N \times C \times e \times f_o \times W_{sa}/W \times d_{sa} + N \times C \times e \times f_o \times W_{ctb}/W \times d_{ctb} \qquad (15\text{-}6)$$

where,

- N = number sorties per year
- C = F-16 crash rate per mile
- e = fraction of crashes initiated by engine failure
- f_o = fraction of F-16s carrying jettisonable ordnance
- W = width of Skull Valley
- W_{sa} = width of cask storage area
- d_{sa} = length of cask storage area
- W_{ctb} = width of the Canister Transfer Building
- d_{ctb} = length of the Canister Transfer Building.

On the basis of the information provided by the U.S. Air Force, PFS estimated that a total of 3,871 F-16 flights transited through Skull Valley in FY1998 (Private Fuel Storage Limited Liability Company, 2000b). It was determined that some of the training bombs are not rigged to be jettisoned (Private Fuel Storage Limited Liability Company, 2000b). Specifically, BDV-33 bombs are not jettisonable. Hence, they cannot hit the Facility independent of a direct F-16 crash onto the site. In 1998 only 678 F-16 sorties out of a total of 5,726 sorties within the UTTR South Area carried jettisonable ordnance (both live and inert). Hence, the fraction of F-16 sorties with jettisonable ordnance onboard, f_o, is equal to 678/5726 or 0.118.

PFS has calculated $P_○$ assuming the number of sorties through Skull Valley, N, equal to 3,871, the width and length of cask storage area W_{sa} equal to 1,520 ft (0.2879 mi) and 1,590 ft (0.3011 mi), respectively; the width and length of the Canister Transfer Building equal to 100 ft (0.0189 mi) and 260 ft (0.0492 mi) respectively; and the effective width of Skull Valley equal to 10 miles (Private Fuel Storage Limited Liability Company, 2000b). PFS has used a value of 0.90 for e in Equation (15-6). In other words, PFS has assumed that 90 percent of the mishaps involving F-16s transiting Skull Valley will be due to engine failure. Based on Table 15-2, 16 out of 19 mishaps that can reasonably take place in Skull Valley during normal operations (i.e., while transiting Skull Valley en route to the UTTR South Area) are due to engine failure, or a fraction of 0.84. Therefore, an assumption of e equal to 0.9 is bounding. The probability $P_○$ is estimated by PFS to be 9.85×10^{-8} per year using Equation (15-6) (Private Fuel Storage Limited Liability Company, 2000b). Using the width of the Canister Transfer Building at its widest point (200 ft or 0.0378 mi), $P_○$ would increase by 1×10^{-9} per year. Therefore, the staff used a P_o value equal to 1.0×10^{-7} crashes per year in Table 15-7.

The staff reviewed the information provided by the applicant and evaluated the analysis of potential hazards to the Facility from jettisoned ordnance from crashing aircraft. The staff found it acceptable because:

- Activities associated with F-16s transiting Skull Valley with different onboard ordnance have been adequately described.

- Appropriate methodology, following NUREG-0800, Section 3.5.1.6 (Nuclear Regulatory Commission, 1981a), has been used to estimate the crash probability.

- Information on aircraft sorties with different ordnance through Skull Valley has been provided by the U.S. Air Force.

- The estimated probability is conservative, as a uniform distribution of F-16 flights through Skull Valley has been assumed, although the practice is to fly predominantly along the eastern edge.

- The estimated probability is also conservative as the cask storage area has been assumed as a single area with uniform distribution of casks. In reality, the cask storage area is comprised of storage pads with open space in between.

On the basis of this information, there is reasonable assurance that jettisoned ordnance from F-16s hitting would not pose a hazard to the Facility.

Potential Explosion of Jettisoned Ordinance from Nearby Crashes of Military Aircraft

PFS assessed the potential hazards to the Facility from a nearby accidental explosion of ordnance carried by F-16s while transiting Skull Valley. This situation arises when a crashing F-16 impacts the ground near the Facility with ordnance aboard and the ordnance explodes or an aircraft jettisons the ordnance upon experiencing in-flight problems and the ordnance impacts the ground near the Facility and explodes.

Aircraft transiting Skull Valley are not allowed to have the armament switches in a release-capable mode. The switches are ‘armed’ only inside the Department of Defense land boundaries within the Utah Test and Training Range (Private Fuel Storage Limited Liability Company, 2000b). Master arm switches are not actually armed until the aircraft are within the restricted areas of the UTTR, where the bombs are dropped. Therefore, operations essential for ordnance release will not be executed while the aircraft are transiting Skull Valley. The U.S. Air Force (1999) has stated that the Utah Test and Training Range has never experienced “an unanticipated munitions release outside of designated launch/drop/shoot boxes.” Hence, the likelihood of an inadvertent release of armed ordnance is judged to be extremely low. Consequently, the principal source of explosion-induced air overpressure is assumed to be unarmed ordnance that either was jettisoned from an aircraft or was onboard when the aircraft crashed.

PFS has submitted documentation from the U.S. Air Force indicating that the potential for explosion of an unarmed ordnance is remote (Private Fuel Storage Limited Liability Company, 2000b, Tab Q). The Air Force could identify only two instances before 1990 of jettisoned live ordnance exploding upon impacting the ground, although the Air Force does not have records of these two incidents. No other similar accidents have taken place since then.

An exploding bomb could potentially pose two problems to the Facility: (1) hazards posed by bomb casing fragments impinging on storage casks or the Canister Transfer Building, and (2) air overpressure developed from the explosion. On the basis of Regulatory Guide 1.91 (Nuclear Regulatory Commission, 1978), PFS concluded that the hazard posed by casing fragments is exceeded by the hazard posed by the air overpressure created by the explosion of the bombs.

Exploding ordnance impacting the ground near the Facility without directly hitting it may create two types of hazards (Private Fuel Storage Limited Liability Company, 2000b):

- An aircraft carrying live but unarmed ordnance impacts the ground near the Facility and the ordnance explodes. The hazard is due to impacts (including aircraft skidding close to the Facility) and explosions occurring at distances close enough to the Canister Transfer Building or a storage cask to exceed the design-basis air overpressure.

- Live ordnance is jettisoned from a crashing aircraft, impacts the ground, and explodes at a distance close enough to exceed the design-basis air overpressure for a cask or the Canister Transfer Building.

PFS (Private Fuel Storage Limited Liability Company, 2000b) has estimated the probabilities of both of these scenarios, P_{nm1} and P_{nm2}, respectively, using a modified version of the formula in NUREG-0800, Section 3.5.1.6, Aircraft Hazards (Nuclear Regulatory Commission, 1981a).

The probability P_{nm1} of an F-16 with unarmed onboard ordnance crashing sufficiently close to the Facility so as to exceed the design-basis air overpressure is defined as :

$$P_{nm1} = N \times C \times A_{nm1}/W \times f_{1o} \times P_e \qquad (15\text{-}7)$$

where,

N = number of flights per year
C = crash rate of F-16 aircraft per mile
W = width of Skull Valley (i.e., airway)
A_{nm1} = area in which the aircraft could impact and produce air overpressure exceeding the design-basis air overpressure (but does not include a direct impact)
f_{1o} = fraction of F-16s crashing with live ordnance
P_e = probability that an unarmed ordnance onboard a crashing F-16 will explode.

The area A_{nm1} is a band around the outside the effective area of either the cask storage area or the Canister Transfer Building. An aircraft crashing anywhere inside this band with onboard exploding ordnance may cause damage to these structures without the aircraft directly impacting the structures. As before, a conservative assumption has been made that the aircraft is approaching from a direction at which the structures present the largest target for the aircraft to hit. PFS does not add a band area to account for aircraft impacting just behind the Facility as this area is accounted for in calculating the shadow area of the Facility (as shown in Figure 4 of Private Fuel Storage Limited Liability Company, 2000b).

The estimated area A_{nm1} is estimated from (Private Fuel Storage Limited Liability Company, 2000b)

$$A_{nm1} = r_e (L_f + W_f + 2S) + \pi r_e^2 \qquad (15\text{-}8)$$

where,

- L_f = length of either the cask storage area or the Canister Transfer Building
- W_f = width of either the cask storage area or the Canister Transfer Building
- r_e = explosion damage radius
- S = skid distance.

With respect to the second scenario described above (explosion of jettisoned ordnance), PFS has calculated the probability P_{nm2} that live ordnance, jettisoned from a crashing aircraft, impacts the ground and explodes at a point close enough to the casks and the Canister Transfer Building to cause damage. The formula is again a modification of the one given in NUREG-0800, Section 3.5.1.6 Aircraft Hazards (Nuclear Regulatory Commission (1981a):

$$P_{nm2} = N \times C \times A_{nm2}/W \times f_{jlo} \times P_e \qquad (15\text{-}9)$$

where,

- N = number of F-16 flights per year
- C = crash rate of F-16 per mile of flight
- W = width of Skull Valley
- A_{nm2} = area in which the jettisoned ordnance could impact the ground and cause damage to structures
- f_{jlo} = fraction of aircraft crashing that jettison live ordnance
- P_e = probability that an unarmed jettisoned ordnance explodes.

The area A_{nm2} is a band around a structure having a width equal to r_e, the explosion damage distance. The area has been illustrated in Figure 5 of Private Fuel Storage Limited Liability Company (2000b) and is given by

$$A_{nm2} = 2 r_e (L_f + W_f) + \pi r_e^2 \qquad (15\text{-}10)$$

where,

- L_f = length of the structure
- W_f = width of the structure.

PFS (Private Fuel Storage Limited Liability Company, 2000b) has estimated the bomb explosion damage radius using U.S. Army Technical Manual TM5-1300 (U.S. Army, 1990). Figure 2-15 of Technical Manual TM5-1300 provides positive phase shock wave parameters for a hemispherical TNT explosion on the surface at sea level. The U.S. Air Force has informed PFS that the explosives in bombs carried by F-16s transiting Skull Valley are primarily Tritonal, H-6, PBX, or Minol-2. This is discussed below, concerning the appropriate bomb to be used in this calculation.

Although smaller bombs are used in the UTTR, PFS conservatively assumed that all ordnance are 2,000 lb bombs. Furthermore, PFS assumed that all ordnance could be represented by PBX-9407 type bombs, with a content equivalent to 1,075 lb of TNT.

PFS has used a limiting air overpressure equal to 10 psi for the HI-STORM storage casks (Private Fuel Storage Limited Liability Company, 2000b). The staff has performed an independent calculation using a more conservative value of 1 psi, as set forth below. The limiting air overpressure for the Canister Transfer Building is 1.5 psi. On the basis of the information in the U.S. Army Technical Manual TM5-1300, PFS has estimated the explosive radius r_e of a 2,000 lb bomb to be equal to 97.3 ft for an air overpressure criterion of 10 psi. Similarly, for an air overpressure criterion of 1.5 psi, the estimated value of r_e is 338 ft.

Private Fuel Storage Limited Liability Company (2000b) indicates that approximately 5 percent of F-16 sorties in 1998 through Skull Valley carried live but unarmed ordnance.

In the event of an aircraft mishap, the likelihood of a pilot failing to jettison live onboard ordnance is the same as the probability that the pilot would have to eject immediately . This probability is the same as the probability that a pilot while transiting Skull Valley would not be able to attempt to divert the aircraft away from the proposed PFS Facility. As discussed above in connection with F-16 transiting Skull Valley, this probability is 10 percent. Therefore, f_{1o} (fraction of F-16s crashing with live ordnance) is estimated to be 0.05 × 0.1 or 0.005.

Conversely, the fraction of the time that pilots of aircraft transiting Skull Valley would be able to jettison the ordnance is the same as the fraction that would be able to execute avoidance procedures with respect to the Facility, i.e., 90 percent. Therefore, f_{jlo} (fraction of aircraft crashing that jettison live ordnance) is estimated to be 0.05 × 0.9 or 0.045.

As discussed above, the U.S. Air Force identified only two possible instances before 1990 where an unarmed ordnance exploded upon impact with the ground. Therefore, the probability, P_e, of unarmed live ordnance either exploding after impacting the ground when jettisoned or when carried on board a crashing aircraft is remote. PFS has assumed P_e to be equal to 1 percent (Private Fuel Storage Limited Liability Company, 2000b). As indicated by PFS, in the professional judgment of Gen Cole, Gen. Jefferson, and Col. Fly, the assumed explosion probability of 1 percent is conservative.

Assuming length L_f and width W_f of the cask storage area to be equal to 1,590 and 1,520 ft, respectively, and the skid distance S for a crashing F-16 to be equal to 246 ft, based on the DOE Standard DOE-STD-3014-96 (U.S. Department of Energy, 1996), PFS has estimated A_{nm1} and A_{nm2} for the cask storage area to be equal to 0.0136 and 0.0228 sq miles, respectively. Similarly, assuming L_f and W_f (at its widest point) for the Canister Transfer Building to be equal to 260 and 200 ft, respectively, PFS estimated A_{nm1} and A_{nm2} to be 0.0244 and 0.0240 sq miles, respectively. In these calculations, PFS has used r_e for the Canister Transfer Building to be 338 ft and for the cask storage area to be 97.3 ft, as discussed before.

As discussed above, for both the Canister Transfer Building and the cask storage area, P_e is equal to 0.01, f_{1o} is 0.005, and f_{jlo} is 0.045. Using these values PFS estimated P_{nm1} and P_{nm2} for both the Canister Transfer Building and the cask storage area using Equations (15-7) through (15-10):

Cask Storage Area:

$P_{nm1} = 7.20 \times 10^{-12}$ per year
$P_{nm2} = 1.09 \times 10^{-10}$ per year

Canister Transfer Building:

$P_{nm1} = 1.29 \times 10^{-11}$ per year
$P_{nm2} = 1.14 \times 10^{-10}$ per year.

Therefore, PFS has estimated P_{nm1} and P_{nm2} for the entire Facility (i.e., Canister Transfer Building and the cask storage area) by summing the probabilities for each area. Hence, for the Facility as a whole, $P_{nm1} = 2.01 \times 10^{-11}$ and $P_{nm2} = 2.23 \times 10^{-10}$ per year, respectively. Therefore, the probability that live ordnance either carried onboard a crashing aircraft or jettisoned from a crashing aircraft is 2.43×10^{-10} per year (Private Fuel Storage Limited Liability Company, 2000b).

The staff performed a confirmatory calculation to verify that the bomb selected by PFS is representative since the actual composition of the bomb explosives may vary. PFS (Private Fuel Storage Limited Liability Company, 2000b) has estimated a 2,000 lb PBX-9407 bomb as equal to 1,075 lb of TNT, using the methodology given in Technical Manual TM5-1300 (U.S. Army, 1990). However, using Minol-2 as the representative explosive, the staff estimated that a 2,000 lb bomb is equivalent to 1,347 lb of TNT, which exceeds the TNT content used by PFS.

As discussed above, Table 3.6-1 of the SAR (Private Fuel Storage Limited Liability Company, 2000a) specifies that the design and layout of the Facility will ensure that the structures, systems, and components important to safety will not be subjected to more than 1 psi air overpressure from all credible onsite and offsite explosions (Nuclear Regulatory Commission, 1981). The distance R in feet at which detonation of W pound of TNT will produce 1 psi overpressure is given by Equation 15-1, based on Regulatory Guide 1.91 (Nuclear Regulatory Commission, 1978). The staff calculated the radius of explosion damage r_e using Equation 1 of Regulatory Guide 1.91 for a 2,000 lb bomb (TNT equivalent is 1,347 lb) to be $45 \times 1347^{1/3}$ or 497 ft for both cask storage area and the Canister Transfer Building. This r_e value is the same for both casks and the Canister Transfer Building as this is the design criterion specified in the SAR.

Data in Table 4 of Private Fuel Storage Limited Liability Company (2000b) show that in FY1998, a total of 1,085 sorties to UTTR South carried live ordnance. This includes 111 sorties of MK84 2,000 lb bombs, 166 sorties of MK82 500 lb bombs, 4 sorties of AGM-65 Maverick missiles, 4 sorties of CBU-87 1,000 lb cluster bombs, and 800 sorties of BDU-33 25 lb training bombs. It should be noted that a 25 lb training bomb BDU-33 contains a significantly smaller amount of explosive than 500 to 2000 lb bombs. For practical purposes, these training bombs may be ignored in the calculations, as was done by PFS (Private Fuel Storage Limited Liability Company, 2000b). However, the number of sorties with BDU-33 is quite large, compared to other live ordnance (800 sorties versus 111 sorties with MK 84). Therefore, the staff carried out a calculation using 1,085 sorties assuming each sortie was with MK 84 2,000 lb bombs. This assumption is quite conservative.

As discussed above, 3,871 out of 5,726 sorties used Skull Valley to reach the UTTR South Area in FY1998. Out of these 5,726 sorties, only 1,085 sorties carried live ordnance. Therefore, 1,085 × 3,871/5,726 or 734 sorties to the UTTR South Area transited through Skull Valley and also carried live ordnance. This assumes that the ratio of sorties carrying live ordnance to the total number sorties remains the same whether the F-16 used Skull Valley route or not. Consequently, 734/3,871 or 19 percent of flights transiting Skull Valley had some live ordnance onboard.

As indicated above with respect to the PFS analysis, the probability that a crashing F-16 would be able to jettison its ordnance is the same as the probability that the pilot is able to execute avoidance procedures. This was shown to be 0.9. Therefore, f_{1o} is estimated to be 0.19 × 0.1 or 0.019 and f_{jlo} is estimated to be 0.19 × 0.9 or 0.171.

In the staff's calculation, the explosion damage radius r_e is 497 ft, substantially larger than 97.3 and 338 ft estimated by PFS for cask storage area and the Canister Transfer Building, respectively. Moreover, a band area to account for aircraft impacting just behind a facility should be included in the estimation of P_{nm}. The staff assumed the band area behind the facility to be the same as the area in front of it. Hence, the total area of eligible strikes is doubled. This is conservative since the actual area of damaging strikes behind the facility is significantly smaller. On this basis, the probability P_{nm1} increases from 7.20×10^{-12} and 1.29×10^{-10} per year to 3.8×10^{-10} and 1.8×10^{-10} per year for the cask storage area and the Canister Transfer Building, respectively. Hence, the combined probability P_{nm1} for both structures is 5.6×10^{-10}. Similarly, probability P_{nm2} is equal to 2.5×10^{-9} and 8.0×10^{-10} per year for the cask storage area and the Canister Transfer Building, respectively. Therefore, the combined probability P_{nm2} for both structures is 3.3×10^{-9} per year.

On the basis of the above results in the staff's calculation, the probability P_{nm} that live ordnance (either onboard or jettisoned from a crashing aircraft) would explode and damage a spent fuel storage cask or the Canister Transfer Building at the Facility is the sum of P_{nm1} and P_{nm2}. That is, P_{nm} is equal to $5.6 \times 10^{-10} + 3.3 \times 10^{-9}$, or 3.9×10^{-9} per year, compared to the PFS estimate of 2.43×10^{-10} per year.

This estimated probability is quite conservative, as it assumes all 1,085 F-16 sorties carried MK 84 2,000 lb bombs. In reality, approximately three-fourths of the sorties carry only 25 lb training bombs which contain a small amount of explosive compared to the MK 84. Also, as indicated by PFS (2000b), the probability will be still relatively small if P_e is assumed arbitrarily to be 10 percent.

The staff reviewed the information and analysis presented concerning the explosion of jettisoned ordnance. The staff also carried out a conservative analysis assuming all F-16 sorties carry the bomb with the largest amount of explosive. The staff found the information and analysis presented by PSF to be acceptable because:

- The applicant has used an acceptable methodology to analyze the explosion hazard of jettisoned ordnance.

- The applicant has provided adequate information about the jettisoned ordnance.

- A conservative estimate of the potential hazard from jettisoned ordnance shows that the hazard is insignificant.

- A tenfold increase in the probability of explosion of unarmed jettisoned ordnance (from 1 percent to 10 percent) would still not present a hazard to the Facility.

- A confirmatory analysis carried out by the staff assuming all 1,085 F-16 sorties carried MK84 2,000 lb bombs did not show a hazard to the Facility.

On the basis of the information and analysis submitted, and the staff's confirmatory analysis, there is reasonable assurance that the potential explosion of ordnance jettisoned from crashing aircraft would not pose a hazard to the Facility.

X-33 Suborbital Demonstrator Vehicle

No information was presented in the SAR about flights of the X-33 space vehicle to Michael Army Air Field. Cole (1999a,b) presented information on schedules for X-33 flights to Dugway Proving Ground. In addition, websites for the X-33 (http://www.x33.com, http://www.venturestar.com, http://afftc.edwards.af.mil/pdec97/cover/x33_future.html, and http://www.ardmoreite.com/stories/012099/tec-x33.shtml) were also searched by the staff for information about the proposed X-33 test flight program.

The X-33 is a demonstrator vehicle for validating new technologies and reducing the risk for construction of VentureStar, a reusable launch vehicle. It is being jointly developed by the National Aeronautics and Space Association (NASA) and Lockheed Martin Skunk Works, Palmdale, California. As a proof-of-concept vehicle, the unmanned X-33 is one-half the size and one-ninth the weight of VentureStar. The X-33 will not reach orbit altitude and will not carry any payload. The X-33 vehicle has a dry weight of approximately 75,000 lb and a gross liftoff weight with fuel of approximately 285,000 lb. The X-33 will take off vertically like a rocket, eventually reaching an altitude of 60 miles at a speed of Mach 9 to over Mach 13, and will land horizontally like a plane. As many as 15 test flights of the X-33 are planned to originate from Edwards Air Force Base, California, beginning in summer 2000, according to the NASA website. Cole (1999a) reported eight test flights beginning in December 1999. Only the first five flights will go to Michael Army Air field at Dugway Proving Ground, Utah, approximately 450 miles from Edwards Air Force Base. A flight to Michael Army Air field will last 14 min at top speeds of between Mach 9 and Mach 11. These five flights will be completed in a period of 6 mo (Cole, 1999a).

The planned approach for the X-33 flight test is to enter UTTR airspace R6402 at 60,000 ft from the southwest (Cole, 1999a). Once over Michael Army Air Field, the X-33 will initiate a descent turning north with a turn radius of 4–6 miles. It will continue turning until it is lined up with Runway 12, which is 13,125 ft long.

Most of the fuel of the X-33 will be expended by the time of landing. Additionally, the X-33 will not fly over Skull Valley. Moreover, the X-33 testing program will be completed before the Facility will be ready to accept any storage casks with spent nuclear fuel.

Based on the information presented previously, there is reasonable assurance that test landing of the X-33 demonstrator vehicle at Michael Army Air Field will not pose any hazard to the Facility. Consequently, the X-33 demonstrator vehicle may be excluded from the list of potential sources of aircraft crash hazard to the Facility.

Threshold Probability for Aircraft Crash Hazards for Private Fuel Storage Facility

NUREG-0800, Section 3.5.1.6, Aircraft Hazards (Nuclear Regulatory Commission, 1981a) provides the methodology to estimate the probability of crash of aircraft onto a nuclear power plant. An operating nuclear power plant requires active systems to control the dynamic nuclear and thermal processes that occur in the conversion of nuclear reactions into thermal power. In the event of a mishap, there are large amounts of thermal energy within the reactor core. Emergency cooling systems are provided as part of a reactor facility's design to avoid core damage or meltdown and the release of radioactive material into the environment.

Hazards that have the potential for initiating onsite accidents leading to loss of coolant at a reactor facility should have a sufficiently low probability of occurrence. NUREG-0800, Section 2.2.3, Evaluation of Potential Accidents (Nuclear regulatory Commission, 1981b), states a probability of occurrence of approximately 10^{-7} per year as the NRC staff objective, so as to screen out external events that may impact the nuclear reactor and have consequences on the safety of the Facility and the potential for significant radiological impacts on public health and safety. However, data are often not available to permit an accurate estimation of the probabilities of occurrence of the postulated events. Accordingly, pursuant to NUREG-0800, a probability of occurrence of potential radiation exposures in excess of the 10 CFR Part 100 dose guidelines of approximately 10^{-6} per year is acceptable for a nuclear power plant provided, when combined with qualitative arguments, the realistic probability can be shown to be lower (Nuclear Regulatory Commission, 1981). In the Policy Statement on Safety Goals, the Commission noted, "Consistent with the traditional defense-in-depth approach and the accident mitigation philosophy requiring performance of containment systems, the overall mean frequency of a large release of radioactive materials to the environment from a reactor accident should be less than 1 in 1,000,000 per year of reactor operation (Nuclear Regulatory Commission, 1986)." This translates to a probability of occurrence of 10^{-6} per year. In addition, the Commission has proposed an annual probability of occurrence of 1×10^{-6} for geologic repositories (Nuclear Regulatory Commission, 1999).

Compared to a nuclear reactor facility, an ISFSI is a relatively passive system that does not have complex control requirements and that has contents with relatively low thermal energy. Therefore, potential fuel damage and the associated radioactive source terms from a potential accident are significantly less than that expected from a potential accident at a nuclear reactor facility. As a result, the estimated consequences from a potential accident at an ISFSI are less severe than from a potential accident at a nuclear reactor facility. Therefore, the staff concludes that a threshold probability of 1×10^{-6} crashes per year is an acceptable value for evaluating aircraft crash hazards at the PFS Facility.

Summary of Review and Discussion

PFS has examined past and present activities in connection with potential hazards from the crash of both civilian and military aircraft flying in the vicinity of the Facility. The activities

examined include aircraft taking off and landing at Salt Lake City International Airport, aircraft flying routes J-56 and V-257, general aviation aircraft taking off and landing at nearby municipal airports, general aviation aircraft flying nearby, large transport aircraft landing and taking off at Michael Army Airfield, aircraft flying military route IR-420, aircraft transiting through Skull Valley on the way to the UTTR South Area, air-to-ground and air-to-air combat training at the UTTR South Area, aircraft returning to Hill Air Force Base through the Moser Recovery route, military helicopter flights, and flights of the X-33 demonstrator vehicle. PFS also examined the potential hazards associated with jettisoned ordnance carried onboard an aircraft about to crash in Skull Valley. The applicant provided sufficient information and used acceptable methods to evaluate the potential hazard to Facility from an aircraft crash including jettisoned ordnance from a crashing aircraft. The staff reviewed the data, information, and analyses presented along with additional referenced documents, as discussed in preceding sections of this SER. In addition, the staff performed various sensitivity and confirmatory analyses.

Summarizing the staff review, the crash probabilities for aircraft and ordnance are given in Table 15-7. As indicated in the discussion of aircraft hazards within this section, these probabilities are estimated on the basis of several elements that determine the overall likelihood that each specific type of aircraft operation may lead to an impact (or overpressurization) at the proposed Facility. Typically, these include measures that reflect traffic density (e.g., flights per year), a crash rate (e.g., crashes per mile, crashes per unit area per unit time), effective target area, as well as specific parameters pertaining to specific aircraft under consideration (e.g., avoidance probability for F-16s, or the probability of on-board live ordnance being present). Other factors, such as human errors in aircraft design, fabrication, or maintenance, also influence the estimated probabilities, but have not been addressed explicitly since their effects are inherently taken into account through the use of historically established crash rate data.

The estimated crash probability values determined by the staff are listed in Table 15-7. These estimated values may be different than those determined by PFS (Private Fuel Storage Limited Liability Company, 2000b) due to sensitivity or confirmatory calculations performed by the staff. Otherwise, the values determined by PFS have been accepted by the staff as reasonable.

Table 15-7. Estimated Probability of Crashes Per Year at Private Fuel Storage Facility.

Source	Estimated Annual Probability (crashes/year)	
	PFS	NRC
Aircraft taking off and landing at Salt Lake City International Airport	0	~0‡
Aircraft flying route J-56	1.9×10^{-8}	1.9×10^{-8}‡
Aircraft flying route V-257	1.2×10^{-8}	1.2×10^{-8}‡
Aircraft taking off and landing at municipal airports	0	~0 ‡
General aviation aircraft	2.36×10^{-7}	2.36×10^{-7}‡
Aircraft taking off and landing at Michael Army Airfield	0	~0‡
Aircraft flying military route IR-420	3×10^{-9}	~3×10^{-9}
Aircraft transiting Skull Valley	2.05×10^{-7}	2.7×10^{-7} *
Aircraft training at the UTTR South Area	7.35×10^{-8}	8.3×10^{-8} **
Aircraft returning using Moser Recovery route	1.32×10^{-8}	1.32×10^{-8}
Military helicopter	0	~0‡
Jettisoned military ordnance - Impact	9.85×10^{-8}	1.0×10^{-7} †
Jettisoned military ordnance - Nearby Explosion	2.43×10^{-10}	3.9×10^{-9} †
X-33 demonstrator vehicle	0	~0‡
Cumulative Hazard	6.60×10^{-7}	7.40×10^{-7}

* using P_{hit} = 10 percent (assumed value in sensitivity analysis given in Table 15-4)
** using maximum straight-ahead glide ratio
† assuming all live ordnance are MK 84 2,000 lb bombs
‡ no independent sensitivity or confirmatory analysis performed

Based on the information presented in Table 15-7 and the threshold probability criterion of 1×10^{-6} crashes per year, the staff concludes that the probability of crash for both civilian and military aircraft and ordnance at the PFS site is acceptable.

The analyses presented by PFS rely on the assumption that the pilots flying military aircraft are aware of the Private Storage Facility site and will attempt to avoid it. A crashing aircraft will be diverted from the Facility if the pilot is able to control the aircraft and sufficient time is available. The Area Planning Guide of the U.S. Department of Defense (DOD) provides guidance to the planners of military training routes. The guide provides coordinates for all nuclear power plants located in the United States and prohibits low-level overflights below 1,500 ft above ground

level over such facilities. The guide also gives coordinates for radioactive waste sites, such as West Valley, New York; Morris Operation, Illinois; Humboldt Bay, California; and LaCrosse, Wisconsin. However, overflights of these radioactive waste sites are not prohibited based on the relatively low degree of risk. The guide reflects the official policy of the Department of Defense for DOD military flight organizations to be aware of the location of radioactive waste facilities. The guide is updated every 56 days. It is expected that the PFS Facility would be included in the list of radioactive waste sites, if constructed, so that the military flight planners and the pilots would be aware of the presence of the Facility in Skull Valley, Utah.

Future Developments

PFS estimated the projected growth of civilian flights based on the FAA long-range forecast (Federal Aviation Administration, 1999). Commercial aircraft operations include air carrier and commuter/air taxi takeoff and landings at all United States towered and non-towered airports. Based on the FAA forecasts, the commercial aircraft operations are projected to increase from 28.6 million in 1998 to 36.6 million in 2010 and to 47.6 million in 2025. Therefore, commercial aviation operations in the United Stated are projected to increase by 66 percent by 2025.

PFS used the projected growth of national commercial aviation operations to estimate the increase in traffic along airways J-56 and V-257. PFS assumed the number of flights on these airways will increase with the same rate as the total numbers of takeoffs and landings, which is 66 percent by 2025. Therefore, the crash probability increases from 3.1×10^{-8} per year ($1.9 \times 10^{-8} + 1.2 \times 10^{-8}$) to 5.1×10^{-8} per year for aircraft flying routes J-56 and V-257 by 2025.

The annual number of general aviation operations (takeoffs and landings) at all towered and non-towered airports in the United States is projected to increase from 87.4 million in 1998 to 92.8 million in 2010 and to 99.2 million in 2025 (Federal Aviation Administration, 1999). Therefore, the FAA projects an increase of general aviation traffic by 14 percent by 2025. Applying this growth factor to the estimated crash probability of general aviation aircraft, the estimated crash probability by 2025 would be 2.7×10^{-7} per year, as compared to 2.4×10^{-7} shown in Table 15-7.

The FAA predicts that the military air traffic would not increase appreciably, if at all, in the foreseeable future. Based upon the projection of the FAA (Federal Aviation Administration, 1999), the number of military aircraft handled at the FAA en route traffic control centers would remain constant at 4.2 million in 1998 through 2025. Based on Air Force Association information (1999), the number of U.S. Air Force aircraft decreased from 7,640 in FY1992 to 6,228 in FY1998. Similarly, the number of hours flown by the U.S. Air Force decreased from 2,790,000 in FY1992 to 2,154,000 in FY1998. Consequently, military aircraft crash probabilities are expected to remain at or below the cumulative value of 4.7×10^{-7} crashes per year for military aircraft.

As a result of the projected air traffic growth by 2025, the cumulative aircraft crash probabilities from commercial, general, and military aviation would increase from 7.4×10^{-7} crashes per year to 7.9×10^{-7} crashes per year at the Facility.

Conclusion

Based on the information and analysis provided by PFS, the staff concludes that the cumulative probability of a civilian or military aircraft crashing at or affecting the Facility is below the threshold probability criterion of 10^{-6} per year. Therefore, there is reasonable assurance that civilian or military air crashes would not pose a hazard to the Facility.

15.1.2.12 Accidents at Nearby Sites - Multiple Launch Rocket System Testing at Dugway Proving Ground

The staff has reviewed the information presented in Section 2.2.1 of the SAR, Hazards from Facilities and Ground Transportation Dugway Proving Ground and information submitted by PFS (Private Fuel Storage Limited Liability Company, 2000c). Supplemental information presented in Matthews (1999a, b) was also used in this review.

PFS has evaluated the hazard to the Facility posed by the use of the Army's Multiple Launch Rocket System on Dugway Proving Ground (Private Fuel Storage Limited Liability Company, 2000c). The multiple launch rocket system is an artillery rocket launcher mounted on a tracked vehicle. The launcher carries a pod of 12 rockets with maximum and minimum ranges of 32 (20 mi) and 5 km (3 mi), respectively. PFS considered two types of rockets, the M26 and the M28. Based upon the information provided by PFS, only training rockets of type M28 have been fired at Dugway Proving Ground. M28 rockets have the same flight characteristics as the M26 rockets; however, instead of the warhead, an M28 rocket has a spotting charge of three smoke canisters. Based on the Field Manual No. 6-60, which covers both M26 and M28 rockets (Department of the Army, 1996), the region at risk from all debris including payload, warhead skin, and rocket motor at longer firing ranges extends about 4 km (2.5 mi) beyond, 2.2 km (1.4 mi) in front, and 3.22 km (2 mi) on either side of the aim point.

Multiple launch rocket system rockets are designed not to deviate significantly from their intended flight path. The rockets have a target location error of 150 m(0.1 mi) or less (Department of the Army, 1996). The rockets follow a free-flight trajectory to the target without any guidance system. Four fins initially stabilize the rocket by maintaining the spin imparted through spin rails mounted on the inner wall of the rocket launcher.

Field Manual No. 6-60 (Department of the Army, 1996) defines two areas of hazard rear of the multiple launch rocket system firing point. One area is the Launcher Danger area immediately behind the launcher. This area is directly exposed to debris and blast. It extends 350 m (0.2 mi) at both sides and 400 m (0.25 mi) to the rear of the firing point. The other area is the Noise Hazard area extending 500 m (0.3 mi) behind the Launcher Danger area for M28 rockets. Mission essential personnel require double hearing protection if they are in the Noise Hazard area.

Based on Field Manual No. 6-60 (Department of the Army, 1996), there are two areas of hazard in front of the firing point. One area is the region around the aim point which will include all rocket debris and will also contain the rocket if there is any malfunction of the fuse. The other area includes the region between the firing point and closest edge of the area around the aim point that would contain the rocket debris.

PFS has stated that in the last 12 years, multiple launch rocket systems have been tested only twice on Dugway Proving Ground–first in 1988 and then in 1995. PFS also submitted a map showing firing points and three impact areas for training on Dugway Proving Ground for multiple launch rocket systems: the (1) White Sage Impact area, (2) Wig Mountain Impact area, and (3) Causeway Impact area. This map shows several areas marked “Target Grids.” PFS (Private Fuel Storage Limited Liability Company, 2000c) has indicated that these are old target areas and are not impact areas currently in use on Dugway Proving Ground.

During 1988 testing at Dugway Proving Ground, 36 M28 rockets were fired into Causeway Impact area, approximately 60 km (37.5 mi) southwest of the Facility. Some of these rockets were fired from the vicinity of the Wig Mountain area approximately 27 km (17 mi) west-southwest of the Facility. The firing direction from Wig Mountain to the Causeway Impact area is away from PFS toward the southwest. Other rockets were fired from unknown locations on Dugway Proving Ground into the Causeway Impact area. The maximum range of multiple launch rocket system is 32 km (20 mi). For the Causeway Impact area to be within range, the firing locations would be no more than 32 km (20 mi) away from the target area, and therefore, no closer than 28 km (17.5 mi) to the Facility site. Based on the information in Field Manual No. 6-60 (Department of the Army, 1996), firing of M28 rockets would not pose a hazard to a location 28 km (17.5 mi) behind the firing point.

An unknown number of multiple launch rocket system M28 rockets were fired in 1995 from the vicinity of Granite Peak into the Wig Mountain Impact Area. The firing points near Granite Peak are approximately 50 km (17.5 mi) southwest of the PFS Facility site. The aim points are located approximately 33 km (20.6 mi) west-southwest of the site. The Facility is out of range of the multiple launch rocket systems from the firing points near Granite Peak.

No multiple launch rocket system rockets have been fired into the White Sage Impact area in the last 20 years. This area is approximately 30 km (18.75 mi) south of the Facility. The firing direction to this impact area is almost directly away from the PFS Facility site. Based on Field Manual No. 6-60, the firing of M28 rockets would not pose any hazard to a location more than 700 m (2,300 ft) behind the firing line even if multiple launch rocket system rockets are fired into the White Sage Impact area in the future.

The safety procedures used by Dugway Proving Ground DPGR 350-2 (Private Fuel Storage Limited Liability Company, 2000c, Tab B) prescribe that personnel firing artillery be certified for safety. The procedures also dictate that all artillery projectiles must be aimed to fall within the established impact areas. Any impact outside an authorized area should immediately be reported to Range Control who will freeze further firing. The Officer in Charge must know and convey to personnel the established limits on azimuth and elevation to keep the weapon within the designated impact area. The procedures also do not permit the surface danger areas to cross or intersect the boundaries of Dugway Proving Ground. The Officer in Charge or his representative must compute the lateral safety limits, the maximum and minimum ranges, and minimum fuze time using locations of the firing position and target area. This information should be converted to a “Safety T” diagram for each charge and projectile. The Officer in Charge must verify the conversion of the calculated safety data into a safety diagram, which is also verified by a separate command safety certified person. The Chief of Firing Section ensures that proper data for quadrant and azimuth are applied to the weapon system. Before allowing the unit to commence firing, Dugway Proving Ground Range Control will verify the left

and right lateral limits and the maximum and minimum ranges. Regardless of the visibility, the impact of all fired rounds must be observed visually or by radar.

The staff has reviewed the information provided by the applicant with respect to potential hazards from multiple launch rocket system testing at Dugway Proving Ground to the Facility. The staff found it acceptable because:

- The applicant has adequately described the potential hazard from multiple launch rocket system testing based on past records of firing at Dugway Proving Ground, current Dugway Proving Ground procedures, and the U.S. Army manual for multiple launch rocket system operations.

- Dugway Proving Ground safety procedures prescribe that all personnel connected with firing artillery are certified for safety.

- Dugway Proving Ground procedures prohibit the establishment of a surface danger area that crosses the Dugway Proving Ground boundaries.

- The Officer in Charge or his representative must compute the safety limits, which will also be verified by a separate command safety person.

- The Chief of Firing Section ensures that proper data for quadrant and azimuth are applied to the weapon system so that all artillery projectiles are aimed to fall within the established impact area.

- Before allowing the unit to commence firing, the Range Control at Dugway Proving Ground will verify the established impact area.

- The impact of every fired round must be observed visually or by radar. Any impact outside an authorized area should be reported immediately to the Range Control who will freeze further firing.

- Multiple launch rocket system firing to the Causeway Impact Area will not pose any hazard to the Facility because the Facility is outside the range of multiple launch rocket system rockets if they are aimed at the Causeway Impact area. Moreover, the direction of rocket firing to the Causeway Impact Area from the firing points is away from the Facility.

- Multiple launch rocket system firing to the White Sage Impact Area will not pose any hazard to the Facility because the firing direction would be directly away from the Facility. Moreover, based on Field Manual No. 6-60, the Facility is sufficiently distant from the rear of the firing points to have any potential hazard.

- Firing of multiple launch rocket system rockets to the Wig Mountain Impact Area from the firing points near Wig Mountain or the White Sage Training Area will be in a direction away from the Facility.

- Rockets fired from the firing points near Granite Mountain into the Wig Mountain impact area will not reach the Facility because it is beyond the range of these rockets.

The applicant has examined present and past activities in connection with multiple launch rocket system testing at Dugway Proving Ground. The applicant also collected and evaluated information about potential hazards from multiple launch rocket system testing at Dugway Proving Ground. The applicant used acceptable methods to evaluate the potential hazard to the Facility from multiple launch rocket system testing at Dugway Proving Ground.

Based on the foregoing information, there is reasonable assurance that multiple launch rocket testing at the Dugway Proving Ground would not pose a hazard to the Facility.

15.1.2.13 Accidents at Nearby Sites - Chemical Munitions and Agents at Dugway Proving Ground

The staff reviewed the information presented in Section 2.2.1 of the SAR, Hazards from Facilities and Ground Transportation Dugway Proving Ground. Supplemental information presented by Carruth (1999), Larsen (1999), and Gray (1999a, b) was also used in this review. The purpose of this review is to ensure that the risks to the PFS Facility due to activities at Dugway Proving Ground involving chemical munitions and agents are sufficiently low. This review was based on an evaluation of information on the potential hazards, safety procedures adopted to minimize the hazard potential, and the distance from the PFS Facility site to the potential site(s) where the hazard may be initiated.

Since 1969, 50 U.S.C. Section 1512 has prohibited open air testing of chemical munitions (a chemical munition has a chemical agent filling) and chemical agents. Additionally, the U.S. Senate ratified the Chemical Weapons Convention on April 24, 1997, which prohibits any testing of chemical munitions intended to be filled with any chemical agent (Carruth, 1999).

Activities at Dugway Proving Ground include indoor testing of chemical agents, storage of agents and unexploded chemical munitions recovered from the firing ranges, and disposal of chemical agents. Tests are conducted using chemical agents in the laboratories of the Combined Chemical Test Facility and the Material Test Facility at Dugway Proving Ground (Carruth, 1999). These facilities are more than 17 miles from the PFS Facility site. These tests are conducted to determine the effectiveness of protective clothing and equipment, sensitivity of detection equipment, resistance of materials to chemical agents, and effectiveness of equipment and processes to destroy chemical agents and munitions. These facilities are specially designed to preclude any release of chemical agents to the atmosphere such as, maintaining the test areas at negative pressure relative to the outside air to allow fresh air to flow into the test areas and carbon filters to remove any agent in the exhaust air (Carruth, 1999).

Dugway Proving Ground also stores chemical munitions fired prior to 1969 but remained unexploded or buried on the firing ranges prior to 1969 and recovered subsequently (Carruth, 1999). The chemical munitions and chemical agents removed from munitions and the chemical agents used in laboratory testing are stored more than 17 miles from the PFS Facility site. Quantities of chemical agents stored are generally small. Testing and use of the Munitions

Management Device (a device being developed for neutralizing nonexplosively configured chemical munitions) is planned, which will require a RCRA permit. After the permit is obtained, 78 L (2.75 ft^3) of nerve and blister agents will be stored at the Material Test Facility to be used for testing (Carruth, 1999).

The Army Chemical Safety and Chemical Surety Programs have been developed specifically to reduce the hazards associated with storage, transportation, and use of chemical agents and munitions. A leak of agents would be detected by the sampling program at Dugway Proving Ground. Any released liquid chemical agent would be decontaminated before a large pool could accumulate (Carruth, 1999).

The DOD Standard, 6055.9–STD (U.S. Department of Defense, 1997), defines a hazard zone for a chemical munition or agent to be the area within 1-percent lethality distance calculated from the maximum credible event for the installation. As the chemical munitions are stored in an approved storage configuration, they are safe from sympathetic detonation. Consequently, estimation of the 1-percent lethality distance from a single munition is considered appropriate (Carruth, 1999). The 1-percent lethality zone calculated from the maximum credible event represents that arc from the GB agent source containing a dose of more than 10.0 mg-min/m^3 (U.S. Department of Defense, 1997). Carruth (1999) states, based on the types of munitions that might be recovered at Dugway Proving Ground and stored in the designated area, that detonation of an 8 in. projectile filled with agent GB (a nerve agent, according to DOD 6055.9–STD) would produce the greatest hazard distance equal to 4,895 m or approximately 3 mi. The distance of the PFS Facility site from the chemical munition storage area is approximately 17 mi. It is expected that the potential hazard to the PFS Facility site from a worst-case detonation of a chemical munition at Dugway Proving Ground would be reduced further due to the intervening Cedar Mountains enhancing dilution and absorption of the agent. Also, the prevailing wind directions are from north-northwest to south-southeast. Therefore, prevailing winds will retard transport of the chemical agent to the PFS Facility site.

Chemical munitions on the ranges and agents used in laboratory testing are disposed of at Dugway Proving Ground in two ways (Carruth, 1999). If the recovered munition is unsafe to move, it is destroyed with a sufficient amount of explosive so the chemical agent is thermally destroyed by the heat of explosion released by the detonation. Air samples are taken to determine if any agent survived the detonation. An emergency permit is necessary from the Utah Division of Solid and Hazardous Waste for destruction of the chemical munition. Alternatively, the munition is taken to the designated storage location for storage if the munition can be moved safely, in accordance with DOD 6055.9–STD. Chemical agents used in testing are chemically neutralized and the residue is managed as a hazardous waste under the RCRA permit.

Small quantities of chemical agents may be transported to Dugway Proving Ground along Skull Valley Road using a common carrier (Carruth, 1999). Packing of these agents is strictly regulated by the U.S. Department of Transportation (DOT) so that approved containers, designed to withstand transportation accidents, are used. Hazardous waste managed under the RCRA permits at Dugway Proving Ground also may be transported through Skull Valley for permanent disposal or destruction. These chemically neutralized wastes are far less hazardous than the chemical agents. Therefore, transport of small quantities of chemical agents to Dugway Proving Ground or neutralized waste from Dugway Proving Ground would not pose a hazard to the PFS Facility site.

Quantities of chemical agents to be used for laboratory testing are shipped to Dugway Proving Ground from Deseret Chemical Depot via Lookout Pass (Carruth, 1999). This route is less traveled and avoids populated areas. The closest point to the PFS Facility from this route is approximately 17 mi. In addition to strict safety requirements imposed by the DOT, 50 U.S.C. Section 1512 requires that the U.S. Secretary of Defense authorize such shipments in the interest of national security, after advanced notification to the Governor of Utah. A recent shipment of 78 L (2.75 ft^3) of three chemical agents from Deseret Chemical Depot to Dugway Proving Ground was completed under this law. The shipment was made in an escorted truck. The transportation plan of that shipment concluded there was no basis for calculating a release of chemical agents from the shipping containers due to the extraordinary safety precautions taken, controls used on the movement, and the packaging used (Carruth, 1999).

In addition, the storage cask systems are designed to be passive so they can maintain their safety functions without operator assistance. Based on the information available, the staff concludes that there is reasonable assurance that chemical munitions and agents at Dugway Proving Ground will not pose a significant hazard to the PFS Facility.

The staff reviewed the information provided by the applicant and evaluated the analysis of potential hazards to the Facility from chemical munitions and agents at Dugway Proving Ground. The staff found it acceptable because:

- Activities at Dugway Proving Ground with respect to chemical munitions and agents have been adequately described.

- Open air testing of chemical munitions and agents is prohibited by 50 U.S.C. Section 1512.

- The U.S. Senate ratified the Chemical Weapons Convention prohibiting any testing of chemical munitions.

- 1-percent lethality distance calculated for the maximum credible event for Dugway Proving Ground using DOD Standard 6055.9–STD is approximately 3 mi. The distance of the PFS Facility site from the chemical munitions storage area is approximately 17 mi.

- Chemical agents from chemical munitions fired prior to 1969 but remaining unexploded or buried on the firing range are stored under a RCRA permit issued by the State of Utah. A munitions management device is being developed for neutralizing chemical munitions under a RCRA permit.

- Chemical agents used in testing are neutralized and managed as a hazardous waste under the RCRA permit.

- Large quantities of chemical agents for laboratory testing are shipped to Dugway Proving Ground following strict safety requirements of the DOT. The route taken is approximately 17 miles from the Facility.

- Small quantities of chemical agents may be transported to Dugway Proving Ground using a common carrier under strict safety requirements of the DOT.

- The storage cask systems are designed to maintain their safety functions passively without any operator assistance.

The applicant examined present and past activities in connection with chemical munitions and agents at the nearby Dugway Proving Ground. The applicant also collected and evaluated information regarding potential hazards of chemical munitions and agents at Dugway Proving Ground. The applicant used acceptable methods to conclude that chemical munitions and agents at Dugway Proving Ground would not impair the ability of the structures, systems, and components to maintain subcriticality, confinement, and sufficient shielding of the stored fuel.

Based on the foregoing information, there is reasonable assurance that chemical munitions and agents at Dugway Proving Ground would not pose a hazard to the Facility.

15.1.2.14 Accidents at Nearby Sites - Biological Defense Activities at Dugway Proving Ground

The staff reviewed the information presented in Section 2.2.1 of the SAR, Hazards from Facilities and Ground Transportation Dugway Proving Ground. Supplemental information presented in Carruth (1999), Larsen (1999), Matthews (1999a,b,c), and Gray (1999a,b) was used in this review. The purpose of this review is to ensure that the risks to the PFS Facility due to biological defense activities at Dugway Proving Ground are sufficiently low. This review was based on an evaluation of information concerning potential hazard, safety procedures adopted to minimize the hazard potential, and the distance from the PFS Facility site to the potential site(s) where the hazard may be initiated.

Biological materials are tested, stored, and disposed at Dugway Proving Ground. Tests are conducted to determine the effectiveness of different protective equipment and detectors against various biological materials (bacteria, viruses, toxins) (Carruth, 1999). The United States has ratified the Biological Weapons Convention, which prohibits the development, production, acquisition, or retention of biological weapons. All biological defense activities are conducted in the Life Sciences Test Facility, approximately 20 miles from the PFS Facility.

The Life Sciences Test Facility is permitted for Biosafety Level III. This is the protection level for biological materials that may cause serious or potentially lethal disease due to exposure through inhalation (U.S. Department of Health and Human Services, 1999). Vaccine or treatment exists for these materials. Design and procedural controls for a Biosafety Level III Facility allow it to be located in a populated area. The Life Sciences Test Facility is approximately 20 miles from the PFS Facility site, thus mitigating the potential hazard. The biological test program at Dugway Proving Ground is under the oversight of the Utah Governor's Technical Review Committee (Carruth, 1999; Matthews, 1999a).

The containment systems at the Life Sciences Test Facility include maintenance of a negative air pressure (Carruth, 1999; Matthews, 1999a) and use of high efficiency particulate air filters for air circulated through the test areas. Air considered likely to contain dangerous biological materials is also incinerated before it is exhausted to the environment. Guidelines for storing and handling biological materials in the laboratory are provided in U.S. Army Pamphlet 385-69. These guidelines are specifically designed to ensure that the biological materials are controlled and not released to the environment (Carruth, 1999).

Guidance prescribed in U.S. Army Pamphlet 385-69 is followed to destroy biological materials (Carruth, 1999). These guidelines ensure the safe destruction of biological materials and prevent any release to the environment. A scenario involving a release from the Life Sciences Test Facility was evaluated as part of the environmental impact statement of the Facility (Carruth, 1999). Results of this study show that released biological materials would have almost no chance of survival in the environment long enough to be carried to the PFS Facility site, which is almost 20 miles away.

Small quantities of biological materials may be transported to Dugway Proving Ground using a common carrier through Skull Valley Road. Biological materials are normally shipped in accordance with the packaging specifications stated in U.S. Army Pamphlet 385-69. The DOT regulates the shipment of biological materials using a common carrier and approved containers designed to withstand transportation accidents.

Moreover, the storage cask systems are designed to be passive so they can maintain their safety functions without operator assistance. Based on the information available, the staff concludes that there is reasonable assurance that biological munitions and agents at Dugway Proving Ground will not pose a significant hazard to the PFS Facility.

The staff reviewed the information provided by the applicant and evaluated the analysis of potential hazards to the Facility from biological defense activities at Dugway Proving Ground. The staff found it acceptable because:

- Activities at Dugway Proving Ground with respect to biological defense activities have been adequately described.

- Biological defense activities are conducted approximately 20 miles from the PFS Facility site.

- Safety guidance provided in U.S. Army Pamphlet 385-69 is followed to destroy biological materials.

- The environmental impact statement for the Life Sciences Test Facility showed almost no chance of survival of the biological materials in the environment long enough for the materials to be carried to the PFS Facility site almost 20 miles away.

- Small quantities of biological materials may be transported to Dugway Proving Ground through Skull Valley using a common carrier in approved containers with packaging specifications given in U.S. Army Pamphlet 385-69 under DOT regulations.

- The storage cask systems are designed to maintain their safety functions passively without operator assistance.

The applicant has examined present and past activities in connection with biological munitions and agents at the nearby Dugway Proving Ground. The applicant also collected and evaluated information about the potential hazards of biological munitions and agents at Dugway Proving Ground. The applicant used acceptable methods to conclude that biological munitions and

agents at Dugway Proving Ground would not impair the ability of the structures, systems, and components to maintain subcriticality, confinement, and sufficient shielding of the stored fuel.

Based on the foregoing information, there is reasonable assurance that the biological defense activities at Dugway Proving Ground would not pose a hazard to the Facility.

15.1.2.15 Accidents at Nearby Sites - Unexploded Ordnance

The staff reviewed the information presented in Section 2.2.1 of the SAR, Hazards from Facilities and Ground Transportation Dugway Proving Ground. Supplemental information presented by Carruth (1999), Larsen (1999), Hawley (1999), and Gray (1999a,b) was also used in this review. The purpose of this review is to ensure that the risks to the PFS Facility due to unexploded ordnance at Dugway Proving Ground are sufficiently low. This review was based on evaluation of information on the potential hazard, safety procedures adopted to minimize the hazard potential, and distance of the potential site(s) where the hazard may be initiated from the PFS Facility site.

Unexploded ordnance is occasionally recovered on the firing ranges of Dugway Proving Ground. This recovered ordnance includes chemical munitions. In 1979 and 1988, the U.S. Army reviewed its weapons firing records in each test range and test grid to determine the presence of any ground contamination, including unexploded ordnance (Carruth, 1999). A visual survey was also conducted in relevant firing ranges. Any discovered unexploded ordnance was destroyed on location or removed if possible.

Gray (1999b) states that Dugway Proving Ground is still identifying potentially contaminated sites. In 1998, 17 new potentially contaminated sites were identified. According to Gray (1999b), one potential GA (nerve agent) round, two HD (blister agent) rounds, and one GB (nerve agent) round were discovered in preceding two years. This does not include one biological munition discovered in 1999; Larsen (1999) states that a biological munition containing biological simulant (nontoxic) had been found at the Carr Facility of Dugway Proving Ground, more than 17 miles from the PFS Facility.

The quantities of explosive involved with unexploded conventional ordnance at Dugway Proving Ground are too small to develop an air overpressure of 1 psi at the PFS Facility. The distance between Dugway Proving Ground and the PFS Facility site is too large for blast fragments to reach the PFS Facility site. Additionally, the Cedar Mountains will significantly reduce the air overpressure and the range on any flying fragments.

Based on Regulatory Guide 1.91 (Nuclear Regulatory Commission, 1978), an explosion with approximately 147,942 lb of TNT explosive is necessary to develop an air overpressure of 1 psi at a distance of 2,380 ft to the proposed ISFSI. Approximately 10,975 lb of TNT is necessary to develop 1 psi overpressure at a distance of 1,000 ft and approximately 170 lb of TNT is necessary for 1 psi overpressure at a distance of 250 ft. As discussed previously, 1 psi is a conservative estimate for structural damage. The information presented does not indicate that any surface-based weapon system can deliver any munition containing such a large amount of high explosive. It is also noted that the natural terrain and prevalent meteorological conditions will affect the actual air overpressure developed. Even with adverse temperature inversion, the quantity of explosive necessary to develop 1 psi at a distance of 2,380 ft will be substantially

larger than that associated with unexploded ordnance. Therefore, the staff concludes that unexploded conventional ordnance will not produce a hazard to structures, systems, and components important to safety at the PFS Facility.

Figure 1.2-1 of the SAR gives the layout of the restricted area of the Facility. Concrete storage pads will be separated from the restricted area boundary by a distance of approximately 2,000 ft. The staff finds it quite unlikely that unexploded ordnance will be discovered near the PFS Facility site due to the distance to Dugway Proving Ground and the presence of the Cedar Mountains (elevation of 5,300 ft above mean sea level or higher) between Dugway Proving Ground (mean elevation of 4,350 ft above mean sea level) and the PFS Facility site (approximate elevation of 4,465 ft above mean sea level). Moreover, any unexploded and as-yet undiscovered munitions would be found, at least within the restricted area, during construction of the Facility.

According to Carruth (1999), unexploded chemical munitions may be found at the Dugway Proving Ground at the North Wig Grid Area (more than 15 miles to the PFS Facility site), CBR Target Area, and Chemical Corps Board Area. The last two sites are several miles southeast of the North Wig Grid; consequently, they are further from the PFS Facility site. As noted earlier, the U.S. Army reviewed its Dugway Proving Ground weapon firing records and visually surveyed the firing ranges for unexploded ordnance in 1979 and 1988. Any discovered unexploded ordnance was removed or destroyed on location (Carruth, 1999). Due to its rocky terrain, the CBR Target Area is unlikely to have any buried ordnance. Due to the similar nature of the ground at North Wig Grid and Chemical Corps Band Area, these areas are unlikely to have any buried ordnance (Carruth, 1999). In any event, these areas are at a sufficient distance from the Facility to preclude any significant hazard to the Facility.

It is unlikely that chemical ordnance left in the range for more than 30 years will spontaneously detonate (Carruth, 1999). However, Gray (1999a,b) states that the U.S. Army Aberdeen Proving Ground in Maryland has experienced spontaneous detonation of undiscovered chemical/biological munitions. Gray (1999b) also states, “DPG has no record of such explosions, but it is possible they are occurring in remote areas and are simply not being detected.” This statement suggests either spontaneous detonation of undiscovered chemical/biological munitions is not happening at Dugway Proving Ground or the effects are too localized to be detected. Therefore, this information gives reasonable assurance that spontaneous detonation of chemical and biological agents would not produce a hazard to the PFS Facility.

Accidental detonation of discovered ordnance is also unlikely as they are destroyed at the location if too dangerous to handle under an emergency permit issued by the Utah Division of Solid and Hazardous Waste (Carruth, 1999; Larsen, 1999; Gray, 1999a). Because chemical munition is classified and regulated as a hazardous waste by the State of Utah, unexploded ordnance is destroyed using a sufficient amount of explosive [according to Larsen (1999), the amount of explosive used is five times the chemical agent] so that the chemical agent is thermally destroyed. Alternatively, if the ordnance is safe to move, it is taken to a storage location more than 17 miles from the Facility for safe storage under the RCRA permit issued by the Utah Division of Solid and Hazardous Waste (Carruth, 1999; Larsen, 1999; Gray, 1999a) and stored in accordance with DOD Standard 6055.9–STD (Carruth, 1999). All chemical munitions currently stored at the designated location and other recovered chemical munitions that are safe to move will be disposed using the Munitions Management Device currently being

developed for the Nonstockpile Chemical Material Program (Carruth, 1999). Moreover, this operation will be performed under a RCRA permit to be issued by the Utah Division of Solid and Hazardous Waste. Additionally, the hazard zone (1-percent lethality region) is approximately 3 miles downwind of the source of detonation of a projectile filled with nerve agent GB (Carruth, 1999). Prevailing wind directions and the intervening Cedar Mountains will also retard the dispersion of the chemical agents toward the PFS Facility site. Additionally, the storage casks are designed to be passive so they can maintain their safety functions without operator assistance.

Containers filled with chemical agents were disposed in the past at Dugway Proving Ground by burial in the ground (Carruth, 1999). These hazardous materials would not pose a threat to the PFS Facility because there is no credible scenario for clouds of these compounds to reach the PFS Facility site after release from the ground. Moreover, areas contaminated by these chemical agents are regulated by the RCRA permit. Cleanup of these areas is under direct oversight by the State of Utah under RCRA requirements (Carruth, 1999; Larsen, 1999; Gray, 1999a).

Carruth (1999) states that no munitions containing biological warfare agents were discovered at Dugway Proving Ground. However, munitions with the biological simulant *Bacillus subtillis* had been found in the Carr Facility (Carruth, 1999; Larsen, 1999), which is more than 17 miles from the PFS Facility site. Biological simulants are used in testing to simulate the behavior of biological agents in the environment. These simulants, however, do not have the toxicity or infectivity of biological agents (Carruth, 1999). Biological agents, except spores, decay rapidly outside the controlled environment. Moreover, biological munitions are generally quite small and contain a limited quantity of the agent (Carruth, 1999). Therefore, because of the long distance between Dugway Proving Ground and the PFS Facility site, biological munitions, even if they contain spores, would not create a hazard to the PFS Facility. Moreover, the storage cask systems are passive, and their radiological safety functions are unaffected by any biological agent.

The staff reviewed the information provided by the applicant and evaluated the analysis of potential hazards to the Facility from unexploded ordnance and buried containers filled with chemical agents at Dugway Proving Ground. The staff found it acceptable because:

- Activities associated with recovering and destroying unexploded ordnance at the firing ranges of Dugway Proving Ground have been adequately described.

- Quantities of explosive in unexploded conventional ordnance at Dugway Proving Ground are too small to create any air overpressure or blast fragment hazards to the Facility.

- Any potential unexploded ordnance within the restricted area of the Facility will be discovered during the construction.

- Potential unexploded chemical munitions may be found more than 15 miles from the proposed site. The 1-percent lethality distance calculated for the maximum credible event for Dugway Proving Ground using DOD Standard 6055.9-STD is approximately 3 mi.

- Discovered ordnance is destroyed, if it is too dangerous to handle, under an emergency permit issued by the Utah Division of Solid and Hazardous Waste.

- Discovered ordnance that is safe to move is stored under a RCRA permit issued by the Utah Division of Solid and Hazardous Waste.

- Areas contaminated by chemical agents buried in the past are not a hazard and cleanup of these areas are regulated by the RCRA permit.

- No munitions containing biological warfare agents were discovered at Dugway Proving Ground.

- Biological munitions are generally quite small and contain a limited amount of agents.

- The storage cask systems are designed to maintain their safety functions passively without operator assistance.

The applicant has examined present and past activities in connection with unexploded ordnance at Dugway Proving Ground and collected and evaluated information on potential hazards of unexploded ordnance at Dugway Proving Ground. The applicant used acceptable methods to conclude that unexploded ordnance containing conventional explosives, biological and chemical munitions, and agents at Dugway Proving Ground do not pose a hazard to the Facility.

Based on the foregoing information, there is reasonable assurance that unexploded ordnance at the Dugway Proving Ground would not pose a hazard to the PFS Facility.

15.1.2.16 Accidents at Nearby Sites - Hung Ordnance

The staff has reviewed the information presented in Section 2.2.3 of the SAR, The Use of Ordnance on the Utah Test and Training Range (UTTR), and Section X.A., Hung Ordnance (Private Fuel Storage Limited Liability Company, 2000b). Supplemental information presented in response to Round 2 RAI 8-2 (Parkyn, 1998) was also used in this review. The purpose of this review of potential consequences from hung ordnance in practice bombing runs by military aircraft on the PFS Facility is to ensure that the risks due to these scenarios are sufficiently low. This review was based on an evaluation of information concerning potential hazards, safety procedures adopted to minimize the hazard potential, and distance of the potential site(s) from the PFS Facility site where the hazard may be initiated.

Hung ordnance is the term for bombs in an aircraft that fail to release. Parkyn (1998) states that the most common cause of hung ordnance is a malfunctioning cart which separates the bomb from its mount. Ordnance can also get stuck in the mount. Additionally, electrical malfunctioning of the wiring circuits of the armament can cause failure to release the ordnance. Ordnance also will not release if the safing pins are not removed on the ground prior to takeoff for bombing.

Michael Army Air Field is the designated primary recovery base in case of a hung ordnance, although Hill Air Force Base is also available for use by Hill Air Force Base aircraft with secure or unexpended ordnance. Based on the information provided by the U.S. Army Dugway Proving Ground (Brunson, 1999), only five hung ordnance events took place in 1998 resulting in aircraft diversion and recovery into Michael Army Air Field. The same number of cases also occurred in 1997. Most aircraft carry training ordnance, such as Bomb Dummy Units (BDUs) or inert filled or empty Mk82 500 lb bombs. Approximately 15 percent of the 13,367 South and North UTTR sorties flown in FY 1998 carried live ordnance. Therefore, approximately 2,000 of these sorties carried live ordnance in 1998. Because only five hung ordnance events took place in 1998, the probability of hung ordnance is approximately 2.5×10^{-3}/sortie.

The fact that an ordnance fails to release does not mean that there will be an inadvertent release leading to an explosion. The UTTR has not experienced any unanticipated release of ordnance outside the designated launch/drop/shoot boxes (U.S. Air Force, 1999). These boxes are within the UTTR. According to the U.S. Air Force (1999), "All weapons tested on the UTTR go through a comprehensive safety review and risk analysis. Footprints are established using guidelines in AFI 13-212, Volumes I–III or as provided by the customer. The 388 RANS establish Shootcones/Release boxes and all aircraft must adhere to safety parameters established. Currently all non-FTS equipped weapon Shootcones/Release boxes are within restricted airspace over DOD owned lands." Additionally, aircraft flying over Skull Valley are not allowed to have their armament switches in a release capable mode. All armament switches are in safe mode until inside DOD land boundaries (U.S. Air Force, 1999; Private Fuel Storage Limited Liability Company, 2000b). Consequently, hung ordnance will not occur because no attempts to release the ordnance will be made while the aircraft is over Skull Valley. Moreover, each weapon tested on the UTTR has a run-in heading established during the safety review process. No run-in heading is currently over Skull Valley area (Private Fuel Storage Limited Liability Company, 2000b; U.S. Air Force, 1999).

In the event of a hung ordnance, the pilot either can jettison the rack and munitions on the range, if possible, or recover to Michael Army Air Field. The pilot informs Clover Control Air Traffic Control Facility and requests clearance to Michael Army Air Field for recovery and landing with a hung ordnance. The pilot flying the aircraft with a hung ordnance remains in Visual Meteorological Conditions by avoiding clouds. Clover Control provides assistance as required and ensures that Michael Army Air Field is prepared to receive the aircraft with firefighting and medical personnel standing by. The pilot maneuvers the aircraft to the northwest of Michael Army Air Field to avoid any rapid or steep turns and abrupt climbs or descents, test facilities, or any populated areas. The pilot lands the aircraft on Runway 12 at a shallow rate of descent. Therefore, aircraft with hung ordnance do not fly over Skull Valley. Dugway Proving Ground explosive ordnance disposal personnel inspect and safe the bombs (Parkyn, 1998). Hung ordnance events are handled in accordance with aircraft technical orders and applicable AFI. Test procedures are provided in the 388 RANS supplement to AFI 13-212 (U.S. Air Force, 1999).

The staff has reviewed the information provided by PFS and evaluated the analysis of potential hazards to the Facility from hung ordnance in practice bombing runs by military aircraft. The staff found it acceptable because:

- The applicant has adequately described the potential for occurrence of a hung ordnance and procedures adopted for recovery to Michael Army Air Field. Information from the U.S. Air Force has been used in the discussion.

- The UTTR has not experienced any unanticipated release of ordnance outside the designated launch/drop/shoot boxes.

- Aircraft with hung ordnance do not fly over Skull Valley.

- Clover Control provides assistance as required to land the aircraft safely with help from fire fighting and ordnance disposal personnel at Michael Army Air Field.

- Aircraft overflying Skull Valley are not allowed to have their armament switches in a release capable mode.

The applicant has examined present and past activities in connection with hung ordnance and collected and evaluated information concerning potential hazards of hung ordnance. The applicant used acceptable methods to conclude that hung bombs do not pose a significant hazard to the Facility.

Based on the foregoing information, there is reasonable assurance that hung ordnance from nearby facilities do not pose a hazard to the PFS Facility.

15.1.2.17 Accidents at Nearby Sites - Conventional Munition Testing

The staff has reviewed the information presented in Section 2.2.1 of the SAR, Hazards from Facilities and Ground Transportation Dugway Proving Ground. Supplemental information presented in Matthews (1999a, b) and Carruth (1999) was also used in this review.

Testing of conventional weapons and smoke munitions takes place at Dugway Proving Ground by army units for military training including the Utah National Guard. The PFS Facility site is located approximately 9 miles from the northern boundary of Dugway Proving Ground. Carruth (1999) stated that weapons tested at Dugway Proving Ground include 60 and 81 mm mortars, 105 and 155 mm and 8 in howitzers, and guns and rocket systems for helicopters. Dugway Proving Ground may also conduct obscurant munitions testing to measure the effectiveness of dispersal from the munitions and conventional munitions as part of acceptance testing. These tests are conducted on ranges south of Ditto Technical Center (Carruth, 1999). The amount of explosives in these weapons is small compared to more than a million pounds of propellants tested at Tekoi Rocket Engine Test Facility. Consequently, air overpressure generated by these weapon systems would be significantly smaller than 1 psi and, as a result, would not be a hazard to the PFS Facility. Testing of Multiple Launch Rocket System at Dugway Proving Ground has been reviewed separately, in Section 15.1.2.12 of this SER.

Carruth (1999) states that the majority of the munitions testing takes place on the southern part of Dugway Proving Ground with the gun oriented in the south and southwest directions and, consequently, away from the PFS Facility site. Additional test firing is conducted near Wig Mountain on the northern part of Dugway Proving Ground; guns are targeted in the northwest

direction and, as a result, away from the PFS Facility site. Matthews (1999a) also corroborates the firing directions. The distance of the PFS Facility site from Wig Mountain impact areas closest to the PFS Facility site is about 15 miles.

The nominal maximum range for the 155 mm howitzer is approximately 11 miles and for the 8-in. howitzer the nominal maximum range is approximately 9 mi. The nominal ranges for the 60-and 81-mm mortars are comparatively less (Carruth, 1999). It is expected that 105-mm howitzers will have a range similar to the 155-mm and 8-in. howitzers. The range of the Hellfire missile is 3–4 miles (Matthews, 1999a). Even assuming the direction of gun firing in munition tests is toward the PFS Facility site (with the Cedar Mountains in between), the distance to the PFS Facility site is farther than the nominal maximum ranges of these weapons.

Firing of weapons at Dugway Proving Ground is governed by a rigorous set of safety regulations (Carruth, 1999). These regulations prescribe policy and procedures to be followed for safe operation of training ranges. These regulations also prescribe controls to be employed regarding approval of the directions at which weapons are fired and define procedural checks ensuring that range safety controls are met. Firing is conducted only after approval is obtained from the Dugway Proving Ground Range Control Office. This approval is given only for an approved weapon system under prescribed controls on designated and surveyed firing ranges to ensure that munitions fired will not fall outside of their designated impact areas. The Range Control Office of Dugway Proving Ground monitors all range firings to ensure safety of the operations (Carruth, 1999). These safety procedures administered by the Range Control Office provide additional assurance that the structures, systems, and components at the PFS Facility will not be subjected to any undue hazard from weapons testing at Dugway Proving Ground.

The staff has reviewed the information provided by PFS and evaluated the potential hazards to the Facility from conventional munition testing at Dugway Proving Ground. The staff found the information acceptable because:

- The applicant has adequately described the potential hazards from conventional munition testing at Dugway Proving Ground.

- Directions of munition firing at Dugway Proving ground are away from the PFS Facility site.

- Firing of weapons at Dugway Proving ground is governed by a rigorous set of safety regulations.

- Firing is conducted only after an approval is obtained from the Range Control Office at Dugway Proving Ground for an approved weapon system under prescribed controls on designated and surveyed firing ranges.

- The distance to the PFS Facility site is farther than the nominal maximum ranges of these weapons.

PFS has examined present and past activities in connection with conventional munition testing at Dugway Proving Ground. PFS also collected and evaluated information about potential hazards of conventional munition testing at Dugway Proving Ground. Acceptable methods

have been used to evaluate the potential effects of conventional munition testing at Dugway Proving Ground on the Facility.

Based on the foregoing information concerning the potential hazards from conventional munition testing at the Dugway Proving Ground, there is reasonable assurance that conventional munition testing would not pose a hazard to the Facility.

15.1.2.18 Accidents at Nearby Sites - Cruise Missile Testing at the UTTR

The staff has reviewed the information presented in Section 2.2.3 of the SAR, The Use of Ordnance on the UTTR. Information presented in Cole (1999a,b), U.S. Air Force (1999), and Private Fuel Storage Limited Liability Company (2000b) was also used in this review. The staff also contacted U.S. Air Force personnel at Hill Air Force Base.

The purpose of this review is to determine whether the hazards to the Facility from cruise missile testing at the UTTR are adequately determined and acceptable. This review is based on an evaluation of information concerning potential hazards, safety procedures adopted to minimize the hazard potential, and distance from the Private Fuel Storage Facility site to the potential areas where a cruise missile hazard may exist.

The applicant has submitted information regarding planning of the flight trajectory of a cruise missile test on the UTTR, establishment of flight avoidance areas, safety planning and review of the test, additional safety procedures conducted prior to and during the test, and the Flight Termination System (FTS) installed on all cruise missiles.

According to the U.S. Air Force (1999), the cruise missiles tested at the UTTR include (1) AGM-86B Air Launched Cruise Missile (ALCM), (2) AGM-86C Conventional Air Launched Cruise Missile (CALCM), and (3) AGM-129 Advanced Cruise Missile (ACM). Both the AGM-86B and AGM-129 missiles use inert warheads. About three to four cruise missiles of each type are tested in a year. The AGM-86C missile is tested once or twice per year with a live warhead (U.S. Air Force,1999).

According to U.S. Air Force information (1999), an ALCM (AGM-86B) is an autonomous guided weapon system. It flies to a target following complex routes using a terrain contour-matching guidance system. Flight profiles vary but they may utilize all restricted areas and Military Operating Areas (MOA) in the South range, subject to restrictions. Missile profiles that transit from the UTTR South Area to the North Area MOAs (Lucin) exist, but are rarely flown. Flight times vary depending on profile, but generally last 3 to 3.5 hours (U.S. Air Force, 1999).

The conventional air launched cruise missile(CALCM) (AGM-86C) is a variant of the AGM-86 equipped with a live conventional warhead. It can fly complex routes to a target through the use of an onboard Global Positioning System in conjunction with its Internal Navigation System. Flight profiles allow it to fly only in restricted airspace and only over DOD withdrawn lands. Its flight time is approximately 1.5 hours (U.S. Air Force, 1999).

The improved version of the ALCM is the advanced cruise missile (AGM-129). AGM-129 missiles have a greater range and accuracy than AGM-86 missiles. Flight profiles vary but may utilize all restricted areas and MOAs in the South range, subject to restrictions. Missile profiles

that transit from the South range to the North range MOA's (Lucin) exist, but are rarely flown. Flight times vary depending on the profile, but generally last 4 to 5 hours (U.S. Air Force, 1999).

Missiles are launched over Department of Defense (DOD) land west of Granite Mountain and may impact at the Parkersville target complex (TS-1 target), about 5 miles northwest of Wig Mountain. The TS-1 target is approximately 18 miles from the PFS Facility site (Private Fuel Storage Limited Liability Company, 2000b, Tabs A and B). Other cruise missiles with inert warheads launched over DOD land west of Granite Mountain may impact at the Sand Island target complex (TS-4 target) (Enges-Maas,1999a). The TS-4 target is more than 40 miles west of the PFS Facility site (Private Fuel Storage Limited Liability Company, 2000b, Tabs A and B).

All of these weapon systems are fitted with an FTS that is installed prior to testing on the UTTR (U.S. Air Force, 1999). An FTS system is installed on every missile since the missiles have the capability to cross the UTTR land boundaries or endanger range assets, inhabited sites, and sensitive areas. The FTS is required by the U.S. Air Force to be designed, tested, documented, and certified under Range Commanders' Council Standard 319-92 or the latest revision (Private Fuel Storage Limited Liability Company, 2000b, Tab B). Compliance with this standard ensures that the FTS will be compatible with the range systems and procedures. FTSs are certified by the Air Force for the duration of a program in the UTTR. Recertification is necessary if any modifications are made to approved systems, components, or test procedures. An FTS is approved only after acceptance of the FTS report and successful demonstration of the complete system (Private Fuel Storage Limited Liability Company, 2000b, Tab B).

The FTS installed on a cruise missile must detect a signal throughout the duration of flight for the missile to continue flying. Otherwise, it will automatically activate and destroy the missile within 60 seconds. In addition, the missile transmits confirmation signals to Mission Control throughout the flight. The Airborne Range Instrumentation Aircraft and the Range Safety Officer at the Mission Control Center can terminate the missile flight almost instantly.
Cole (1999a) and the U.S. Air Force (1998) state that prior to launching a cruise missile from a bomber, the Mission Control Center verifies that the FTS as well as the flight control systems and the missile's remote control are working properly.

The Air Force uses avoidance as a primary safety measure to protect facilities. Specifically, according to Air Force regulations, pilots are required to avoid occupied sites and no-fly areas by a minimum of one nautical mile. However, a safety buffer of 2 nautical miles has been established by the 49th Test Squadron and 388th Range Squadron to avoid known occupied sites and no-fly areas to minimize risks. Test personnel and chase pilots are informed of the known avoidance areas. Several chase fighter aircraft are assigned to follow a missile throughout its flight path to enhance safety. Chase aircraft remain behind the missile to monitor its performance and heading until the missile impacts the ground.

The flight trajectory of a cruise missile test is selected under the restriction of the range avoidance rule of 2 nautical miles. An extensive test planning process, involving all test participants, is used to prepare for a missile test. The trajectory of the missile is verified by test members and is programmed to remain within the restricted air spaces and MOAs.

A missile is considered to have experienced an uncontrolled crash only if the crash occurred before reaching the programmed target. On the basis of information from the Range Safety Officer, approximately 150 cruise missile tests have been conducted in the UTTR.

Approximately 21 missiles (including some uninhabited aerial vehicles) have been lost in mishaps in the State of Utah since 1983, with two of the mishaps involving the activation of the FTS (Cole 1999a, Banas 1999).

The staff examined the reported or estimated crash locations of cruise missiles and uninhabited aerial vehicles in the UTTR. These locations occurred in general north-south trend, which correlates with the general flight path used in the missile tests (U.S. Air Force, 1999). Moreover, the crash locations cluster near Granite Mountain and Wig Mountain, the intended target sites for the missile tests.

There are two basic modes of malfunction of a test missile: (1) navigation system failure and (2) vehicle system failure. A missile test is aborted either by diverting the missile path or by terminating the missile flight. Generally, the FTS would be activated only if the test data telemetry was downgraded or if a safety-related situation developed. All missile crashes in the UTTR listed by Banas (1999) are characterized as having met the range avoidance criterion. there was no case in which the FTS failed when it was needed to be activated. According to the U.S. Air Force (1999), the UTTR never experienced a FTS failure.

FTS activation and missile diversion is effective only if there is sufficient time available. At low altitude test flights, it may not always be possible to activate the FTS in time to divert a malfunctioning missile away from a non-mission facility. Therefore, the flight trajectory is planned in such a way that a missile crash footprint including debris would avoid any non-mission facilities. The data show that the missiles generally crashed within half-mile or less of the intended flight trajectory. However, one case may have occurred in which the missile crashed more than one-half mile from the flight path (Lightfoot, 2000).

Cole (1999b) provided an excerpt from Accident Investigation Board Report, U.S. Air Force AGM–129, ACM, Serial Number 90-0061 (Department of the Air Force, 1998), about the crash of an AGM–129 ACM on December 10, 1997, near Dugway, Utah. The missile crashed after the completion of Nuclear WSEP test 98-02. The missile hit the ground at the site of a consortium of universities' cosmic ray observatory. Two trailers used for supporting telescope operations were damaged. According to the findings of the report, test planners were unaware of the astrophysical observation trailers on the Cedar Mountains. Therefore, the principal factor responsible for damage occurring to these trailers in this mishap was that the test planners were not informed of the presence of the observatory. The cosmic ray observatory is a non-mission facility located close to the target complex. The mission planners would have programmed the flight path of the missile differently had they been aware of the existence and location of the observatory (Department of the Air Force, 1998).

Another cruise missile crashed in June 1999 in the southern part of the Sevier B MOA on Bureau of Land Management property (Enges-Maas, 1999a). The exact location of this cruise missile crash was not available (Matthews, 1999b). Based on the description from the U.S. Air Force (Enges-Maas, 1999a), an approximate location for this missile would be at least 60 miles from the PFS Facility. According to Matthews (1999c), the missile crashed outside the designated area although the mission was to be completed within the UTTR/Dugway Proving Ground land boundaries. Additionally, Matthews (1999c) states that it is was not clear that a FTS functioned to prevent the missile from exceeding the test boundaries, and either the FTS failed, someone failed to activate it, or it was never installed. The U.S. Air Force has not released any information on this crash. Therefore, it is not possible to state conclusively

whether this particular missile was fitted with an FTS, although the U.S. Air Force uses an FTS on all weapons capable of exceeding the range boundaries. In any event, regardless of whether or not a FTS was present or activated, a malfunctioning missile flight may be aborted by diverting the missile path or terminating the flight. Therefore, it may not be necessary to activate the FTS in every crash if planning of the missile trajectory allows the missile to be diverted to remote locations without violating the range avoidance restriction.

The current standard defines a reliability requirement for the FTS of 99.9 percent at a confidence level of 95 percent. According to the Range Safety Officer, it is not possible to guarantee that the missile being tested would meet the existing range reliability criteria. However, the U.S. Air Force reviews the missile reliability specifications during the safety review process. If the specifications do not meet the current range reliability criteria, compensating measures are implemented to achieve a comparable level of safety.

The 388th Range Squadron of 388th Wing of Air Combat Command is the organization responsible for the UTTR. The 388th Range Squadron testing procedures for cruise missiles, developed by Air Force Flight Test Center, require operational hazard analyses and formal safety reviews of all test programs as well as safety reviews of a particular test mission. Safety review includes an operational hazard analysis comprising 31 steps to minimize risk. These steps include:

- routes planned to avoid property and personnel,
- remote command and control capabilities to steer a missile,
- minimum weather characteristics to ensure chase aircraft can follow a missile,
- airborne range instrumentation aircraft relay of telemetry data to Mission Control Center,
- Mission Control Center real time picture for timely safety decisions,
- remote control system and FTS parameters and plans to keep the missile in safe areas,
- separate components for FTS and missile normal control,
- airborne range instrumentation aircraft relay of telemetry data to let test conductors know if the missile is receiving the FTS signal,
- airborne range instrumentation aircraft monitoring FTS signal to warn Mission Control Center of hazards,
- “what-if” procedures to decide on steps to follow under special circumstances, and
- multiple tracking capabilities monitoring the flight path at all time.

The 49th Test Squadron, responsible for conducting operational tests, specifies additional safety criteria. In addition, the 49th Test Squadron maintains comprehensive lessons learned documentation from previous tests.

The UTTR uses optical tracking, radar tracking, radio and telemetry relay, and ground stations that can transmit either remote control or flight termination instructions to a cruise missile. Transmitters located on the range relay commands from the Mission Control Center. Hence, there are substantial provisions for monitoring and controlling cruise missiles to maintain a low probability of an uncontrolled crash.

As discussed in Private Fuel Storage Limited Liability Company (2000b, Section XIII), the DOD maintains an Area Planning Guide. The guide gives coordinates of all nuclear power plants in the United States along with the coordinates of four radioactive waste sites. The guide is updated every 56 days. Therefore, the mission planners would be aware of the existence and location of the Facility while planning for a flight path of a new cruise missile test. As the Facility will be a non-mission Facility for cruise mission tests, existing test planning procedures would direct the test planners to program the flight trajectories in such a way that the missile crash footprint including debris would avoid the Facility.

A crash of a cruise missile onto the Facility is possible only if there is a series of multiple failures of redundant safety features. As defined by Enges-Maas (1999a), a missile crash is considered "uncontrolled" if it does not reach its intended target. An uncontrolled missile crash is possible only if there are simultaneous failures (e.g., operational or procedural error, component failure) associated with test planning and operations, Range Control Officer and Mission Control personnel, personnel at Airborne Range Instrumentation Aircraft, chase pilots, and the remote control and FTS. The probability of failure or malfunction of each of these elements of the overall system for missile safety and control is small. Therefore, the combined probability of a missile crash onto the Private Fuel Storage Facility site due to the systematic failure of a series of safety features is judged to be extremely low. This conclusion is supported by the missile crash experience described above. Further, an assessment of the cruise missile hazard to the Facility can be made on the basis of historical data by considering the distribution of uncontrolled crash locations. The reported strike locations generally show an approximate orientation in a north-south direction, approximately following the general flight path followed by these missiles. These locations are also generally clustered near the target locations. Hence, the distribution of reported crashes supports the expectation that probability of a crash onto the Facility site is low.

The staff reviewed the information with respect to potential hazards of cruise missile testing at the UTTR. The staff found the information acceptable because:

- Information from the U.S. Air Force was used to determine the number of cruise missile tests carried out annually, targets used in these tests, and location of previous crashes.

- The U.S. Air Force uses avoidance as a primary safety measure to protect facilities. It establishes a 2-mile wide avoidance area from all non-mission facilities and no fly area. Test personnel and chase pilots are informed of the known avoidance areas.

- The U.S. Air Force uses operational hazard analyses and formal safety reviews for all cruise missile tests. Additionally, a comprehensive list of lessons learned is maintained.

- The UTTR, using optical tracking, radar tracking, radio and telemetry relays, and ground stations, monitors missile flights throughout a missile test and provides remote control or flight termination instructions to a cruise missile.

- Redundant and independent missile control is provided through Mission Control and Airborne Range Instrumentation Aircraft.

- Chase pilots verify the performance of the test missile including flight status and location at all times.

- All cruise missiles are fitted with an FTS, which will terminate the missile if it does not receive the radio signal. The FTS also can destroy and terminate the cruise missile flight path on command from the Mission Control Room in case a weapon anomaly is detected.

- Almost all, if not all, previous crashes are within one half-mile from the planned flight path.

- If there is a non-mission facility in the path of a non-functioning missile, the missile will be diverted or terminated to avoid a strike.

- It is expected that cruise missile test planners will be aware of the existence and location of the Facility, if constructed, through the flight avoidance instructions in the Department of Defense Area Planning Guide.

Based on the foregoing information, there is reasonable assurance a cruise missile test at the UTTR will not pose a hazard to the Facility, because (1) the selected impact areas are at substantial distances from the proposed Facility site; (2) several low probability events need to take place before a cruise missile would hit a non-mission target within the UTTR; (3) run-ins for the weapons delivery do not cross Skull Valley; (4) a thorough safety review process is conducted prior to testing; (5) telemetry and chase planes are used to ascertain the flight of the cruise missile; (6) no-fly areas are established during the test; (7) an approved FTS system on all weapons is used; (8) historical data indicate a clustering of the missile strikes in areas in close proximity to intended targets; and (9) the frequency of cruise missile testing is relatively low.

15.1.2.19 Accidents Associated with Pool Facilities

The PFS Facility will use dry storage technology and there will be no pool at the Facility. Therefore, accidents associated with pool facilities is not applicable.

15.1.2.20 Building Structural Failure and Collapse onto Structures, Systems, and Components

Chapter 4 of the SAR evaluates the Canister Transfer Building for response to the design criteria identified in Chapter 3, Design Criteria, of the SAR. The Canister Transfer Building is designed to survive these events. Therefore, a accident involving structural failure of the building is not applicable.

15.1.2.21 Hypothetical Failure of the Confinement Boundary

The HI-STORM 100 MPC is a seal welded pressure vessel, designed, fabricated, and tested in accordance with the ASME Code. The MPCs have redundant welds to ensure that radioactive fuel is confined. The PFS Facility SAR and HI-STORM 100 FSAR have demonstrated that the MPC would maintain its integrity and the fuel would be adequately protected under site-specific and generic design basis normal, off-normal, and accident conditions. As discussed in Chapter 9 of this SER, the dose (at the owner controlled area boundary) calculated from a hypothetical failure of the confinement boundary is below the dose limits specified in 10 CFR 72.106(b).

15.2 Evaluation Findings

The applicant has provided acceptable analyses of the design and performance of structures, systems, and components important to safety under credible off-normal events and accident scenarios. The off-normal events analyzed by PFS included a cask drop from less than the design allowable height, partial vent blockage, and operational events. The accident events analyzed by PFS included cask tipover, cask drop, flood, fire and explosion, lightning, earthquake, loss of shielding, adiabatic heatup of the cask, tornadoes and missiles generated by natural phenomena, accidents at nearby sites, building structural failure and collapse onto structures, systems, and components, and a hypothetical failure of the confinement boundary. Hazards from nearby sites that were considered include offsite explosions, aircraft crashes, and other potential hazards from nearby military facilities.

The applicant's analyses of off-normal and accident events demonstrate that the PFS Facility will be sited, designed, constructed, and operated such that during all credible off-normal and accident events, public health and safety will be adequately protected. Based on the applicant's analyses and the staff's foregoing evaluation, the staff finds that the PFS Facility will maintain subcriticality, maintain confinement and provide sufficient shielding for all credible off-normal events and accident scenarios.

15.3 References

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