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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D.C. 20555-0001

OFFICE OF THE
GENERAL COUNSEL

November 13, 2001

G. Paul Bollwerk, III, Chairman
Administrative Judge
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dr. Peter S. Lam
Administrative Judge
Atomic Safety and Licensing Board
U.S. Nuclear Regulatory Commission
Washington, DC 20555

Dr. Jerry Kline
Administrative Judge
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U.S. Nuclear Regulatory Commission
Washington, DC 20555

In the Matter of
Private Fuel Storage L.L.C.
(Independent Spent Fuel Storage Installation)
Docket No. 72-22-ISFSI

Dear Administrative Judges:

In accordance with the schedule set forth in the Licensing Board's "Order (General Schedule Revision)," dated September 20, 2001, enclosed please find the NRC Staff's supplement to its Safety Evaluation Report ("SER") for the Private Fuel Storage Facility, issued on September 29, 2000, pertaining to aircraft crash hazards. This supplement includes the following revised SER sections, which replace the corresponding sections in the Staff's SER of September 29, 2000:

1. Revised § 15.2.2.11 ("Accidents at Nearby Sites - Aircraft Crash Hazards");
2. Revised § 15.1.2.18 ("Accidents at Nearby Sites - Cruise Missile Testing at the UTTR"); and
3. Revised § 15.3 ("References").

Copies of the enclosed documents are also being transmitted by electronic mail.

Sincerely,

Sherwin E. Turk

Sherwin E. Turk
Counsel for NRC Staff

Enclosures: As stated
cc w/Encl.: Service List

15.1.2.11 Accidents at Nearby Sites - Aircraft Crash Hazards

The staff has reviewed the information presented in SAR Section 2.2 (Private Fuel Storage Limited Liability Company, 2001a) and the report, Aircraft Crash Impact Hazard at the Private Fuel Storage Facility (Private Fuel Storage Limited Liability Company, 2000b). In addition, the staff has reviewed information presented by PFS in response to the staff's requests for additional Information (Private Fuel Storage Limited Liability Company, 2001b, c, d, e). The staff review also included a crash hazard analysis for the X-33, a suborbital demonstrator vehicle (Cole, 1999a, b). 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 II.1 of NUREG–0800, Section 3.5.1.6, Aircraft Hazards provides three screening criteria that must be satisfied to conclude, by inspection, that the aircraft hazards at a nuclear power plant are less than 1×10^{-7} per year for accidents that could result in radiological consequences greater than 10 CFR Part 100 exposure guidelines. The staff review indicates that the proposed Facility site does not satisfy screening criterion II.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." It fails to satisfy this criterion because the number of flights to the Utah Test and Training Range (UTTR) transiting Skull Valley was 3,871 in FY 1998 and 5,757 in FY 2000. 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 from 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 is about 50 statute miles northeast of the Private Fuel Storage Facility site (Cole, 1999a). The North-South alignment of the runways at Salt Lake City International Airport places the Facility away from the takeoff and landing segments of flights departing from and arriving at Salt Lake City International Airport. In 1998, a total of about 365,000 takeoffs and landings took place at Salt Lake City International Airport (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 will increase from 385,000 in FY 1997 to 552,000 in FY 2021. According to screening criterion II.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 mi 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 Salt Lake City International Airport are well below the $1000 \times D^2$ criterion. Hence, the probability of an aircraft crash on the proposed Private Fuel Storage Facility site due to operations at Salt Lake City International Airport is significantly smaller than 1×10^{-7}. 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 well beyond 10 mi from the runway. However, historical data on crash locations suggest that the crash probability of an aircraft in this mode decreases to a negligibly small value beyond 10 mi 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

High altitude jet route J-56 passes 11.5 statute miles north of the Private Fuel Storage Facility site. It has a maximum 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. 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 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 Victor route 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 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, 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 a crash is significantly less than 1×10^{-7} 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

There are no airports within 15 mi of the PFS site. The nearest airport used by General Aviation aircraft is the Bolinder/Tooele Valley Airport, 26 statute miles east-northeast of the proposed site. In order to exceed the screening criterion II.1(a) of Section 3.5.16 of NUREG–0800 (Nuclear Regulatory Commission, 1981a), Bolinder/Tooele Valley Airport would have to sustain over 723,610 operations per year. Currently, the airport handles about 57 operations per day (www.airnav.com), or 20,805 operations per year. Hence, the risk to the proposed PFS Facility from General Aviation activities associated with this airport is less than 1×10^{-7} per year. Similarly, staff review indicates that none of the other airports beyond 10 mi of the proposed PFS site have annual operations in excess of the NUREG–0800, Section

3.5.1.6 acceptance criterion. On this basis, the General Aviation hazard with respect to the proposed PFS site is judged to be insignificant.

The applicant has provided information and analyses that give additional support to the above observations regarding General Aviation hazards to the proposed PFS Facility. The Private Fuel Storage Facility site is located in the Sevier B Military Operating Area (MOA), which is adjacent to restricted airspace areas R-6406 and R-6402. Civilian aircraft are prohibited from flying through these restricted areas. Additionally, General Aviation flights through the MOA will be limited when it is used by the U.S. Air Force. Therefore, the opportunity for General Aviation aircraft flying over or near the proposed PFS Facility site is limited. PFS previously used national statistics for General Aviation. In the revised analysis, PFS instead considered the observed level of flight activity in the area. It should be noted that this category does not include business jets, which fly through federal airways rather than through the Sevier B MOA and Skull Valley. These flights are accounted for in the data for federal airways.

The expectation of a low General Aviation traffic density in the vicinity of the proposed Facility is supported further by the personal observations and experience of PFS expert Colonel Ronald Fly and Lieutenant Colonel Dan Phillips, who have flight experience in the vicinity of the proposed PFS Facility. They stated that they never had any indication of such aircraft flying in Skull Valley (Private Fuel Storage Limited Liability Company, 2000b). Additionally, Lieutenant Colonel Hugh Horstman (ret.), a State of Utah expert, who also has flight experience in the vicinity of the proposed PSF Facility, estimates the level of General Aviation traffic through Skull Valley to be "minimal."[1] Pilots flying General Aviation aircraft tend to transit through Rush Valley on the eastern side of the Stansbury Mountains (Private Fuel Storage Limited Liability Company, 2001b). The low altitude sectional aeronautical chart for Skull Valley specifically directs any General Aviation pilot to contact Clover Control at Hill Air Force Base before transiting the MOA. Clover Control, which controls flights over the MOAs and restricted airspaces over the UTTR South area, does not have any record of General Aviation flight through Skull Valley (Private Fuel Storage Limited Liability Company, 2000b) and such flights are believed to be very limited in number.

The staff concludes that the annual number of General Aviation aircraft flying in Skull Valley is quite low when compared to areas that do not have military aviation restrictions.

On the basis of the above considerations regarding the relatively low General Aviation aircraft traffic in Skull Valley, PFS views the General Aviation hazard to the proposed facility to be small. Nevertheless, PFS provided an analysis to quantify the risk due to potential General Aviation accidents in Skull Valley. Specifically, PFS considered the General Aviation accident rate, the traffic frequency, the airway width in the vicinity of the site, and the crash target area. In addition, PFS took into account the design features of the facility with respect to tornado missile protection requirements. As discussed in Section 15.1.2.9, Tornadoes and Missiles Generated by Natural Phenomena, of this SER, both the HI-STORM 100 storage cask and the Canister Transfer Building are designed to withstand appropriate design-basis tornado missiles.

The estimated crash rate per flight mile for fixed wing, powered General Aviation aircraft during the cruise mode of flight (as distinct from landing and taking off, as discussed above) is based

[1] Horstman deposition (December 11, 2000) at pages 220-22.

on the information presented in Kimura et al. (1996). Kimura et al. (1996) reported a total of 2,783 crashes during 1986 through 1993 and estimated a crash rate of 1.51×10^{-7} per flight mile. Out of 2,783 crashes, only 705 or 25.3 percent of crashes resulted in fatalities. PFS assumes that the pilot flying in a General Aviation aircraft would be a casualty if the crash results in a significant impact (i.e., a head on impact). Therefore, PFS considered only those General Aviation aircraft crashes that resulted in a fatality. On this basis, the General Aviation crash rate in cruise mode was estimated to be approximately 3.82×10^{-8} per flight mile.

Because accurate information on General Aviation traffic in Skull Valley is not available, PFS estimated the number of flights required to develop a crash probability of 1×10^{-7}, 1×10^{-8}, and 1×10^{-9} per year. The staff reviewed the PFS analysis and determined that there is reasonable assurance that the probability of a General Aviation aircraft crashing onto the proposed Facility is equal to or less than 1×10^{-8} per year.

With respect to storage casks, PFS carried out additional analysis to demonstrate that a General Aviation aircraft crash will not cause any significant penetration of the storage canisters. The staff has determined that the PFS analysis is conservative.

In addition, PFS considered the hazard associated wtih spent fuel canisters during cansister transfer operation. The annual probability that the Canister Transfer Building would be hit by a General Aviation aircraft during a canister transfer operation is no more than approximately 1×10^{-10}.

The staff performed an independent assessment of the General Aviation aircraft hazards with respect to the proposed Facility and found the risk to be within the acceptance criteria of NUREG-0800, Section 3.5.1.6. In addition, the staff reviewed the data and analyses presented by PFS with respect to crash potential of General Aviation aircraft onto the proposed Facility. The staff found them to be acceptable because:

- Adequate information has been presented to describe the potential hazards.
- PFS used the methodology of the DOE Standard (U.S. Department of Energy, 1996) to estimate the effective area of the Facility.
- PFS used crash information from the DOE Aircraft Crash Risk Analysis Methodology (ACRAM) Study (Kimura et al., 1996).
- PFS took into account the protection provided by the Facility's tornado missile design-basis protection in examining the risk of an on-site General Aviation aircraft crash.
- The proposed site is located within Sevier B MOA and is only 2 mi from a restricted airspace. Also, it is located at a distance from major population areas that have higher densities of General Aviation aircraft operations. Consequently, the General Aviation aircraft traffic density in the area is expected to be significantly less than the nationally based average.

- F-16 pilots who regularly flew through the airspace over the proposed site characterize the number of General Aviation aircraft as infrequent and, at best as "minimal."

On the basis of the staff's review, as well as the information and analysis presented by the applicant, there is reasonable assurance that General Aviation aircraft would not pose a significant crash hazard to the proposed 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 Salt Lake City International Airport 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 mi 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 mi, this amounts to 289,000 operations per year for the crash probability to be larger than 1×10^{-7} per year. The U.S. Army has indicated, however, that only approximately 1,929 flight operations took place at Michael Army Airfield in FY 2001 (Private Fuel Storage Limited Liability Company, 2001c). Hence, aircraft crash hazards associated with Michael Army Airfield operations are well within the acceptance criterion.

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:

- Adequate information has been presented to describe the potential hazards.
- 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) information 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 an unacceptable hazard to the proposed Facility. The crash probability from military aircraft using the Michael Army Air Field will be significantly less than 1×10^{-7} per year, and its contribution to the cumulative overall crash probability can be neglected.

Aircraft Flying in 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 and terminates at the northern boundary of Sevier B MOA. PFS assumed that all aircraft traffic, except for F-16s, flying to and from Michael Army Airfield in the vicinity of the proposed Facility site (Private Fuel Storage Limited Liability Company, 2001c), used IR-420.

Michael Army Airfield has stated that 89 percent of flight operations at the airfield involve aircraft from Hill Air Force Base (Private Fuel Limited Liability Company, 2001c). The majority of these operations are F-16 fighters conducting "recurring training" on approaches and landings. In addition to F-16s, military and civilian cargo aircraft, such as C-5, KC-10, C-141, C-130, C-21, C-17, C-12, and Boeing 727, fly to and from Michael Army Airfield (Private Fuel Limited Liability Company, 2000b, 2001c).

F-16s using Michael Army Airfield often fly directly from the UTTR South area ranges without using route IR-420. Also, F-16 aircraft flying directly from Hill Air Force Base to Michael Army Airfield already have been considered in the analysis and estimation of the crash probability for military aircraft transiting Skull Valley.

Therefore, for estimating the crash hazard to the proposed Facility due to aircraft flying route IR-420, only transport and large aircraft similar to commercial civilian aircraft need to be considered. Large multi-engine military cargo aircraft are similar to commercial airliners. PFS has indicated that crash data for destroyed military cargo aircraft compare "very favorably" to those for civilian commercial aircraft (Private Fuel Storage Limited Liability Company, 2000b).

PFS analyzed U.S. Air Force accident reports for mishaps involving large militay cargo aircraft during FY1989 through FY1998. PFS concluded that no destroyed aircraft mishaps took place under circumstances representative of flying in airway IR-420 (Private Fuel Limited Liability Company, 2000b). For example, some of these mishap circumstances 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. According to Major General Wayne O. Jefferson, USAF (Ret.), a former B-52 wing commander, none of the aircraft was 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 for large military cargo aircraft to be reasonable.

PFS argued that a Class A or Class B mishap can 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 with one of the engines. As the pilot 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, which the nearest airport is too far away to attempt a landing, the pilot would have an opportunity to guide the aircraft away from a facility such as the PFS Facility. Consequently, using Class A and Class B mishap data would significantly overstate the crash rate for multi-engine military cargo aircraft. Based on this

assessment, the staff finds PFS use of destroyed aircraft class data for calculating the crash probability of multi-engine cargo aircraft to be acceptable.

Using DOE Standard DOE-STD-3014-96 (Department of Energy, 1996), PFS estimated the total effective area of the Facility. Also, based on information from the U.S. Army, PFS estimated approximately 414 flights per year fly along airway IR-420 to and from Michael Army Airfield (Private Fuel Storage Limited Liability Company, 2000b). Using the formula specified in NUREG–0800, Section 3.5.1.6 (Nuclear Regulatory Commission, 1981a) and on the basis of an airway width of 11.5 mi, the probability of crash is estimated by PFS to be 3×10^{-9} per year.

As indicated above, the staff finds use of a commercial airliner crash rate to represent the crash rate of large military cargo aircraft to be reasonable. However, in order to access the acceptability of this assumption, the staff completed a confirmatory analysis using crash data for destroyed large military cargo aircraft. There were 6 crashes with destroyed aircraft from FY 1989 to FY 1998 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} mi 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 mi in every hour of flight in this period. Assuming that the average speed of these cargo aircraft did not change from FY 1989 to FY 1998, the estimated crash rate is 3.66×10^{-9} per flight mile. This is about a factor of ten higher than the crash rate for commercial aviation. However, 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 involved flight conditions not found on IR-420. Therefore, the actual specific crash rate is expected to be much less than 3.66×10^{-9} per flight mile. Given this, the staff finds that the use of the NUREG–0800 value of 4×10^{-10} crashes per mile is appropriate. Therefore, the staff accepts PFS onsite crash probability of 3×10^{-9} crashes per year as a reasonable estimate.

A total of 1,929 flight operations took place at Michael Army Airfield in FY 2000 (Private Fuel Storage Limited Liability Company, 2001c). It should be noted that a flight by a single aircraft to Michael Army Airfield may represent more than one flight operation, as the pilot may engage in repeated approaches and landings as part of flight training. Each of these activities would be counted as a separate operation (Private Fuel Storage Limited Liability Company, 2001c). Assuming 89 percent or 1,717 flight operations were associated with aircraft from Hill Air Force Base, as reported by Michael Army Airfield, the remaining 212 operations were by aircraft from other airfields and could have approached Michael Army Airfield from any direction. The inherent assumption is that each operation at Michael Army Airfield is equivalent to one aircraft flight in route IR-420, which results in a conservative over-statement of the number of aircraft using IR-420. As stated before, the majority of the 1,717 flight operations would have been by F-16s from Hill Air Force Base and have been accounted for in estimating the crash probability for transiting Skull Valley. A small proportion of the 1,717 operations was conducted by non-F-16 aircraft from Hill Air Force Base. PFS concludes that the proportion of flights that do not fly near the proposed Facility would offset the proportion of non-F-16 flights from Hill Air Force Base. Consequently, the assumption of 212 flights by aircraft other than F-16s originating at Hill Air Force Base would be reasonable (Private Fuel Storage Limited Liability Company, 2001c). PFS has used 414 flights through IR-420 in FY 1998 in the crash hazard estimation, which is conservative (Private Fuel Storage Limited Liability Company, 2001b).

The staff reviewed the data and analysis presented by PFS with respect to the potential hazards of large transport aircraft flights in military airway IR-420 to and from Michael Army Airfield. The staff found them to be 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 the relevant aircraft from the U.S. Air Force to justify the crash rate used in the analysis.
- PFS used the methodology of the DOE Standard (U.S. Department of Energy, 1996) to estimate the effective area of the Facility. As discussed in connection with the analysis of 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 (Nuclear Regulatory Commission, 1981a).

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 credible 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 mi 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 for each of these groups and the estimated probability of aircraft crash onto the proposed Facility are 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 FY 1998 were F-16s. (This information was later updated, as discussed below.) 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 proposed Facility location, the Sevier B MOA extends approximately 2 mi to the west of the site and 10 mi 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 ft 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 only under visual meteorological conditions, that is, clear of clouds with at least 5 mi 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 (U.S. 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 rate for F-16s for 1975 through 1993. PFS used this 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 the number of crashes per 100,000 hr of flight. PFS estimated the crash rate on a per mile basis 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 FY 1975 to FY 1993 with data from FY 1994 to FY 1998. Hence, PFS used the crash rate based on the last 10 years data (i.e., from FY 1989 to FY 1998). 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. 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 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 F-16 crashes due to engine failures from those due to other causes, the formula was resolved into two components, as follows:

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

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, since these analyses best 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). Additionally, military aircraft such as the F-16 normally are destroyed in a crash landing on terrain other than an airfield runway. In view of the above, the staff finds the use of the data set consisting of mishaps with destroyed aircraft in the analyses to be appropriate.

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 (U.S. Department of Energy, 1996). As discussed in connection with jet route J-56, the DOE Standard for estimating the effective target area is consistent with the NRC guidelines given in NUREG–0800, Section 3.5.1.6, Aircraft Hazards (Nuclear Regulatory Commission, 1981a). The staff finds the PFS estimation of the effective area to be acceptable.

At the latitude of the Facility, the Sevier B MOA east-west width is about 12 mi. However, the F-16s are required to fly higher than 1,000 ft above ground level and below 9,500 ft mean sea level in the Sevier B MOA. These limitations, coupled with the presence of the Stansbury Mountains, make it impractical and unlikely for F-16s to fly in a small portion of the easternmost 2 mi of the Sevier B MOA (Private Fuel Storage Limited Liability Company, 2000b, Figure 1). Therefore, PFS has used 10 mi as the width of the airway for estimating the crash probability.

PFS obtained 126 F-16 aircraft Class A accident investigation reports, conducted under Air

Force Instruction (AFI) 51–503, (Private Fuel Storage Limited Liability Company, 2000b). Of these, 117 reports involved 121 destroyed aircraft.

PFS analyzed the F-16 accident reports using three different approaches. Specifically, three subsets of the original data set were developed to estimate the fraction of accidents in which the pilot would be able to avoid the proposed Private Fuel Storage Facility site. Each data subset provided a different perspective. The three approaches to analyze the original data set are described in the following discussion:

(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, or 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 gravity-induced loss of consciousness. These types of mishaps may occur during the 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 could equally likely occur in Skull Valley. PFS also included in this population those mishaps that occurred during taking off and landing but were not attributable to the unique circumstances associated with these events.

(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 evaluated in this group that are encountered by all F-16s transiting the Sevier B MOA near the Facility include altitude (between 1,000 to 5,000 ft above ground level), speed, weather (typically visual meteorological conditions clear of clouds with visibility at least 5 mi), 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 assessed each accident report to determine:

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

- Cause of the Accident: whether the accident was caused by an engine failure due to a mechanical problem or other 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, Gravity-induced loss of consciousness, spatial disorientation, etc.;

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

    - weather at the time of the initiating event;

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

    - pilot retaining control of the aircraft based on the initiating event.

Based on the results of the evaluation of the three data sets, the panel identified the fraction of mishaps in which the pilot would have been able to avoid a surface site, such as the proposed Facility. The details are summarized 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 PFS 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, that 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. Hence, only 61 out of the 121 destroyed aircraft mishaps were assessed as Skull Valley Type Events by the PFS expert panel (Private Fuel Storage Limited Liability Company, 2000b). Within these 61 Skull Valley Type Events, PFS estimated the number 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 compared to ability 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

On the basis of the analysis conducted for the 61 Skull Valley Type Events by its 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 a surface facility. Specifically, 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 the 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 the Sevier B MOA flight environment that include 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 regarding 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 (Private Fuel Storage Limited Liability Company, 2000b, Tab H). 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 the ACRAM Flight Phase is representative of Skull Valley conditions.

As discussed previously, using three different data subsets PFS has estimated the avoidance probability. PFS concluded that a pilot having trouble with the aircraft would have sufficient time to avoid the PFS Facility approximately 90 percent of the time. This value is based on the mishap histories for the ACRAM Flight Phase and Sevier B MOA Flight Conditions data subsets. Similarly, PFS 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 and since the ACRAM Flight Phase data subset produces the lower bound estimate, the staff has used a value of 90 percent in its review for the avoidance probability.

PFS calculated the probability, P_{hit} in Eq. (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 procedures, 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 Eq. (15-4), is equal to 0.05. In accordance with the definitions presented in Eq. (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.

Based on the estimated values of *N, C, A, W,* R_1, and R_2, discussed above, with 3,871 aircraft flights per year, PFS estimated the crash probability of F-16s transiting Skull Valley to be 2.05×10^{-7} per year for the Facility (Private Fuel Storage Limited Liability Company, 2000b).

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 proposed 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 accepted the PFS crash probability of 2.05×10^{-7} per year for F-16s using FY 1998 sortie information as reasonable. However, the staff conservatively used a P_{hit} value of 0.10 in estimating crash probability.

<u>Additional Analysis</u>

PFS has updated some information given in Private Fuel Storage Limited Liability Company (2000b) and provided additional information regarding F-16 flights through Skull Valley in response to a staff request for additional information (Private Fuel Storage Limited Liability Company, 2001c,d,e). Consequently, the report on aircraft crash hazard assessment has been updated (Private Fuel Storage Limited Liability Company, 2001b). The staff's review of the revised analysis is provided below.

It should be noted that the airspace over Skull Valley, as discussed above, is used for transiting to the UTTR South area. However, the narrow width of Skull Valley with mountain ranges on either side does not provide adequate airspace for large force maneuvering with 12 or more aircraft (Private Fuel Storage Limited Liability Company, 2001e). Consequently, the pilots also use the Sevier D MOA, which ovelies the Sevier B MOA, to transit Skull Valley during large force exercises.

Number of Flights

PFS has provided the F-16 flight information through the Sevier B and Sevier D MOAs for FY 1998 through FY 2000 (Private Fuel Storage Limited Liability Company, 2001c), as given in Table 15-5.

Table 15-5. Number of F-16 flights through Sevier B and Sevier D MOAs (Based on Private Fuel Storage Limited Liability Company, 2001b).

	Sevier B MOA	Sevier D MOA	Total
FY 1998	3,871	215	4,086
FY 1999	4,250	336	4,586
FY 2000	5,757	240	5,997

Both Sevier B and Sevier D MOAs are approximately 145 mi long and extend more than 100 mi south of Skull Valley. The Sevier D MOA overlies the Sevier B MOA. The Sevier D MOA is normally used to transit Skull Valley during large force exercises. Additionally, some flights in the Sevier B MOA may have entered using routes other than through Skull Valley. Based on information from Hill Air Force Base, up to 10 percent of flights in Sevier B MOA do not transit through Skull Valley. Consequently, considering the traffic through the MOAs as equivalent to flights through Skull Valley, as assumed by PFS in the sensitivity analysis (Private Fuel Storage Limited Liability Company, 2001b), is conservative.

PFS has stated, based on information from the U.S. Air Force, that the 388th Fighter Wing at Hill Air Force Base had 54 F-16 aircraft for FY 1998 through FY 2000 (Private Fuel Storage Limited Liability Company, 2001b). The 419th Fighter Wing stationed at Hill Air Force Base had 15 authorized F-16s over the same period. Therefore, a total of 69 F-16 aircraft were stationed at Hill Air Force Base through FY 2000.

An additional 12 F-16 aircraft were assigned to the 388th Fighter Wing in the third quarter of FY 2001. Consequently, the number of F-16 aircraft stationed at Hill Air Force Base has increased to 81 in FY 2001, a 17.4 percent increase (Private Fuel Storage Limited Liability Company, 2001b). An increase in the number of assigned aircraft to the 388th Fighter Wing will result in an approximately proportional increase in the number of pilots and maintenance personnel, financial resources, and flying hours. PFS has stated that an increase in these determining factors would result in a proportional increase in the number of sorties flown by the aircraft stationed at Hill Air Force Base (Private Fuel Storage Limited Liability Company, 2001e). Therefore, the estimated annual number of flights through Skull Valley with 81 F-16 aircraft would be approximately 17.4

percent greater, or 7041. This increase in the number of F-16 aircraft is discussed in this section.

Crash Rate

The staff reviewed factors that may increase the crash rate C, established by PFS, for F-16s flying in normal and special in-flight modes. As discussed before, PFS modified the crash rate of F-16s estimated in the DOE ACRAM study (Kimura et al., 1996) by taking the average of F-16 crashes in 10 years from FY 1989 through FY 1998 (Private Fuel Storage Limited Liability Company, 2000b). PFS stated that given the trend toward lower rates for F-16s and other military aircraft, the ten-year average would be appropriate. The staff specifically examined two factors to determine whether they might increase the crash rate of F-16 aircraft. The factors considered are:

- Bird strike
- Aircraft aging.

The staff reviewed the information submitted by PFS and also obtained information from U.S. Air Force web sites to determine the likelihood of any bird strike in Skull Valley that might increase the crash rate. The staff also carried out an analysis using information from the U.S. Air Force to determine whether aging of F-16 aircraft is manifested in a higher crash rate at later stages of the F-16 aircraft life.

The U.S. Air Force has collected information on all reported bird strikes with aircraft in the database used in the Bird Avoidance Model (www.ahas.com/bam). According to this model, no bird strikes occurred in Skull Valley from 1985 through June 25, 2000, the period for which the data are available (Private Fuel Storage Limited Liability Company, 2001e). There is no large water body near the proposed PFS Facility site to attract a flock of very large birds. Based on the Utah State Division of Wildlife Resources, American White Pelicans and several other species of large birds have been observed seasonally in the Timpie Springs Wildlife area, approximately 25 mi north of the proposed PFS Facility site, at the edge of the Great Salt Lake (Private Fuel Storage Limited Liability Company, 2001e). Canada Geese are also seen in this area. The bird strike closest to the proposed PFS Facility site took place on April 7, 1994. A B-52 bomber struck a sharp-shinned hawk at 600 ft above ground level in restricted area R-6406A, approximately 25 statute miles from the proposed PFS Facility site. The aircraft sustained negligible damage ($726). The next closest bird strike event took place on March 2, 1988. An F-16 struck a vulture at 800 ft above ground level in the UTTR North area, approximately 37 statute miles from the proposed PFS Facility site. The aircraft did not sustain any damage.

All bird strikes within 50 statute miles of the proposed PFS Facility site that are included in the Bird Avoidance Model database occurred below 800 ft above ground level. Approximately 70 percent of all bird strikes occur at or below 1,000 ft above ground level (Private Fuel Storage Limited Liability Company, 2001e). Data from the U.S. Air Force support this conclusion (http://safety.kirtland.af.mil/AFSC/Bash/stats/web_alt_ll.html). In contrast, the Sevier B MOA is at least 1,000 ft above ground level.

F-16s transiting Skull Valley normally fly at 350 to 400 knots. PFS has concluded that the risk of breaking the aircraft canopy windshield is small (Private Fuel Storage Limited Liability Company, 2001e). The U.S. Air Force database on wildlife strikes of all types of aircraft show that the

windshield was penetrated in only 0.3 percent of the incidents (http://safety.kirtland.af.mil/AFSC/Bash/stats/web_impact_stat.html).

If a bird strike occurs near the Timpie Springs Wildlife area, where large birds may be present, and forces the pilot to eject immediately, the aircraft would not be able to reach the proposed site. However, if the aircraft remained flight-worthy, the pilot would recover to a nearby airport. It is, therefore, reasonable to conclude that F-16s incurring large bird strikes in this area would not be flying through Skull Valley near the PFS Facility.

The staff at Hill Air Force Base also indicated that the likelihood of a damaging bird strike occurring in Skull Valley is so low that it is normally not a part of mission planning. The mission planners would take appropriate measures, such as selection of alternate altitudes, if returning sorties report bird strikes. Therefore, it is reasonable to conclude that the possibility of a bird strike in Skull Valley is remote and will have an insignificant effect on the F-16 crash rate.

Analysis of failure of a complex system, such as an F-16, as a function of time is dependent on several factors. Consideration has been given to the potential for a "bathtub" curve, whereby for a given aircraft type, crash rates may be greater toward the beginning and end of the operational life of the aircraft. To determine whether the F-16 crash rate has characteristics of a typical "bathtub" curve requires information on failure modes, special working conditions, true flying time, repair time, and frequency of periodic maintenance and inspection, among others of each component of the aircraft that causes a crash. Additionally, approximately 50 percent of all crashes of F-16 aircraft are due to operation-related causes. For example, aircraft crashing due to a pilot undergoing gravity-induced loss of consciousness (GLOC), mid-air collision, bird strike, running out of fuel, pilot error, or weather-related causes may not contribute to the crash rate of a system due to the "bathtub" effect. It is necessary to separate these operation-related mishaps from the crash database to determine whether the crash rate shows any "bathtub" behavior.

For a complex system, such as the F-16 aircraft, early failures ("infant mortality") tend to be random because of high quality control requirements (McCormick, 1981). Focus upon the middle and late periods of F-16 aircraft life is important to determine whether aging related wear-out contributes to an increased crash rate. In this regard, periodic maintenance and replacement of components help to mitigate wear-out effects and prolong the useful life of the system (McCormick, 1981). Thus, the useful life of the system is prolonged by the maintenance and replacement of necessary components.

Information necessary for a rigorous analysis of these effects is not readily available. However, consideration of all data (without going into specific failure modes, actual flying time, or frequency of maintenance) will lead to a conservative estimate, since causes of mishaps that do not contribute to "bathtub" effect would also be included in the analysis. The staff has analyzed the data of engine-related F-16 mishaps from the U.S. Air Force (http://www-afsc.saia.af.mil/afsc/rdbms/flight/stats/). Additionally, mishap data for F-16A, F-16B, F-16C, and F-16D aircraft have also been analyzed to determine whether there is any potential "bathtub" effect in these data sets.

A power law failure rate consisting of the superposition of two separate power functions, as given by Pulcini (2001), was used in this analysis. The method involves plotting the cumulative number of events versus cumulative operating time on a log-log graph. A concave shape of the

curve is a necessary condition for exhibiting the "bathtub" behavior (Pulcini, 2001). Applying this method to Class A crash data for the F-16B, F-16C, and F-16D, the staff found that plots of the cumulative number of mishaps versus cumulative flying time do not conform to a straight line or a concave shape. F-16A data for Class A mishaps show a negligible effect (the slope of the line is 1.03; by comparison, a slope of 1.00 shows no effect). Similarly, analysis of F-16A mishaps with destroyed aircraft does not show a "bathtub" effect (slope is equal to 1.0). Engine-related mishaps for all F-16 aircraft produce a straight line with a slope less than 1.0. This indicates that the crash rate is decreasing with time and, therefore, there is no "bathtub" effect present in the engine-related F-16 crash data. This supports a determination that aging has not contributed significantly to the F-16 crash rate.

Width of Airway

The width of both the Sevier B and Sevier D MOAs at the latitude of the proposed PFS Facility is 12 mi (Private Fuel Storage Limited Liability Company, 2000b, 2001e). As indicated previously, PFS and the staff used 10 mi as the effective flying width for flights in the Sevier B MOA. This effective width is assumed on the basis of the existing elevation restrictions and the presence of the Stansbury Mountains. Additionally, the staff has carried out a sensitivity analysis assuming 8 and 9 mi widths for the Sevier B MOA. A full 12 mi width was assumed in the analysis for the Sevier D MOA.

The staff reviewed other factors that may reduce the effective width of the Sevier B MOA. Specifically, information on potential use of the proposed Facility as a steer point for navigation and for updating the onboard navigational equipment, in addition to formation flights by F-16s while transiting Skull Valley, were reviewed for a possible reduction of the navigational width of the MOA.

F-16s are equipped with an Inertial Navigation System (INS) for onboard navigational capability. Additionally, Tactical Air Navigation (TACAN), which provides distance and bearing from a ground station at a given time, is used. Also, Block 40 F-16 aircraft flown by the 388th Fighter Wing (a total of 66 aircraft) are equipped with the Global Positioning System (GPS) (Private Fuel Storage Limited Liability Company, 2001e). The GPS provides precise aircraft location by using orbiting global positioning satellites. The F-16 aircraft flown by the 388th Fighter Wing are also equipped with the Low Altitude Navigation and Targeting Infrared for Night (LANTIRN) system, which provides pilots the capability to fly at high speed while avoiding detection by using mountains, valleys, and the cover of darkness. Both the INS and TACAN systems will operate in case of an engine failure; however, the GPS and LANTIRN systems will not function under these conditions.

Pilots generally fly toward the selected INS steer points. Therefore, it is reasonable to expect that some of the pilots would fly toward and perhaps fly over the proposed site if the PFS Facility is selected as a turning point. However, if the proposed Facility is instead selected as a pilotage point (that is, a visually identifiable feature used for navigation in VFR flights), direct fly-over of the proposed Facility will not occur.

Skull Valley is primarily used as a transition corridor to the UTTR South area. During a typical mission to the UTTR South area, pilots will use the onboard INS; external navigational aids (such as TACAN; and, if available, GPS), and visual references to maintain positional and situational awareness (Private Fuel Storage Limited Liability Company, 2001e). The normal

flight path for transiting Skull Valley uses a south-southwesterly heading while over the western part of the Great Salt Lake. The pilots enter Skull Valley from the north and follow a southerly heading toward the narrow neck of the Sevier B MOA airspace east of English Village on Dugway Proving Ground (Private Fuel Storage Limited Liability Company, 2001e). The Sevier B MOA is approximately 17 statute miles wide at the northern part of Skull Valley. The MOA narrows to about 7 statute miles at the southern end (Private Fuel Storage Limited Liability Company, 2001e). Because the MOA "funnels" the aircraft eastward as they approach the southern part of Skull Valley, pilots favor the eastern part of the airspace while transiting from north to south in the valley (Private Fuel Storage Limited Liability Company, 2001e). Consequently, the operational utility of the airspace west of Skull Valley Road decreases significantly toward the southern part of Skull Valley.

In addition, a pilot using the proposed Facility for updating onboard instruments would still need to remain cognizant of the restricted airspace to the south and west of the proposed site. Moreover, another turning point would be necessary approximately 10 mi southeast of the proposed PFS Facility to stay within the MOA (Private Fuel Storage Limited Liability Company, 2001e). PFS has stated that it is reasonable to assume that, in such cases, pilots would turn before flying over the proposed Facility (Private Fuel Storage Limited Liability Company, 2001e). Additionally, F-16s using the Stansbury Mountains for practicing terrain masking maneuvers fly down the eastern part of the MOA (Private Fuel Storage Limited Liability Company, 2000b). In view of the above, it is reasonable to assume that most of the aircraft transiting Skull Valley to the UTTR South area will remain east of the proposed PFS Facility,. Accordingly, analytical use of a 10-mi width as the effective width of the airway, thereby increasing the number of aircraft assumed to fly closer to the PFS Facility, is conservative.

Probability of Avoidance

The staff reviewed the following scenarios under which a pilot, having sufficient time and control of the aircraft, still may not be able to avoid a specific ground facility such as the proposed PFS Facility:

- Lack of knowledge of the location of the proposed Facility
- Weather phenomena, such as cloud cover that reduces ability of the pilot to visually locate the proposed Facility
- Level of experience of the pilot.

In addition, the staff also reviewed the effect of using the proposed Facility for pilotage or for updating navigational equipment on the avoidance probability.

If the proposed Facility is built, its existence and location will be known to military flight planners. The Area Planning Guide of the U.S. Department of Defense (DOD) provides guidance to the planners of military training routes. The guide reflects the official policy of the DOD for 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, if licensed, would be listed therein, so that military flight planners and pilots would be aware of the presence of the Facility in Skull Valley, Utah.

In addition, the proposed Facility would be the largest man-made structure in Skull Valley. As discussed previously, some of the pilots may use the Facility as a navigational steer point or pilotage point. Alternatively, the pilots may elect to correct the drift error of the INS, the parallax error of the imaging infrared sensor mounted on the navigational pod of the LANTIRN system, or manually adjust the focus of the targeting pod of the LANTIRN system using the structures of the proposed PFS Facility. In view of the above, pilots are expected to be aware of the location of the proposed Facility. Hence, the applicant's assumption that pilots will be aware of the Facility and its location is reasonable.

Weather conditions in Skull Valley are similar to those present at Dugway Proving Ground and Michael Army Airfield (Private Fuel Storage Limited Liability Company, 2001e). It is expected that the weather at the UTTR South area, especially the restricted airspaces adjacent to Skull Valley, will be similar to that in Skull Valley. However, the UTTR South area encompasses a large area. Therefore, the weather at the UTTR South area may change with increasing distance from Skull Valley, especially for those airspaces farther away from Skull Valley.

Typically, weather in Skull Valley area is well suited for VFR flight conditions. For example, based on Air Weather Service data (Private Fuel Storage Limited Liability Company, 2001e), the Sevier B MOA has no ceiling (i.e., less than approximately 60 percent cloud cover), with 7 or more miles of visibility 91.5 percent of the time (approximately 334 days a year). Therefore, pilots can fly through the Sevier B MOA under VFR conditions for approximately 334 days a year. The Sevier D MOA has at least 7 mi visibility 74 percent of the time (approximately 270 days a year) (Private Fuel Storage Limited Liability Company, 2001e). Consequently, VFR flight is possible in the Sevier D MOA about 270 days in a year.

U.S. Air Force pilots are trained to maintain situational and positional awareness at all times. To fly under VFR flight conditions in Skull Valley, the pilots must have at least 3 mi visibility (Private Fuel Storage Limited Liability Company, 2001e). The aircraft must have a vertical clearance of 500 ft below and 1,000 ft above the clouds. Additionally, 2,000 ft lateral separation from the clouds is required.

The presence of a ceiling does not necessarily preclude VFR flying. If cloud layers prevent flying at specific altitudes, the pilots may fly above or below those cloud layers under VFR conditions if the VFR weather requirements can be satisfied. Pilots can fly under VFR conditions above the cloud cover and still maintain positional awareness using the onboard navigational systems (e.g., INS, TACAN, GPS, if available). F-16s routinely operate under VFR conditions over cloud covers when required (Private Fuel Storage Limited Liability Company, 2001e). Additionally, F-16s are equipped with an onboard Horizontal Situation Indicator (Private Fuel Storage Limited Liability Company, 2001d). This equipment displays distance and bearing to selected navigational steer points. A pilot can use this equipment to maintain a precise ground track of the flight. The onboard radar of an F-16 aircraft can penetrate through the clouds and can be used for identifying and locating ground features. Consequently, the onboard radar can be used to improve navigation provided by the INS (Private Fuel Storage Limited Liability Company, 2001e).

Prominent terrain features, such as the Cedar Mountains, the Stansbury Mountains, Deseret Peak (11,031 ft above mean sea level or approximately 6,530 ft above ground level), and two peaks bounding Johnson Pass southeast of the proposed PFS Facility site are particularly useful in maintaining positional and situational awareness by the pilots (Private Fuel Storage Limited

Liability Company, 2001e). For example, an F-16 pilot, while transiting Skull Valley at the top of the Sevier B MOA (9,500 ft above mean sea level) above a cloud layer, could locate Deseret Peak and use it as a visual aid for positional and situational awareness.

Pilots flying at an altitude of 1,000 ft above ground level and a speed of 350 knots (a worst case scenario) would have approximately 45 seconds (s) to perform "zooming" and commence air start operations in accordance with established procedures to respond to engine problems. Higher initial altitudes or faster speeds would provide additional time to carry out the necessary actions. Pilots would be able to restart the engine or reach the minimum ejection altitude of 2,000 ft within this time (Private Fuel Storage Limited Liability Company, 2000b). A pilot, flying above a 3,000 ft ceiling with no significant additional clouds and experiencing engine trouble, would be able to perform the necessary emergency actions to avoid impact on a ground facility.

Pilots, as a general rule, rely on visual references if the visibility and cloud cover permit and reinforce them with the onboard systems. Prominent geographic features provide general positional awareness to the pilots. A pilot can use smaller features for more precise position determination while cross-checking the aircraft position using onboard navigational systems (Private Fuel Storage Limited Liability Company, 2001e). Prominent terrain features would also aid the pilots with situational and positional awareness as it relates to avoiding the proposed Facility. Reliance on onboard systems increases as darkness or weather begins to limit visual contact with outside references.

If the cloud cover in Skull Valley does not permit VFR operations, it can be assumed that the weather in the UTTR South area, at least in the restricted airspaces nearby, would be similar. As most of the aggressive maneuvering in combat training, such as that may occur in the UTTR South area, requires VFR conditions, it is expected that training would be suspended if extensive vertical and horizontal cloud covers are present in the range (Private Fuel Storage Limited Liability Company, 2001e). If weather in some restricted airspaces of the UTTR South area does permit VFR flight activities, there are five other routes besides Skull Valley to enter the UTTR South area (Private Fuel Storage Limited Liability Company, 2001c). Thus, flights transiting Skull Valley are less likely in the absence of VFR conditions.

Additionally, pilots have requirements for instrument flying proficiency. Therefore, if the cloud cover in the range precludes flying under VFR conditions, pilots may proceed to the UTTR South area flying under Instrument Flight Rules (IFR) conditions to fulfill the proficiency requirements (Private Fuel Storage Limited Liability Company, 2001e). Moreover, some restricted airspaces may still support VFR flights even though the cloud covers in Skull Valley and adjacent ranges do not allow flying under VFR conditions; in such cases, the pilots may proceed to the UTTR South area through Skull Valley under IFR flying conditions.

If the weather conditions and cloud cover in Skull Valley preclude VFR flying, the pilot must request and secure an IFR clearance from the Air Traffic Control (Private Fuel Storage Limited Liability Company, 2001e). In these cases, the pilots will be under the radar control of the Air Traffic Control and will receive direction on radar separation from other aircraft. Hence, the controllers, who would be aware of the precise location of the proposed Facility, will be able to guide the pilot in case of emergencies.

In summary, the weather characteristics in Skull Valley are such that a pilot will seldom be without some visual indication of position relative to the proposed Facility. In those cases in

which cloud cover precludes VFR flight rules, alternative means of maintaining position awareness are available and the aircraft will be controlled by persons who are aware of the location of the proposed Facility.

The staff also reviewed information provided by Cole et al. (2000) on the potential effects of pilot experience on the probability of avoiding a surface facility if the aircraft engine experiences a problem in flight.

The purpose of the required initial and mission-ready training of a pilot after arriving at an F-16 operational wing is to provide a sufficient level of experience to proficiently operate the F-16 in routine and emergency situations. The U.S. Air Force classifies a pilot as "experienced" after 500 hours of flying time in the F-16 (Cole et al., 2000). If the pilot has flown another fighter aircraft, the pilot may be classified as "experienced" with as few as 100 hr of flying time in an F-16. No prescribed performance level or any specific evaluation is associated with a pilot reclassified as "experienced" from the "inexperienced" category. The U.S. Air Force generally tries to keep a 40/60 split between "inexperienced"/"experienced" pilots in an operational wing to ensure adequate intake of new pilots for maintaining a viable fighter pilot force over time (Cole et al., 2000).

As discussed above, PFS analyzed 126 F-16 aircraft accident reports (Private Fuel Storage Limited Liability Company, 2000b). PFS did not find any indications in these reports that a pilot's limited experience had resulted in failure to steer the aircraft away from an inhabited area (Cole et al., 2000). In all cases in which avoidance of inhabited areas was necessary, pilots always guided the aircraft away from those areas.

PFS has determined that a majority of the mishaps that could take place in Skull Valley would be due to mechanical engine failure (Private Fuel Storage Limited Liability Company, 2000b). F-16 mishaps that could happen in Skull Valley involved pilots with various levels of experience. No correlation was observed between the pilot's flight experience level and the mishaps. Based on the information provided by PFS (Cole et al., 2000), it is reasonable that the estimated 5 percent of the time that pilots would fail to avoid a surface facility bounds any differences among pilots' experience levels. As discussed above, the staff conducted a sensitivity analysis with a 10 percent probability that a pilot with adequate control of the aircraft and time available would not be able to steer away from a specific surface facility. The results did not show any appreciable difference in the estimated crash probabilities. Therefore, the staff accepts the PFS estimate of 5 percent probability as a reasonable assumption although, as discussed above, the staff conservatively assumed 10 percent probability in its estimation.

Sevier D MOA Flights

Private Fuel Storage Limited Liability Company (2001b) specifically examined reports of F-16 crashes in normal in-flight mode that took place at altitudes within the Sevier D airspace. The Sevier D MOA is between 9,500 and 18,000 ft above mean sea level. Only four normal in-flight crashes occurred in this altitude band: (1) April 4, 1991; (2) December 16, 1991; (3) June 7, 1996; and (4) November 21, 1996. All these crashes are included in Skull Valley Type Events and ACRAM Flight Phase Events in the PFS analysis (Private Fuel Storage Limited Liability Company, 2000b).

According to PFS, three out of the four crashes were due to engine failures in which the pilots

retained control of the aircraft and would have been able to avoid a surface structure. Therefore, PFS has concluded that, as a lower bound estimate, in about 75 percent of cases in the Sevier D MOA conditions, the pilot would be able to avoid a specific structure on the ground, such as the proposed Facility. Therefore, $P_{Able\text{-}to\text{-}Avoid}$ would be at least 0.75 for aircraft transiting the Sevier D MOA.

As discussed above, the staff accepted F-16 crashes in the ACRAM Flight Phase category as representative of Skull Valley events. The four crashes referenced above are included in the ACRAM Flight Phase category, as presented in Private Fuel Storage Limited Liability Company (2000b, Tab H). Therefore, the 0.9 value for $P_{Able\text{-}to\text{-}Avoid}$ estimated for ACRAM Flight Phase category crashes includes contributions from these crashes. Consequently, this value would still be applicable for estimating the potential crash hazard from flights through the Sevier D MOA. However, as discussed above, PFS has estimated the lower bound to be 0.75. Therefore, the staff has used $P_{Able\text{-}to\text{-}Avoid}$ equal to 0.75 for the sensitivity calculations provided below.

PFS has estimated the crash probability of F-16s transiting Skull Valley using updated information (Private Fuel Storage Limited Liability Company, 2001b). The crash probability has been calculated with N, the average of FY 1999 and FY 2000 flights through the Sevier B MOA after adjusting for 12 additional F-16s, equal to 5,870. On this basis, PFS estimated the annual crash probability to be equal to 3.11×10^{-7}. Additionally, Private Fuel Storage Limited Liability Company (2001b) carried out a sensitivity analysis to estimate the crash hazard using only FY 2000 flight information after adjusting for 12 additional F-16s, equal to 6,759. This yielded an estimated crash probability of 3.58×10^{-7} per year.

Confirmatory Calculations

The staff conducted a confirmatory analysis of the potential crash hazard of F-16s transiting Skull Valley using Eq. (15-4). In this analysis, F-16 flights through both the Sevier B and Sevier D MOAs in FY 2000 were considered. Furthermore, the increase of the crash hazard due to 12 additional F-16s stationed at Hill Air Force Base (an increase of 17.4 percent) also was estimated. Additionally, 50 percent of the flights were assumed to have negligible crash potential on the proposed Facility, since the aircraft fly in formation.[2] A value of 0.10 has been assumed for P_{hit} for flights through the Sevier B and Sevier D MOAs, which is conservative

[2]F-16 aircraft transiting through Skull Valley fly in either a two-ship or a four-ship formation. Based on the information from Hill Air Force Base, a solo flight through Skull Valley is an exception. It occurs occasionally, for example, when a pilot's departure on a sortie is delayed. In terms of aircraft flight path distribution, a four-ship formation may be considered as two formations of two aircraft each – one formation flying a few miles behind the first, with either a left or a right offset. There is approximately a 9,000 ft lateral separation between the leader and the wingman in a two-ship formation (Private Fuel Storage Limited Liability Company, 2001e). Consequently, at least one of the aircraft in a two-ship formation will not be in a position from which it can strike the proposed Facility in the event of a crash, considering the distribution of aircraft across the width of the airspace. Additionally, in a four-ship formation (which is generally two two-ship formations in a staggered pattern), only one aircraft may point at the proposed Facility (Private Fuel Storage Limited Liability Company, 2001d). Therefore, for estimating the crash hazard from aircraft transiting Skull Valley, approximately half of the flights may be counted as having a negligible potential for striking the proposed Facility.

because the results of the sensitivity analysis given in Table 15-4 show that the value of P_{hit} has negligible influence on the estimated crash probability, and use of P_{hit} equal to 0.05 is acceptable. Although, as discussed before, a value of 0.90 for $P_{Able\text{-}to\text{-}Avoid}$ should be applicable to both the Sevier B and Sevier D MOAs, a more conservative value of $P_{Able\text{-}to\text{-}Avoid}$ equal to 0.75 has been assumed for the Sevier D MOA flights based on Private Fuel Storage Limited Liability Company (2001b). Consequently, R_2 for the Sevier B and Sevier D MOAs would be 0.10 and 0.25, respectively. The results, given in Table 15-6, indicate that the estimated crash probability due to F-16s transiting the Sevier B and D MOAs is on the order of 10^{-7} per year.

Table 15-6. Estimated crash probability of F-16s while transiting Sevier B and Sevier D MOAs.

Sevier B MOA		Sevier D MOA		Annual Crash Probability
Number of Flights	Width (mi)	Number of Flights	Width (mi)	
Number of F-16s Stationed at Hill Air Force Base = 69				
5757	10	240	12	2.1×10^{-7}
5757	9	240	12	2.3×10^{-7}
5757	8	240	12	2.6×10^{-7}
Number of F-16s Stationed at Hill Air Force Base = 81				
6759	10	282	12	2.5×10^{-7}
6759	9	282	12	2.8×10^{-7}
6759	8	282	12	3.1×10^{-7}

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 to be acceptable because:

- Adequate information has been presented to describe the potential hazards.
- 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 consistent with 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 the DOE ACRAM Study (Kimura et al., 1996) crash data for Class A and Class B mishaps for normal operations and updated the crash rate with recent (after FY 1993) information on mishaps from the U.S. Air Force. This

crash rate is higher than the crash rate considering only the mishaps with destroyed aircraft.

- PFS used relevant accident reports from the U.S. Air Force to estimate the 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 P_{hit} value has been estimated qualitatively. However, the value used by PFS for P_{hit} is acceptable, because the overall crash probability is not highly sensitive to the value selected for P_{hit}.

- The probability of an F-16 striking large birds while transiting Skull Valley and initiating a crash is remote, as confirmed by the staff at Hill Air Force Base.

- Hill Air Force Base staff has confirmed that the pilots of all military aircraft transiting Skull Valley are in constant communication with the air traffic controllers at Clover Control. The air traffic controllers would be able to guide the pilot of an aircraft experiencing emergencies while transiting Skull Valley.

- The weather in Skull Valley permits VFR flight operations during most of the year. If the weather in Skull Valley does not permit VFR operations, pilots can fly under IFR after obtaining permission from the air traffic controllers. Under IFR, pilots would be under the control of the traffic controllers at Clover Control, so that positional awareness would be maintained under adverse weather conditions.

- The presence of substantial mountain ranges on either side of Skull Valley, as well as onboard navigational equipment, provide additional means for pilots to maintain positional awareness when taking measures to avoid striking the proposed Facility.

- Data on engine-related mishaps for F-16s indicate that the rates have been decreasing with time.

- The level of a pilot's experience does not have any significant correlation with the crash rate of F-16 aircraft.

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 MOAs only with permission from the military air traffic controllers at Clover Control.

As indicated previously, the UTTR North area is over 30 mi 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 mi from the Facility.

According to the U.S. Air Force (1999), a Weapons System Evaluation Program, 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 mi (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 mi (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 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 vary from about 21 to more than 40 mi.

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). The target complexes are more than 21 mi from the proposed PFS Facility site. 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 unlikely event of simultaneous failure of all engines or a catastrophic structural failure, the crew would eject and 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 mi 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 on the basis of the following factors (Private Fuel Storage Limited Liability Company, 2000b):

- density of air-to-air combat training operations over the UTTR South area sectors closest to the proposed 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 mi of the edge of the UTTR South area near the proposed Facility is the same as the density in the center of the range.
- Aircraft becoming disabled up to 10 mi from the Facility would fly the distance to the proposed 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 mi radius and a 3 mi wide buffer zone.

On the basis of the information from the U.S. Air Force, PFS stated the number of sorties flown by fighter aircraft in the UTTR South area during FY 1998, FY 1999, and FY 2000 (Private Fuel Storage Limited Liability Company, 2001c), as shown in Table 15-7.

Table 15-7. Number of sorties on the UTTR South Area for different fighter aircraft (Based on Private Fuel Storage Limited Liability Company, 2001c)*.

Aircraft Type	FY 1998		FY 1999		FY 2000	
	Sorties	Percentage of Total	Sorties	Percentage of Total	Sorties	Percentage of Total
F-16	5,726	90.0	7,232	95.3	7,059	94.1
F-15	265	4.2	266	3.5	270	3.6
F-18	294	4.6	76	1.0	86	1.1
F-117	0	0.0	2	0.03	6	0.08
F-14	0	0.0	4	0.05	48	0.64
Mixed Fighters	75	1.2	8	0.1	31	0.41
Total for UTTR South area	6,360	100.0	7,588	100.0	7,500	100.0

* Bombers and cargo aircraft are discussed above and, therefore, are not reflected in this table.

On the basis of the DOE ACRAM Study (Kimura et al., 1996), the single engine F-16 has the highest crash rate of these aircraft. All other fighter 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 fighter 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 a 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 consistent with the NRC guidelines given in NUREG–0800, Section 3.5.1.6, Aircraft Hazards.

According to PFS and information provided by the Vice Commander of the 388th Fighter Wing at Hill Air Force Base, about one third of the sorties 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 FY 1998. In FY 2000, fighter aircraft spent a total of 9,687 hr on the UTTR South area. Hence, the number of hours spent in air-to-air combat training is estimated to be 3,229 by an estimated 2,500 sorties engaged in air-to-air combat training in FY 2000 (Private Fuel Storage Limited Liability Company, 2001c). In contrast, approximately 2,468 hr were spent in air-to-air combat training in FY 1998 (Private Fuel Storage Limited Liability Company, 2000b).

PFS Analysis Prior to 2001

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 (Private Fuel Storage Limited Liability Company, 2000b). The U.S. Air Force has information on the number of air operations in each range area during FY 1998. 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 (Private Fuel Storage Limited Liability Company, 2000b). On the basis of the U.S. Air Force data, a total of 27,229 air operations took place in FY 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 in FY 1998 were 82.4 and 605.4 hr, respectively (Private Fuel Storage Limited Liability Company, 2000b).

PFS (Private Fuel Storage Limited Liability Company, 2000b) 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 (Private Fuel Storage Limited Liability Company, 2000b) 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 were 3.26×10^{-3} and 2.40×10^{-2} per year respectively.

The ground areas are 1,295 mi^2 and 1,172 mi^2 for R-6402 and R-6406, respectively. Therefore, the expected crash density in R-6402 was 2.52×10^{-6} and in R-6406 was 2.05×10^{-5} per square mile per year (Private Fuel Storage Limited Liability Company, 2000b). 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 was concentrated toward the center. PFS used these crash rates to estimate the crash probability for the Facility for aircraft engaged in UTTR training (Private Fuel Storage Limited Liability Company, 2000b).

PFS also concluded that air-to-air combat training missions conducted more than 10 mi from the proposed 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) require about 1.5 minutes to glide 10 mi. 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 GLOC, he or she will remain incapacitated for about 20 to 30 s, based on centrifuge tests on pilots. The accident report for the February 28, 1994, mishap stated that average time of total GLOC is 24 s (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 mi in that time. Accident reports for all six GLOC 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 a 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 indicated that in such accidents the aircraft impacted the ground well within 10 mi from the point of the initiating event. Moreover, PFS argued that any crashing aircraft able to reach the proposed site from more than 10 mi 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 mi 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). To account for this, a cut-out area, A_c, was defined by a 10 mi radius arc, centered on the Facility and a 3-mi buffer zone on the edge of the restricted areas (Private Fuel Storage Limited Liability Company, 2000b, Tab A).

The distance a crashing aircraft is able to glide is dependent on the altitude at which it is flying when the emergency initiates. For example, at sufficiently low altitudes, a disabled aircraft may be limited to glide distances much less than 10 mi. To account for altitude dependent glide distances for aircraft, PFS (Private Fuel Storage Limited Liability Company 2000b) divided the vertical airspace into four altitude bands. The crash hazard was estimated for each of these altitude bands separately and then combined to estimate the total crash hazard to the proposed site. Within each restricted area and altitude band, the annual crash rate density, C_a, was calculated by multiplying the crash rate C per square mile per year by the fraction of aircraft in each band (Private Fuel Storage Limited Liability Company, 2000b). 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).

PFS calculated the cut-out area, A_c of Eq. (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 15-8. PFS also calculated the footprint area, A_p, of Eq. (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, as shown in Table 15-8.

Table 15-8. 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 a 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 Eq. (15-5) is quantified based on 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 on 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 FY 1989 to FY 1998 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 were 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 (Private Fuel Storage Limited Liability Company, 2000b). This is reflected in the staff's SER of September 2000.

The analysis of the potential risk of aircraft crash from air-to-air training operations in the UTTR South area includes some conservative assumptions (Private Fuel Storage Limited Liability Company, 2000b). 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 more recent information (after FY 1993) from the U.S. Air Force.

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 a 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 Eq. (15-5); this is not a significant change in the estimated crash probability. Therefore, the staff found that use by PFS (Private Fuel Storage Limited Liability Company, 2000b) of a crash probability of 7.35×10^{-8} per year was acceptable.

PFS (Private Fuel Storage Limited Liability Company, 2000b) also carried out a sensitivity analysis assuming that disabled aircraft engaged in air-to-air combat training missions would not fly more than 5 mi. According to PFS, accident data support the expectation that disabled aircraft would not glide beyond 5 mi from the point where they were disabled. Using the 5 mi. glide distance, PFS found that the likelihood that a disabled aircraft within the training zone of the UTTR South area reaching and crashing onto the proposed facility would be negligibly small. On this basis, PFS concluded that air operations within the UTTR South area would not pose a credible crash hazard to the proposed Facility.

<u>PFS 2001 Analysis</u>

In a recent revision of the SAR (Private Fuel Storage Limited Liability Company, 2001b), PFS stated that the assumption of a 10 mi cut-off radius is overly conservative. Instead, a more realistic distance of 5 mi was used in the revised analysis. In support of this, PFS notes the following:

- Based on an assessment of F-16 crashes in special in-flight operation (Private Fuel Storage Limited Liability Company, 2000b, Tab Y), most crashes in which the pilots did not have control of the aircraft would have occurred toward the center of the restricted ranges. The aircraft in most of such crashes would not travel more than 5 mi before ground impact.

- If pilots were able to maintain control of the aircraft, they would divert the aircraft away from a large ground facility. A distance of 5 mi would provide sufficient time for steering away from the proposed Facility. The UTTR provides a relatively safe area for landing a disabled aircraft. It is reasonable that the pilot of an aircraft experiencing engine failure or such mishaps in which he/she is able to retain the control of the aircraft would not glide it across the Cedar Mountains toward Skull Valley, outside the restricted airspace boundaries.

The staff reviewed the revised analysis considering the types of mishaps that can occur in special in-flight mode, as given in Private Fuel Storage Limited Liability Company (2000b, Tab Y). As discussed above, the proposed site is 2 mi outside the restricted airspace. Additionally, PFS has assumed a 3 mi wide interior buffer zone within the edge of the UTTR South area restricted airspaces near the proposed Facility (Private Fuel Storage Limited Liability Company, 2000b). In practice, no aggressive training takes place in this buffer zone. For mishaps involving continued control of the aircraft, the pilots would preferentially avoid an occupied site. If possible, the pilots would steer the aircraft toward the Michael Army Airfield for recovery. If the Michael Army Airfield was too far away for possible recovery, the pilots would guide the aircraft toward a controlled bailout area or an open area of the range before ejecting. This action would be taken in order to avoid collateral damage (Private Fuel Storage Limited Liability Company, 2001b). A distance of 5 mi would provide at least 45 s for the pilots to take necessary actions. Based on Private Fuel Storage Limited Liability Company (2000b), 45 s would be adequate for the pilot to take actions to avoid the Facility. The staff accepts that a cut-off radius of 5 mi is reasonable as discussed below.

Based on the information provided by Private Fuel Storage Limited Liability Company (2000b, Tab Y), five types of mishaps are possible in which the pilot would not be able to maintain control of the aircraft. These mishaps are: (1) Midair Collision, (2) Departed Controlled Flight, (3) Spatial Disorientation, (4) Collision with Ground, and (5) GLOC. All of these mishaps occur during aggressive maneuvering in a range. Training requiring such aggressive maneuvering occurs toward the center of the restricted airspaces of the UTTR South area, well beyond 5 mi of the proposed Facility (Private Fuel Storage Limited Liability Company, 2000b, Tab Y).

Midair collisions take place during aggressive combat maneuvering training, such as air-to-air intercept or close-in dogfight. As the likelihood of a collision in such maneuvers is relatively high, these activities, as a safety precaution, are deliberately carried out near the centers of the restricted ranges (Private Fuel Storage Limited Liability Company, 2000b, Tab Y). In each midair collision mishap reviewed by PFS (Private Fuel Storage Limited Liability Company, 2000b, Tab Y), the destroyed aircraft was not able to fly any appreciable distance before impacting the ground or a body of water.

Loss of aircraft control also can occur during special operations wherein the pilot is being trained to cope with flight conditions that are near the edge of the aircraft's aerodynamic capabilities. Accidents occurring during these operations are called Departed Controlled Flights. Typically, in these types of accidents, the aircraft impacts the ground at a steep angle. Private Fuel Storage Limited Liability Company (2000b) stated that such operations are normally planned near the center of the range. Therefore, they do not pose an unacceptable hazard to the proposed Facility.

One cause of spatial disorientation is poor visibility or cloud cover, when the pilot loses outside references to the horizon. However, air-to-air combat training in the UTTR South area is conducted under VFR conditions (Private Fuel Storage Limited Liability Company, 2000b). Hence, spatial disorientation for combat air operations due to limiting weather conditions is not likely in the UTTR South area. Another cause of spatial disorientation or loss of situational awareness can be aggressive maneuvering, when the pilot is focused on another aircraft or a ground target. Typically, accidents in these cases lead to ground collisions, such that appreciable glide distances do not occur. All five mishaps in this category took place in air-to-air

engagements or near a ground target (Private Fuel Storage Limited Liability Company, 2000b, Tab Y). Moreover, ground attack training is not conducted near the edge of the restricted airspace of the range. Hence, for air-to-air and air-to-ground combat training operations, spatial disorientation mishaps in the UTTR South area are not likely to happen near the proposed PFS Facility site. On this basis, they do not pose a credible hazard to the proposed Facility.

Another cause of aircraft control loss is GLOC. When unconscious, the pilot ceases to operate the aircraft controls. Typically, the resulting loss of aircraft control causes the aircraft to return to 1g (Private Fuel Storage Limited Liability Company, 2000b, Tab Y). Centrifuge tests indicate that the time required for a pilot to regain consciousness and to be cognizant of the situation is about 20 to 30s (Private Fuel Storage Limited Liability Company, 2000b, Tab Y). Accident reports for all six GLOC 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. All six mishaps took place during aggressive maneuvering in air-to-air combat training (Private Fuel Storage Limited Liability Company, 2000b, Tab Y). This type of training is generally planned near the center of the ranges in the UTTR South area. Consequently, it is extremely unlikely that an aircraft with the pilot suffering from GLOC will fly over the restricted airspace boundaries and crash onto the proposed Facility.

In summary, based on the information in Tab Y of Private Fuel Storage Limited Liability Company (2000b), PFS concluded that for air operations in the UTTR South area involving aggressive or tactical maneuvering, any mishaps leading to loss of aircraft control would occur toward the center of the restricted ranges. As noted above, in such cases, the aircraft would not fly a long distance. As the proposed Facility is outside the restricted airspace, far from the central area of the UTTR South area, PFS concluded that all mishaps during aggressive maneuvering pose a negligible crash hazard to the proposed Facility (Private Fuel Storage Limited Liability Company, 2001b). On this basis, PFS assumed the probability of an on-site crash to be less than 1×10^{-8} per year (Private Fuel Storage Limited Liability Company, 2001b).

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 to be acceptable because:

- Adequate information has been presented to describe the potential hazards.
- Based on 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 mi 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 accident reports from the U.S. Air Force to estimate the fraction of mishaps occurring in special in-flight mode. 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.

- PFS analyzed reports for all F-16 crashes during special in-flight mode (i.e., aggressive maneuvering in combat training) in restricted ranges. The accident reports show that in mishaps where the pilots retained control of the aircraft, they would be able to divert the aircraft away from a specific surface structure. However, if the pilots did not have control or had to eject immediately, typically the mishap aircraft crashed not far from the location of the event(s) leading to the crash.

On the basis of its review of the PFS data, information, and analyses, the staff concludes that air combat training at the UTTR South area results in an aircraft crash hazard of $< 1 \times 10^{-8}$ per year, and that such training will not pose a hazard to the Facility.

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 mi (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 about 2 to 3 mi north of the proposed site at an altitude of 15,000 ft above mean sea level and is an instrument recovery route (Private Fuel Storage Limited Liability Company, 2000b, Tab W). 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).

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 (Private Fuel Storage Limited Liability Company, 2000b, 2001b). Therefore, the number of flights using the Moser Recovery route annually is $0.05 \times 5{,}726$, where 5,726 is the number of flights of F-16s to the UTTR South area in FY 1998. This amounts to 286 aircraft per year.

Based upon Private Fuel Storage Limited Liability Company (2001c), a total of 7232 and 7059 F-16 sorties took place at the UTTR South area in FY 1999 and FY 2000. Consequently, the estimated number of F-16 flights through the Moser Recovery was 362 and 353 respectively in FY 1999 and FY 2000.

Night vision goggles have been introduced for use in military aircraft; however, personnel at Hill Air Force Base stated that the introduction of night vision goggles did not appreciably change the traffic density through the Moser Recovery. Therefore, this development does not affect the assumption made by Private Fuel Storage Limited Liability Company (2000b, 2001b) that approximately 5 percent of the UTTR South area sorties would return to Hill Air Force Base via the Moser Recovery route.

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} crashes 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) 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 the relative likelihood of a pilot of a disabled aircraft not being able to steer the aircraft away from the site prior to ejection. As discussed above, 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 in FY 1998, 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 Fuel Storage Facility site to be 1.32×10^{-8} (Private Fuel Storage Limited Liability Company, 2000b). This is reflected in staff's SER of September 2000.

In its recent analysis, PFS analyzed the effects of increased sorties in the UTTR South area and 12 additional F-16s stationed at Hill Air Force Base in FY 2001 on the potential aircraft crash hazard (Private Fuel Storage Limited Liability Company, 2001b). PFS used the average of FY 1999 and FY 2000 sorties through Skull Valley (assumed to be same as in Sevier B MOA) in the calculation. The updated crash hazard to the proposed Facility from flights through the Moser Recovery route was estimated to be 1.70×10^{-8} per year. Taking into account 12 additional F-16s, PFS estimated the annual crash probability is 2.00×10^{-8}. Additionally, PFS estimated the crash hazard based on FY 2000 data of F-16s transiting Skull Valley. PFS concludes that the estimated annual crash probability increases to 2.30×10^{-8}.

As discussed above, PFS had used the UTTR South area sorties in FY 1998 to estimate the crash hazard given in Private Fuel Storage Limited Liability Company (2000b). The staff believes use of the UTTR South area sortie data, instead of Skull Valley flight information (which PFS used in its more recent analysis), may be more appropriate for estimating the annual crash probability of F-16s flying through the Moser Recovery route. Therefore, the staff carried out an

independent analysis to estimate the crash hazard onto the proposed Facility from aircraft flying through the Moser Recovery route using the sorties from the UTTR South area.

The staff used FY 2000 sortie information (rather than the average of FY 1999 and FY 2000 data) to estimate the probability of crash. (Use of FY 1999 sortie information would lead to an insignificant change to the estimated probability of a crash compared to FY 2000 data.) On this basis, the annual probability of a crash onto the proposed PFS Facility site of aircraft using the Moser Recovery route is estimated to be 1.6×10^{-8}. Additionally, adjusting for 12 more F-16 aircraft stationed at Hill Air Force Base, the estimated annual probability changes to approximately 1.9×10^{-8}. These estimated probabilities by PFS include 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.

As discussed in connection with the crash hazard from aircraft transiting Skull Valley, the P_{hit} value does not have a significant influence on the estimated crash probability, and use of 0.05 as P_{hit} is acceptable. However, as before, the staff has carried out a sensitivity analysis using a P_{hit} value equal to 0.10. With P_{hit} equal to 0.10, R becomes 0.19. On this basis, the estimated annual crash probability from aircraft flying through the Moser Recovery route is 2.1×10^{-8}. Considering 12 additional F-16s stationed at Hill Air Force Base, the annual probability of crash is estimated to be 2.5×10^{-8}.

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.

- The aircraft flying the Moser Recovery route will be under control of the air traffic controllers as it is an instrument route.

- Qualitative judgments specific to the Moser Recovery route, in addition to those 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 Base 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 Limited Liability Company, 2000b).

According to DOE Standard DOE-STD-3014-96 (U.S. 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 mi from the centerline of the flight path.

Because there are no regularly scheduled flights through Skull Valley and the site is 2 mi 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 to PFS 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. This is done typically 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 a '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 unarmed live 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 the dead weight impact of the ordnance. Nevertheless, PFS has evaluated the explosion scenario in its analysis. The staff's evaluation of the analysis is presented below.

PFS has conservatively assumed 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. Also, it is likely that a pilot would take steps to avoid striking a populated site with jettisoned ordnance, but the PFS analysis conservatively assumes no such steps have been taken by the pilot (Private Fuel Storage Limited Liability Company, 2000b, 2001b).

PFS calculated the probability, P_o, of jettisoned ordnance striking the Facility by using a modified version of the NUREG–0800 formula (Nuclear Regulatory Commission, 1981a). The individual probabilities of jettisoned ordnance striking both the Canister Transfer Building and the cask storage area are summed to calculate the aggregate probability of impacting the Facility. The aggregate probability P_o is defined as

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

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). As discussed above, the number of flights through the Sevier B MOA increased to 5757 in FY 2000. In addition, there were 240 flights through the Sevier D MOA, which overlies the Sevier B MOA. It should be noted that both the Sevier B and Sevier D MOAs are approximately 145 mi long and extend more than 100 mi south of Skull Valley, and some MOA flights do not involve transit through Skull Valley. To be conservative, PFS has included all flights through the Sevier B MOA in determining the flight frequency for Skull Valley.

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. Therefore, they were appropriately omitted in estimating the hazard from jettisonable ordnance carried onboard an F-16.

An F-16 can carry several different types of armaments. Table 15-10 provides information on different ordnance typically carried onboard by F-16s to the UTTR South area.

Table 15-9. Ordnance onboard F-16s during sorties by the 388th (and 419th)* Fighter Wings to the UTTR South Area (adopted from Private Fuel Storage Limited Liability Company, 2001c).

Ordnance	Number of Sorties		Number of Munitions	
	FY 1998	FY 2000	FY 1998	FY 2000
MK-84 (Live)	111	7 (9)	156	14 (18)
MK-84 (Inert)	38	21 (27)	89	43 (55)
MK-82 (Live)	166	56 (72)	544	224 (286)
MK-82 (Inert)	355	44 (56)	1029	182 (233)
AGM-65 Maverick	4	0	4	0
CBU-87 Cluster Bomb	4	0	16	0
Total	678	128 (164)	1838	463 (592)
Fraction of sorties to UTTR South Area with ordnance	678/5726 or 0.118	164/7059 or 0.023		

* Numbers in parentheses reflect combined values for the 388th and 419th Fighter Wings.

Based on the information provided to PFS by the U.S. Air Force, ordnance carried by the F-16s in FY 1999 is similar to that in FY 2000. The 388th Fighter Wing flew 151 sorties to the UTTR South area carrying ordnance in FY 1999, as compared to 678 such sorties in FY 1998 and 128 such sorties in FY 2000.

PFS has indicated that the information on sorties carrying ordnance may not include ordnance carried by the 419th Fighter Wing stationed at Hill Air Force Base (Private Fuel Storage Limited Liability Company, 2001c, Footnote 27). To incorporate the ordnance carried by aircraft of the 419th Fighter Wing to the UTTR South area, PFS has assumed that the 419th Fighter Wing would fly sorties with ordnance at the same rate and using the same munitions as the 388th Fighter Wing. The Vice Commander of the 388th Fighter Wing concurred with the PFS that this would be a reasonable assumption (Private Fuel Storage Limited Liability Company, 2001c, Footnote 27). Therefore, the ordnance usage has been multiplied by (54 + 15)/54 or 1.278 to incorporate the proportional increase attributable to the 419th Fighter Wing, taking into account 54 F-16s and 15 F-16s assigned to the 388th and 419th Fighter Wings respectively. The revised numbers (for both wings) are shown in the parentheses in Table 15-9.

In FY 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 in FY 1998 with jettisonable ordnance onboard, f_o, is equal to 678/5726 or 0.118. In FY 2000, a total of 164 sorties to the UTTR South area out of 7059 sorties carried jettisonable ordnance, taking into

account both the 388th and 419th Fighter Wings. Hence, portion of the sorties that carried jettisonable ordnance in FY 2000, f_o, is equal to 164/7059, or 0.023.

PFS has used a value of 0.90 for e in Eq. (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 (or a 0.84 fraction of the total) mishaps that reasonably could 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. Therefore, an assumption of e equal to 0.9 is bounding.

PFS estimated the probability of jettisoned ordnance striking the Facility site using 3,871 sorties through Skull Valley in FY 1998. The estimated annual probability P_o is 9.85×10^{-8} using Eq. (15-6) (Private Fuel Storage Limited Liability Company, 2000b). In the estimate, the effective width of Skull Valley is equal to 10 mi (Private Fuel Storage Limited Liability Company, 2000b). Using the width of the Canister Transfer Building at its widest point would increase P_o by 1×10^{-9} per year.

PFS calculated P_o in FY 2000 assuming the number of sorties through Skull Valley, N, to be equal to 5,870 (Private Fuel Storage Limited Liability Company, 2001b). PFS estimated that 5,870 sorties would fly through Skull Valley by taking the average number of flights through Skull Valley in FY 1999 (4,250) and FY 2000 (5,757) with an additional increase of 17.4 percent to account for the increased number of F-16s stationed at Hill Air Force Base. PFS also carried out another analysis using the number of flights through Skull Valley in FY 2000 and accounting for a 17.4 percent increase (Private Fuel Storage Limited Liability Company, 2001c).

The staff carried out an independent estimation of the probability of jettisoned ordnance striking the Facility. The staff estimated P_o including the contribution from the Canister Transfer Building as well as from the cask storage area. Three separate estimates were made using: (1) N = 4086, (2) $N = 5997$, and (3) $N = 7040$. Case 1 with N equal to 4086 uses the total number of F-16 sorties through the Sevier B and Sevier D MOAs in FY 1998. In Case 2, the number of F-16 sorties through the Sevier B and D MOAs in FY 2000 has been used to estimate P_o. Case 3 uses the number of F-16 flights through the Sevier B and Sevier D MOAs in FY 2000, including the anticipated increase in number of sorties (17.4 percent) in the future from 12 additional F-16s stationed at Hill Air Force Base. The staff's calculations are based on the cask storage area estimated by PFS. With respect to the Canister Transfer Building, however, the staff used a length and width at the widest point. In these calculations, while a 10 mi effective width is reasonable, for conservatism the staff used an effective width of 8 mi for Skull Valley.

Information presented in Table 15-9 shows that the number of F-16 sorties through Skull Valley with jettisonable ordnance has decreased in past several years. Similarly, the number of munitions carried onboard the aircraft has also decreased in past several years. This is reflected in the probability values estimated by PFS and the staff.

Using Equation (15-6), the staff's analysis resulted in estimated values of P_o for the three cases as follows:

Case 1: $P_o = 1.3 \times 10^{-7}$ per year
Case 2: $P_o = 3.7 \times 10^{-8}$ per year

Case 3: $P_o = 4.4 \times 10^{-8}$ per year.

As discussed above, Case 1 includes sorties and ordnance information from FY 1998 only. Although the number of sorties through the Sevier B and Sevier D MOAs is less than that in FY 2000, the fraction f_o of F-16s carrying jettisonable ordnance is larger (11.8 percent compared to 2.3 percent in FY 2000). Consequently, the estimated annual probability is higher. Taking into consideration more recent data, including 12 additional F-16 aircraft stationed at Hill Air Force Base (Case 3), the estimated annual probability is 4.4×10^{-8} per year.

Based upon the Joint Munitions Effects Manual Trajectory Model prepared by the Joint Technical Coordinating Group at Eglin Air Force Base, Florida, PFS also considered the effects of impact angle on the estimated probability. The analysis showed that the estimated probability would increase by an insignificant amount.

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 to be acceptable because:

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

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

- Adequate information has been provided on aircraft sorties with different ordnance through Skull Valley.

- The estimated probability is conservative as a uniform distribution of F-16 flights through Skull Valley was assumed.

- The estimated probability is conservative since 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 and around the casks and pads.

On the basis of this information, there is reasonable assurance that jettisoned ordnance from F-16s hitting would not pose a significant 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 UTTR (Private Fuel Storage Limited Liability Company, 2000b). 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.

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. With respect to fragment impacts, PFS notes that Regulatory Guide 1.91 (U.S. Nuclear Regulatory Commission, 1978), views the effects of air overpressure to bound the fragmentation effect. Specifically, Regulatory Guide 1.91 indicates that missile effects associated with explosions need to be considered explicitly only if the overpressure criteria within the guide are exceeded. Hence, the hazards associated with exploding bombs can be addressed solely on the basis of overpressure effects as long as these do not exceed the criteria in Regulatory Guide 1.91.

PFS indicates that exploding ordnance impacting the ground near the Facility (without directly hitting it) may occur in two distinct modes (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 exploding onboard ordnance crashing sufficiently close to the Facility so as to exceed the design-basis air overpressure is defined as :

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

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_{lo} = 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 an outer band surrounding 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, PFS made a conservative assumption that the aircraft is approaching from a direction at which the structures present the largest target for the aircraft to hit. PFS did 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 effective area A_{nm1} is estimated by PFS as (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

$$A_{nm2} = 2\, r_e\, (L_f + W_f) + \pi\; r_e^{\,2} \tag{15-10}$$

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-9407, or Minol-2. The discussion below addresses the appropriate explosive to be used in these calculations.

Although smaller bombs are used in the UTTR, PFS conservatively assumed that all of the ordnance to be MK-84 (Private Fuel Storage Limited Liability Company, 2000b, 2001b). Furthermore, PFS assumed that all ordnance could be represented by PBX-9407 explosive (Private Fuel Storage Limited Liability Company, 2000b, 2001b).

PFS indicated that in FY 1998 approximately 5 percent of F-16 sorties through Skull Valley carried live but unarmed ordnance. Based on the above information, PFS 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 explodes while either carried onboard a crashing aircraft or jettisoned from a crashing aircraft, using FY 1998 data, is 2.43×10^{-10} per year (Private Fuel Storage Limited Liability Company, 2000b).

PFS has obtained additional information from the U.S. Air Force on F-16 sorties for the UTTR South area during FY 2000 that carried onboard live ordnance (Private Fuel Storage Limited Liability Company, 2001b). This information is given in Table 15-9. Based on this information, PFS revised the estimated probability of exploding ordnance (either carried onboard a crashing aircraft or jettisoned from a crashing aircraft) potentially damaging the storage casks or the Canister Transfer Building (Private Fuel Storage Limited Liability Company, 2001b), as discussed below.

PFS indicates that 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, and the same as the probability that a pilot transiting Skull Valley would not be able to divert the aircraft away from the proposed PFS Facility. As discussed above in connection with F-16s transiting Skull Valley, this probability was estimated by PFS to be about 10 percent.

Table 15-9 shows that 7 F-16 sorties to the UTTR South area in FY 2000 carried MK-84 bombs. Additionally, 56 sorties carried MK-82 bombs. As noted above, ordnance carried onboard by F-16 aircraft of the 419th Fighter Wing may not have been included in these figures. Assuming that F-16 aircraft of the 419th Fighter Wing, on a per aircraft basis, would fly sorties to the UTTR South area with ordnance at the same rate and using the same munitions as the 388th Fighter Wing, the estimated numbers of sorties with MK-84 and MK-82 bombs are 9 and 72, respectively. The staff has assumed that all F-16 sorties with live ordnance carried only MK-84 bombs; this is a conservative assumption based on the information presented in Table 15-9. Therefore, an estimated 81 F-16 sorties out of 7,059 to the UTTR South area carried live ordnance in FY 2000.

Assuming a proportional increase in sorties with live ordnance to the UTTR South area due to the 12 additional F-16 aircraft stationed at Hill Air Force Base, approximately 95 sorties out of an estimated total of 8,287 would carry live ordnance. As discussed before, the estimated number of flights through Skull Valley would be 7,040, considering a proportional increase in sorties because of the 12 additional F-16 aircraft. The staff has assumed flights through the Sevier B and Sevier D MOAs as equivalent to flights through Skull Valley. Therefore, the estimated number of sorties through Skull Valley with live ordnance would be 95 × 7040/8287, or 81. In other words, 81/7040, or, 0.0115 or 1.15 percent of flights through the Sevier B and Sevier D MOAs would carry some kind of live ordnance. Therefore, f_{lo} (fraction of F-16s crashing with live ordnance), is estimated to be 0.0115 × 0.1 or 0.00115.

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., about 90 percent. Therefore, f_{jlo} (fraction of aircraft crashing that jettison live ordnance) is estimated to be 0.0115 × 0.9 or 0.01.

PFS has submitted documentation from the U.S. Air Force indicating that the potential for an explosion of unarmed ordnance is remote (Private Fuel Storage Limited Liability Company, 2000b, Tab Q). The U.S. 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 similar accidents have taken place since then. 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 General Cole, General Jefferson, and Colonel Fly, the assumed explosion probability of 1 percent for unarmed jettisoned ordnance is conservative.

PFS calculated the effective area of the Facility using the methodology of DOE-STD-3014-96. As discussed previously, P_e is equal to 0.01 for both the Canister Transfer Building and the cask storage area. In its recent analysis, using FY 1998 ordnance and sortie information, PFS set f_{lo} equal to 0.005 (Private Fuel Storage Limited Liability Company, 2001b). Similarly, PFS set f_{jlo} to 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:

$P_{nm1} = 2.10 \times 10^{-11}$ per year
$P_{nm2} = 1.88 \times 10^{-10}$ per year.

Combining these results PFS concluded that the aggregate probability of live ordnance exploding while either carried onboard a crashing aircraft or jettisoned from a crashing aircraft is about 3.25×10^{-10} per year (Private Fuel Storage Limited Liability Company, 2001b). PFS concluded that a simultaneous explosion of multiple ordnance would not increase the risk (Private Fuel Storage Limited Liability Company, 2000b, 2001b) to a significant level.

The staff performed a confirmatory calculation to verify that the explosive selected by PFS is appropriate to represent the ordnance typically carried by F-16s flying through Skull Valley. Additionally, the staff's calculation accounted for the projected increase in the number of F-16s stationed at Hill Air Force Base and the simultaneous detonation of multiple ordnance. The staff also used a conservative air overpressure limit for both the storage casks and the Canister Transfer Building with Minol-2 as the representative explosive. The staff estimated the equivalent TNT amount using the methodology given in Technical Manual TM5-1300 (U.S. Army, 1990). In addition, the staff considered that an F-16 may carry two MK-84 bombs onboard, and conservatively assumed that all F-16 with jettisonable ordnance carried two MK-84 bombs.

As discussed above, the staff has estimated that approximately 81 sorties to the UTTR South area can be expected to carry some jettisonable live ordnance. Therefore, 1.15 percent (81/7040) of the sorties through Skull Valley can be expected to carry jettisonable live ordnance. As previously noted, PFS assumes that the probability of a pilot of a crashing F-16 being able to jettison its ordnance is the same as the probability of the pilot being able to execute avoidance procedures. This was estimated to be about 0.9. Therefore, f_{lo} is estimated to be 0.0115×0.1, or 0.00115, and f_{jlo} is estimated to be 0.0115×0.9, or 0.01.

In the staff's calculation, a band area has been included in the estimation of P_{nm} to account for aircraft impacting just behind a facility. The staff assumed this area to be the same as the area in front of it. Hence, the total area for 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} is 7.0×10^{-11} and 3.6×10^{-11} per year for the cask storage area and the Canister Transfer Building, respectively. Hence, the combined probability P_{nm1} for both structures is 1.1×10^{-10}. Similarly, the probability P_{nm2} is equal to 4.4×10^{-10} and 1.6×10^{-10} per year for the cask storage area and the Canister Transfer Building, respectively. Therefore, the combined probability P_{nm2} for both structures is 6.0×10^{-10} per year.

The aggregate 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}. On the basis of the above, staff estimates that P_{nm} is equal to $1.1 \times 10^{-10} + 6.0 \times 10^{-10}$, or 7.1×10^{-10} per year. This is about a factor of two higher

than the PFS estimate of 3.25×10^{-10} per year (Private Fuel Storage Limited Liability Company, 2001b).

These estimated probabilities are conservative, as it is assumed that all F-16 sorties armed with live ordnance would carry two MK-84 bombs. In reality, only approximately one-third of the sorties carry MK-84 bombs. Also, as indicated by PFS (2000b), the probability will still be very small even 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 from jettisoned ordnance.
- The applicant has provided adequate information about the jettisoned ordnance.
- A tenfold increase in the probability of explosion of unarmed jettisoned ordnance (from 1 to 10 percent) would still not present an unacceptable hazard to the Facility.
- A confirmatory analysis carried out by the staff assuming all F-16 sorties carrying live ordnance would carry two MK-84 bombs did not show a significant 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 significant hazard to the Facility.

X-33 Suborbital Demonstrator Vehicle

[Note: Based on the information from the National Aeronautics and Space Administration (NASA), further development of the X-33 project has been stopped and the project has been canceled. Therefore, the X-33 demonstrator vehicles no longer pose a hazard to the proposed PFS Facility. However, the X-33 vehicle was in the development stage when the staff initiated the review of the PFS Facility application. Therefore, the potential impact of the X-33 vehicle is included in this SER.]

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 proposed for validating new technologies and reducing the risk for construction of VentureStar, a reusable launch vehicle. It was being jointly developed by

the National Aeronautics and Space Administration (NASA) and Lockheed Martin Skunk Works, Palmdale, California. As a proof-of-concept vehicle, the unmanned X-33 would be one-half the size and one-ninth the weight of VentureStar. The X-33 would not reach orbit altitude and would not carry any payload. The X-33 vehicle would have a dry weight of approximately 75,000 lb and a gross liftoff weight with fuel of approximately 285,000 lb. The X-33 would take off vertically like a rocket, eventually reaching an altitude of 60 mi at a speed of Mach 9 to over Mach 13, and would land horizontally like a plane. As many as 15 test flights of the X-33 were 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 would go to Michael Army Air field at Dugway Proving Ground, Utah, approximately 450 mi from Edwards Air Force Base. A flight to Michael Army Air field would last 14 min at top speeds of between Mach 9 and Mach 11. These five flights were to be completed in a period of 6 mo (Cole, 1999a).

The planned approach for the X-33 flight test was to enter UTTR airspace R-6402 at 60,000 ft from the southwest (Cole, 1999a). Once over Michael Army Air Field, the X-33 would initiate a descent turning north with a turn radius of 4–6 mi. It would continue turning until it is lined up with Runway 12, which is 13,125 ft long.

Most of the fuel of the X-33 would be expended by the time of landing. Additionally, the X-33 would not fly over Skull Valley. Moreover, the X-33 testing program was to 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.

Probability Acceptance Criterion 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 1×10^{-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 1×10^{-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, 1981b). 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 1×10^{-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 those 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 probability of 1×10^{-6} crashes per year is an acceptable acceptance criterion 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's review, the crash probabilities for aircraft and ordnance are given in Table 15-10. 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 onboard 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 15-10. These estimated values may be different than those determined by PFS (Private Fuel Storage Limited Liability Company, 2000b, 2001b) due to sensitivity or confirmatory calculations performed by the staff. Otherwise, the values determined by PFS have been accepted by the staff as reasonable.

Based on the information presented in Table 15-10 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 Fuel 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 DOD provides guidance to the planners of military training routes, and it is expected that the PFS Facility would be listed therein so that military flight planners and pilots would be aware of the presence of the Facility in Skull Valley, Utah.

Additionally, as military aircraft approach Skull Valley, pilots tune to a discrete radio frequency directed by Clover Control for communication with each other and the range controllers (Private Fuel Storage Limited Liability Company, 2001e). The staff at Hill Air Force Base confirmed that the pilots are in constant communication with the controllers at Clover Control while flying through Skull Valley. Also, Clover Control has the means to provide the pilot with location information, if necessary.

Table 15-10. Estimated probability of crashes per year at Private Fuel Storage Facility.

Source	Estimated Annual Probability[3] (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	$< 1.0 \times 10^{-8}$	$< 1.0 \times 10^{-8}$‡
Aircraft taking off and landing at Michael Army Airfield	0	~0‡
Aircraft flying military route IR-420	3×10^{-9}	$\sim 3 \times 10^{-9}$
Aircraft transiting Skull Valley	3.11×10^{-7}	2.5 to 3.1×10^{-7} *
Aircraft training at the UTTR South Area	$< 1.0 \times 10^{-8}$	$< 1.0 \times 10^{-8}$
Aircraft returning using Moser Recovery route	2.0×10^{-8}	2.5×10^{-8}*
Military helicopter	0	~0‡
Jettisoned military ordnance - Impact	3.2×10^{-8}	4.4×10^{-8} †
Jettisoned military ordnance - Nearby Explosion	3.25×10^{-10}	7.1×10^{-10} †
X-33 demonstrator vehicle	0	0
Cumulative Hazard	$< 4.17 \times 10^{-7}$	3.7 to 4.3×10^{-7}

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

The staff reviewed the scenarios presented by PFS in connection with the proposed Facility and also carried out independent confirmatory analyses in selected cases. The confirmatory analyses relied on assumptions different from those applied by PFS. For example, the staff utilized the data for FY 2000, increased by the 12 additional F-16 aircraft received in FY 2000. The staff took into account the use of formation flights (either 2-ship or 4-ship) by the F-16 pilots while transiting Skull Valley on the way to the UTTR South area (a fact not taken into account by

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[3] As discussed in Private Fuel Storage Limited Liability Company (2001e, Footnote 39), a change of design of the Canister Transfer Building has increased its exterior dimensions by a small amount. Consequently, the effective area of the proposed Facility has increased by approximately 2 percent for general aviation aircraft and approximately by 1 percent for other aircraft Private Fuel Storage Limited Liability Company (2001e). The resulting increase of crash probability is negligible.

PFS), which would have the result that about 50 percent of the flights would not be in a position to pose a credible crash hazard to the proposed Facility. Furthermore, the staff used a higher (factor of 2) probability that a pilot with sufficient time and control of the aircraft would still not avoid the proposed Facility. This higher probability value has been used in all cases where the F-16 aircraft fly in the normal in-flight mode in the vicinity of the proposed Facility. Consequently, the staff's independent analyses tested the robustness of the analyses and estimates presented by PFS. Based on these confirmatory analyses and the staff's evaluation of the PFS analyses, it is concluded that the aircraft crash probability estimated by PFS is acceptable.

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 takeoffs 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 States 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 at the same rate as the total numbers of takeoffs and landings, which is 66 percent by 2025. Therefore, the estimated 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 would be 1.1×10^{-8} per year by 2025, as compared to $< 1.0 \times 10^{-8}$ shown in Table 15-10.

PFS has discussed the long term trend of military aviation to project the estimated aircraft crash probability onto the proposed Facility (Private Fuel Storage Limited Liability Company, 2001b). The U.S. Air Force is replacing older and less capable aircraft with modern, more advanced aircraft. Since the newer aircraft are typically more costly than the aircraft being replaced, significant resources are spent on research, improved design, manufacturing, and quality control so as to make the aircraft safer to operate. Figure 1 of Private Fuel Storage Limited Liability Company (2000b) illustrates the continued improvement of aircraft performance with time. The crash rates of newer aircraft are decreasing relative to those of their predecessors.

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. The U.S. Air Force has experienced an approximately one-third reduction in personnel, equipment, and funding since the end of the

Cold War (Private Fuel Storage Limited Liability Company, 2001b). The number of aircraft in the inventory of the U.S. Air Force has decreased from 7,640 in FY 1992 to 6,205 in FY 2000, with a corresponding decrease of flying hours from 2,790,000 to 2,036,000 (Private Fuel Storage Limited Liability Company, 2001b). Reduced budgets and increased fuel costs have resulted in constrained flying hours for training. Use of constantly improving flight simulators is enabling the pilots to advance flying proficiency with reduced actual flying hours. Additionally, the Joint Strike Aircraft is expected to replace the F-16 aircraft. Based on information from the Joint Strike Fighter Public Affairs Office, PFS has stated that the U.S. Air Force plans to procure a total of 1,763 Joint Strike Aircraft over the lifetime of the airplane, approximately 78 percent of the 2,230 F-16s that have been ordered (Private Fuel Storage Limited Liability Company, 2001b). Although it is difficult to predict the structure of the U.S. Air Force in the future, historic trends and current acquisition programs indicate a smaller future force structure.

Based on the above discussion, military aircraft crash probabilities are expected to remain at or below the staff's projected cumulative value of 3.9×10^{-7} crashes per year for military aircraft in the future. Therefore, the cumulative hazard to the proposed PFS Facility, taking into account commercial, general aviation, and military aircraft would increase from 4.3×10^{-7} crashes per year, currently estimated by the staff, to 4.5×10^{-7} crashes per year in 2025. Consequently, the above conclusions concerning the aircraft crash hazard for the Facility based on current information would still be valid for the foreseeable future, assuming the projected air traffic growth based on the long-term projections, as discussed above, remains valid. It should be noted that if the flight activities near the Facility change significantly in the future, including the introduction of new types of aircraft whose crash statistics are not bounded by those of the aircraft considered herein, the above conclusions could be subject to change.

Conclusion

Based on the information and analyses provided by PFS and the staff's independent confirmatory and sensitivity analyses, the staff concludes that the cumulative probability of a civilian or military aircraft crashing at or affecting the Facility is within the acceptance criterion of 10^{-6} per year. Therefore, there is reasonable assurance that civilian or military air crash accidents do not pose a significant 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), Wagner and Girman (2000), Private Fuel Storage Limited Liability Company (2000b), and Girman and Wagner (2001) 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), Wagner and Girman (2000), and Girman and Wagner (2001), the cruise missiles currently tested at the UTTR include (1) AGM-86B Air Launched Cruise Missiles (ALCM), (2) AGM-86C Conventional Air Launched Cruise Missiles (CALCM), and (3) AGM-129 Advanced Cruise Missiles (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). Tomahawk (BGM-109) cruise missiles were last tested at the UTTR in 1998 (Wagner and Girman, 2000). All of these missiles (AGM-86, AGM-129, and BGM-109) are subsonic and autonomous cruise missiles. They can fly preprogrammed flights along designated routes. Approximately six cruise missile tests are planned annually at the UTTR.

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).

The Tomahawk cruise missile can fly autonomously at subsonic speed along a preprogrammed route for the entire mission. It was developed in the 1970s to be launched from surface ships or submarines against land targets. It can fly preplanned mission profiles to the target through the use of a very accurate inertial measuring unit and a global positioning system in conjunction with the digital maps stored on board.

The UTTR restricted airspace has an area of 8,125 square nautical miles. Additionally, another 8,875 square nautical miles belong to various Military Operating Areas adjacent to the UTTR. However, only 2,700 square nautical miles of the UTTR airspace lies above the Department of Defense land (Figure attached with Private Fuel Storage Limited Liability Company, 2001c). The remaining 14,300 square nautical miles of air space is situated over lands belonging to the Bureau of Land Management, the State of Utah, and some privately owned lands (Girman and Wagner, 2001). The air traffic at the UTTR is maintained by Clover Control (299th Range Control Squadron).

Typically, cruise missiles are launched over Department of Defense (DOD) land west of Granite Mountain with adherence to the following limitations. The launches are confined to the northern and western parts of the UTTR. The launch sites are at least 30 statute miles away from the proposed PFS Facility site. The missiles are released from north-to-south or east-to-west directions. Therefore, the missiles are directed away from the proposed PFS Facility site (Wagner and Girman, 2000). The missiles are launched at altitudes between 15,000 and 20,000 ft above ground level, and descend to the planned altitudes after release. The nominal enroute altitudes depend on the mission profile and are usually between 10,000 to 500 ft above ground level.

There are four cruise missile target areas in the UTTR. The TS-1 target (Parkersville target complex about 5 mi northwest of Wig Mountain) is approximately 18 mi from the proposed PFS Facility site (Private Fuel Storage Limited Liability Company, 2000b, Tabs A and B; Girman and Wagner, 2001) and is located beneath the restricted airspace R-6402A. Target TS-2, located beneath R-6406A restricted airspace, is approximately 21 statute miles west of the proposed facility. Both the TS-3 and TS-4 targets are located beneath the restricted airspace of R-6407. These targets are approximately 42 and 44 statute miles west of the proposed facility (Private Fuel Storage Limited Liability Company, 2000b, Tabs A and B; Girman and Wagner, 2001). Cruise missiles with inert warheads launched over Department of Defense land west of Granite Mountain may impact at the Sand Island target complex (TS-4 target) (Enges-Maas,1999a).

The planning for a cruise missile test involves several organizations and requires a number of steps to ensure proper execution with maximum safety. The steps include mission planning (specifying test objectives, missile flight route selection with associated restrictions), target selection, missile and launch platform configuration specifications, mission firing plan (go/no-go decision criteria, mission recovery or termination requirements, contingency plans for anomalous events), and test system readiness assessment (Wagner and Girman, 2000). 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. Steps that influence the safety of the proposed Facility from a cruise missile crash 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 to gather and relay telemetry data of vital missile parameters to the 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 inform test conductors 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 specifies additional safety criteria. In addition, the 49th Test Squadron maintains comprehensive lessons learned documentation from previous tests which is used in subsequent test planning. Additionally, contingencies for unusual events such as loss of Airborne Range Instrumentation Aircraft radio and chase aircraft radio relay; Remote Control and Command; and visual contact with the missile by the chase aircraft pilots, chase aircraft, Airborne Range Instrumentation Aircraft, and tanker(s) are reviewed before each test (Wagner and Girman, 2000).

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 will relay commands from the Mission Control Center. The Mission Control Center is located at Hill Air Force Base. The control center continuously receives signals from the missile in flight. Additionally, the Advanced Range Instrumentation Aircraft monitors the cruise missile test and relays telemetry data to the Mission Control Center.

Four to eight F-16/F-14 chase aircraft (a minimum of three is required for conducting a cruise missile test) accompany the missile throughout its flight path to enhance safety. These aircraft remain behind the missile to monitor its performance until the missile impacts the ground. If the chase aircraft pilots detect any malfunction of the missile, the Advanced Range Instrumentation Aircraft can be alerted so that the missile can be flown manually, or its flight can be remotely terminated. These aircraft are fitted with Remote Command and Control pods for manually flying the missile, if required. Two aircraft always track the missile while other aircraft refuel from a tanker. Hence, there are substantial provisions for monitoring and controlling cruise missiles to maintain a low probability of an uncontrolled crash.

The Air Force uses avoidance as one of the primary safety measures 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 (the organization responsible for conducting operational tests of the cruise missiles at the UTTR) and by the 388th Range Squadron of 388th Wing of Air Combat Command (the organization responsible for the UTTR) to avoid known occupied sites and no-fly areas so as to minimize risks. Test personnel and chase pilots are informed of the known avoidance areas.

At present, there are 17 inhabited locations in Skull Valley. The 49th Test Squadron does not plan the flight path of a missile test within 10 nautical miles of the proposed PFS Facility due to flight restrictions in Skull Valley and Dugway Proving Ground, the missiles' turn radii, and the locations of the targets at the UTTR (Wagner and Girman, 2000). The test squadron has elected to avoid the entire Skull Valley, the northern part of Sevier B MOA, and restricted areas R-6406B, and R-6402B for cruise missile testing (Girman and Wagner, 2001).

The flight trajectory of a cruise missile test is selected under the restriction of the range avoidance rule of 2 nautical miles and no-fly regions. 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 the test members and is programmed to remain within the restricted air spaces and military operating areas.

All cruise missiles are fitted with an FTS that is installed prior to testing on the UTTR (U.S. Air Force, 1999) since the missiles have the capability to cross the UTTR range 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 and Flight Termination Commonality Standard Document 319-99 (Private Fuel Storage Limited Liability Company, 2000b, Tab B; Wagner and Girman, 2000). Compliance with these standards 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 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 approved FTS installed on each cruise missile can (1) alter or terminate its flight almost instantly on command from the Airborne Range Instrumentation Aircraft or the Range Safety Officer at the Mission Control Center, and (2) terminate its flight automatically after failing to receive a designated signal from the Airborne Range Instrumentation Aircraft or ground stations for a preset time period (generally within 60 seconds). The Airborne Range Instrumentation Aircraft and support aircraft can also override the missile's programmed flight path and redirect it, if necessary, using the FTS to avoid weather or any other hazards. The missile also

transmits confirmation signals in addition to the critical operating parameters to the Mission Control Center throughout the flight so that the Mission Control Center can monitor the missile and flight status. 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 systems are working properly (U.S. Air Force, 1998; Cole, 1999a; Wagner and Girman, 2000).

A missile is considered to have experienced an uncontrolled crash only if the crash occurred before reaching the programmed target (Enges-Maas, 1999a). 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 unmanned 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). Wagner and Girman (2000) and Girman and Wagner (2001) stated that 12 documented cruise missiles have crashed at the UTTR in the last 10 years out of approximately 80 tests.

There are two basic modes of malfunction of a test missile: (1) navigation system failure and (2) vehicle system failure. When required, a missile test is aborted either by diverting the missile path to an alternate 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 has never experienced an FTS failure. The staff examined the reported or estimated crash locations of cruise missiles and unmanned aerial vehicles in the UTTR. These locations were distributed in a pattern having a general north-south orientation 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.

FTS activation and missile diversion are effective only if there is sufficient time available. During 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). This cruise missile crashed in the Lake Sevier area, approximately 90 mi from the proposed Facility. Although the missile crashed outside DOD land boundaries, it remained within the UTTR air space. Accordingly, this crash does not reflect a cruise missile hazard to the proposed PFS Facility.

As discussed in Private Fuel Storage Limited Liability Company (2000b, Section XIII), the DOD maintains an Area Planning Guide. The guide is updated every 56 days. It is expected that the PFS Facility would be listed in the Area Planning Guide. 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 missile 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.

An uncontrolled crash of a cruise missile onto the Facility is possible only if there is a series of multiple failures of redundant safety features. Specifically, this would require 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 failure of a series of safety features is judged to be extremely low.

Moreover, as discussed above, avoidance of a non-target facility is one of the primary safety measures used by the U.S. Air Force. The Air Force does not plan any cruise missile flight path to be closer than 10 nautical miles of the proposed PFS Facility. Also, as discussed earlier, the provision of the FTS provides an additional reliable means of termination of the missile flight before it can reach the proposed facility. Further, a qualitative 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 show an approximate orientation in a north-south direction, approximately 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 negligibly 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:

- Verifiable 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 the location of previous crashes.
- The U.S. Air Force uses avoidance as one of the primary safety measures to protect facilities. It establishes a 2-mi wide avoidance area from all non-mission facilities and no fly areas. The U.S. Air Force does not plan the flight path of a missile test within 10 nautical miles of the proposed PFS Facility and, in addition, avoids the entire Skull Valley. 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 equipped with an FTS, which will terminate the missile if it does not receive a radio signal. The FTS also can destroy and terminate the cruise missile flight on command from the Mission Control Room in case a weapon anomaly is detected. Based on the available information on FTS performance, the FTS would be able to terminate the missile flight significantly before it could reach the proposed facility, if required.

- 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 that 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.

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