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

OFFICE OF THE
GENERAL COUNSEL

February 19, 2002

Michael C. Farrar, 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
Atomic Safety and Licensing Board
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 filing requirements discussed during the telephone prehearing conference of January 17, 2002, and the schedular modification approved by the Licensing Board Chairman on February 1, 2002, enclosed please find the following documents:

1. "NRC Staff's Outline of Proposed Key Determinations for Contention Utah K/ Confederated Tribes B";

2. "Preface to NRC Staff's Testimony of Drs. Kazimieras Campe and Amitava Ghosh Concerning Contention Utah K/ Confederated Tribes B";

3. "NRC Staff Testimony of Kazimieras M. Campe and Amitava Ghosh Concerning Contention Utah K/Confederated Tribes B (Inadequate Consideration of Credible Accidents)," together with the attached statements of professional qualifications for Drs. Campe and Ghosh;

4. NRC Staff's Proposed Exhibit D, entitled "Skull Valley Elevation Profile at PFSF Latitude."

By letter dated November 13, 2001, the Staff served upon the Licensing Board and parties a copy of Supplement No. 1 to the Staff's Safety Evaluation Report ("SER") concerning the PFS Facility. SER Supplement No. 1 consisted of three sections of SER Chapter 15 (issued on September 29, 2000), revised in their entirety (§§ 15.1.2.11 (aircraft crash), 15.1.2.18 (cruise missiles), and 15.3 (references). The Staff is currently preparing a unified SER, which will incorporate into one document (a) the SER, (b) the changes set forth in SER Supplement No. 1, and (c) the changes set forth in Supplement No. 2, issued on December 21, 2001 (geotechnical issues). *See* Tr. 2804. The Staff expects to provide copies of the unified SER to the Licensing Board and parties within the next two weeks, and will offer that document into evidence as Staff Exhibit C.

Sincerely,

Catherine L. Marco

Catherine L. Marco
Counsel for NRC Staff

Sherwin E. Turk

Sherwin E. Turk
Counsel for NRC Staff

cc: Service List

February 19, 2002

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING BOARD

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

NRC STAFF'S OUTLINE OF PROPOSED KEY DETERMINATIONS FOR CONTENTION UTAH K/ CONFEDERATED TRIBES B

I. General

A. PFS based its analyses on NUREG-0800 methodology. Certain modifications to the formula presented in NUREG-0800 were made by PFS and found to be acceptable by the Staff. NUREG-0800 sets forth a formula for determining the probability of a crash, which includes: "C" (the in-flight crash rate per mile for aircraft using the airway), "W" (width of the airway in miles), "N" (number of flights per year along the airway), and "A" (effective area of the facility in square miles).

B. The Staff presented its evaluation of the matters raised in this contention in SER Supplement No. 1, § 15.2.2.11 (Nov. 13, 2001), and its testimony. The Staff concluded that the probability of a crash onto the PFSF from all sources is within the acceptance criterion of 10^{-6} per year, and that there is reasonable assurance that aircraft crash accidents do not pose a significant hazard to the PFSF.

II. F-16 Aircraft Transiting Skull Valley from HAFB to the UTTR

A. PFS applied NUREG-0800 methodology to estimate crash probability, modified to reflect the potential for a pilot to direct the aircraft away from a fixed ground site, such as the proposed ISFSI.

B. PFS utilized the DOE ACRAM study data (FY 1975 to 1993) in estimating the in-flight crash rate per mile (C), which it updated with more recent data from FY 1994 to FY 1998. This calculation of "C" is acceptable.

1. The ACRAM study categorizes the crash rate data by mode of flight (take-off, landing, normal flight, and special operation). PFS used the "normal" flight mode as representative of the conditions in which F-16s transit Skull Valley. This is acceptable.

2. The potential for bird strikes is accounted for in the DOE and U.S. Air Force actual crash rate data. Skull Valley does not present unique bird strike hazards.

3. The crash probability rate is not affected by aircraft fleet aging. There is no discernible "bathtub" effect *(i.e.,* a "bathtub" curve for crash rate versus time) in the F-16 crash rate data. Also, newer military aircraft are expected to exhibit a decreasing trend in crash rates.

C. PFS estimated "W" (width of the airway) for the Sevier B MOA to be 10 miles. This effective width is acceptable, considering the existing elevation restrictions for the Sevier B MOA and the presence of the Stansbury Mountains. A 12 mile width was utilized for the Sevier D MOA.

D. PFS utilized recent information as to the number of flights per year (N), provided by the U.S. Air Force. The PFS estimation of "N" is acceptable.

1. PFS used the average number of F-16 sorties through Skull Valley for FY 1999 through FY 2000. It also provided a separate calculation using data for FY 2000 alone; and it accounted for additional flights resulting from the recent acquisition of 12 additional F-16s at HAFB.

2. The PFS estimate of "N" is conservative. Up to 10 percent of all flights assumed for "N" do not transit Skull Valley. Also, approximately half of the flights would have negligible potential for striking the PFSF because they fly in two-ship or four-ship formations, whereby no more than one of two aircraft would be pointing at the PFSF.

E. The Applicant's estimation of "A" (effective area of the facility in square miles), utilizes appropriate methodology and is acceptable.

F. Ability of Pilot to Avoid Facility

1. The NUREG-0800 formula was properly modified to account for the probability that a pilot would be able to direct an F-16 away from the facility.

2. PFS evaluated U.S. Air Force accident reports for 121 destroyed aircraft, and excluded those accidents which are not typical of Skull Valley conditions. This is acceptable.

3. PFS examined the accident reports to determine the number of crashes in which pilots would have been able to direct the aircraft away from a fixed site on the ground. This is acceptable.

4. Pilots are likely to know of the location of the PFS facility on the ground, such that lack of knowledge would not decrease the pilot's ability to avoid the facility. The pilot's ability to avoid the facility would not be affected by weather conditions in Skull Valley or the level of the pilot's experience.

G. The probability of a crash of an F-16 aircraft transiting Skull Valley from HAFB to the UTTR onto the facility is very low, or approximately 2.5 to 3.1 x 10^{-7} per year.

III. <u>Potential F-16 Ordnance Impacts at the PFS Site</u>

A. PFS appropriately followed the NUREG-0800 methodology in assessing potential ordnance impacts at PFS facility, modified to determine the individual probabilities of jettisoned ordnance impacting the facility or exploding near the facility.

B. The probability of military ordnance crashing onto or exploding near the facility so as to cause damage is very low, or approximately 4.5×10^{-8} per year.

IV. Potential F-16 Crashes at the PFS Site from Aircraft Returning to the HAFB from UTTR South on the Moser Recovery Route.

A. The Applicant appropriately followed the NUREG-0800 methodology, modified to account for ability of a pilot to avoid the facility.

B. The likelihood of a crash onto the PFSF from an F-16 using the Moser Recovery route is very low (approximately 2.5×10^{-8} per year) and does not pose an undue hazard to the facility.

V. Potential of Aircraft From Michael Army Air Field at Dugway Proving Ground on Airway IR-420 Crashing into the PFS Site.

A. The Applicant followed the NUREG-0800 formula, using appropriate in-flight crash rate data for large military aircraft.

B. PFS did not include F-16 flights in estimating this crash rate, in that F-16 flights on airway IR-420 are already accounted for in the analysis of F-16s transiting Skull Valley.

C. The likelihood of a crash onto the PFSF of aircraft using airway IR-420 is very low (approximately 3×10^{-9} per year) and does not pose an undue hazard to the facility.

VI. <u>Air to Air Combat Training on the UTTR</u>

A. The Applicant followed a modified NUREG-0800 formula.

B. The likelihood of an aircraft crash onto the PFSF due to air-to-air combat training on the UTTR is very low (approximately 1×10^{-8} or less per year) and does not pose an undue hazard to the facility.

VII. <u>The Cumulative Hazard</u>

A. The probabilities with respect to all sources were summed to arrive at the cumulative hazard, which is estimated to be 3.7 to 4.3×10^{-7} per year.

C. The cumulative hazard falls under the Commission's accepted criteria of 10^{-6} per year, and does not pose an unreasonable risk to the facility.

February 19, 2002

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In the Matter of	)	
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PRIVATE FUEL STORAGE, L.L.C.	)	Docket No. 72-22-ISFSI
	)	
(Independent Spent Fuel Storage Installation)	)	
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PREFACE TO NRC STAFF'S TESTIMONY
OF DRS. KAZIMIERAS CAMPE AND AMITAVA GHOSH
CONCERNING CONTENTION UTAH K/CONFEDERATED TRIBES B

The NRC Staff (Staff) is filing the joint testimony of Drs. Kazimieras Campe and Amitava Ghosh, concerning the issues raised in Contention Utah K/Confederated Tribes B.

Dr. Amitava Ghosh is a Principal Engineer at the Center for Nuclear Waste Regulatory Analyses (CNWRA), a division of the Southwest Research Institute, in San Antonio, Texas. Dr. Ghosh has experience with respect to probabilistic risk assessments and the design of surface and subsurface facilities. He assisted in the Staff's safety review of the Private Fuel Storage (PFS) Facility (PFSF) with respect to aircraft crash hazards, as set forth in Supplement No. 1 to the Staff's Safety Evaluation Report (SER) for the PFSF.

Dr. Kazimieras Campe is a Senior Reactor Engineer in the Probabilistic Safety Assessment Branch, Division of System Safety and Analysis, NRC Office of Nuclear Reactor Regulation, in Rockville, MD. Dr. Campe has had 30 years' experience in the NRC (and AEC) assessing the risk posed by external man-made hazards with respect to nuclear facilities. He was the principal contributor for Section 3.5.1.6, "Aircraft Hazards," of the NRC's Standard Review Plan, NUREG-0800, which is utilized by the Staff in evaluating aircraft crash hazards at nuclear power reactors and other facilities. He assisted in the Staff's safety review of the PFSF with respect to aircraft crash hazards, as set forth in SER Supplement No. 1.

The Staff's testimony describes the Applicant's aircraft crash analysis and the Staff's review thereof, including certain sensitivity and confirmatory analyses that were performed by the Staff, concerning the remaining issues subject to litigation in this contention.

The Staff's evaluation of the Applicant's analysis is set forth in SER Supplement No. 1, § 15.1.2.11. In sum, the Staff determined that PFS had utilized appropriate methodology in its analyses, based on the NUREG-0800 methodology, as modified in certain respects. Further, with respect to the specific issues in Contention Utah K/Confederated Tribes B, aircraft crash hazards were determined to be as follows:

(1) The probability of a crash of an F-16 aircraft transiting Skull Valley from Hill Air Force Base (HAFB) to the Utah Test and Training Range (UTTR) is very low, or approximately 2.5 to 3.1 x 10^{-7} per year.

(2) The probability of military ordnance crashing onto or exploding near the facility so as to cause damage is very low, or approximately 4.5 x 10^{-8} per year.

(3) The probability of a crash onto the PFSF from an F-16 using the Moser Recovery route is very low, or approximately 2.5 x 10^{-8} per year.

(4) The probability of a crash onto the PFSF of aircraft using airway IR-420 is very low, or approximately 3 x 10^{-9} per year.

(5) The probability of an aircraft crash onto the PFSF due to air-to-air combat training on the UTTR is very low, or approximately 1 x 10^{-8} or less per year.

(6) The cumulative crash hazard, in which the probabilities with respect to all sources are summed, is estimated to be 3.7 to 4.3 x 10^{-7} per year.

Thus, the Staff concluded that the probability of a crash onto the PFSF from all sources is within the acceptance criterion of 10^{-6} per year, and that there is reasonable assurance that aircraft crash accidents do not pose a significant hazard to the PFSF.

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	)	
(Independent Spent Fuel Storage Installation)	)	
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NRC STAFF TESTIMONY OF
KAZIMIERAS M. CAMPE AND AMITAVA GHOSH
CONCERNING CONTENTION UTAH K/CONFEDERATED TRIBES B
(INADEQUATE CONSIDERATION OF CREDIBLE ACCIDENTS)

Q1. Please state your names, occupations, and by whom you are employed.

A1(a). My name is Kazimieras M. Campe (KMC). I am employed as a Senior Reactor Engineer in the Probabilistic Safety Assessment Branch, Division of Systems Safety and Analysis, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission (NRC), in Washington, D.C. A statement of my professional qualifications is attached hereto.

A1(b). My name is Amitava Ghosh (AG). I am employed as a Principal Engineer at the Center for Nuclear Waste Regulatory Analyses, which is a division of the Southwest Research Institute (SwRI), in San Antonio, TX. I am providing this testimony under a technical assistance contract between the NRC Staff (Staff) and (SwRI). A statement of my professional qualifications is attached hereto.

Q2. Please describe your current responsibilities.

A2(a). (KMC) I currently perform safety reviews of nuclear reactor and spent fuel facilities with respect to external man-made hazards associated with nearby transportation activities (*e.g.*, highways, railroads, pipelines, barges, aircraft) as well as military and industrial facilities. My review areas include probabilistic risk assessments as well as thermal hydraulic analyses. My safety reviews include both new nuclear facility license applications and amendments to existing licenses.

A2(b). (AG) I am currently performing safety reviews of spent fuel facilities with respect to human-induced hazards associated with nearby industrial and military facilities. I am also currently performing prelicensing activities and reviews of the proposed high-level waste repository at Yucca Mountain with respect to the design of the facilities, natural and human-induced hazards, and Integrated Safety Analysis. My review areas include probabilistic risk assessments as well as the design of surface and subsurface facilities.

Q3. Please explain what your duties have been in connection with the NRC Staff's review of the application of Private Fuel Storage, L.L.C. (PFS or the Applicant) for a license to construct and operate an Independent Spent Fuel Storage Installation (ISFSI) on the reservation of the Skull Valley Band of Goshute Indians.

A3(a). (KMC) As part of my official responsibilities, I have provided technical support to the NRC Office of Nuclear Material Safety and Safeguards (NMSS) in its safety evaluation of the risks associated with accidents due to external events and facilities in the general vicinity of the Applicant's proposed ISFSI. My involvement included review of the Applicant's Safety Analysis Report (SAR) pertaining to external hazards; review of the Applicant's responses to the Staff's Requests for Additional Information (RAIs); and participation in the Staff's preparation of the "Safety Evaluation Report Concerning the PFS Facility" (SER), issued on September 29, 2000, and SER Supplement No. 1, dated November 13, 2001. In addition, among other tasks, I assisted the Staff in preparing the "NRC Staff's Response to Applicant's Motion for Summary Disposition of Contention Utah K and Confederated Tribes B," dated January 30, 2001, and in responding to various discovery requests that had been submitted by the State of Utah.

A3(b). (AG) As part of my official responsibilities, I have provided technical support to the NRC Staff (NMSS) in its safety evaluation of the risks associated with accidents due to external events and facilities in the general vicinity of the Applicant's proposed ISFSI. My involvement included review of the Applicant's SAR pertaining to external hazards; review of the Applicant's responses to the Staff's Requests for Additional Information (RAIs); and participation in the Staff's preparation of the SER issued on September 29, 2000, and SER Supplement No. 1, dated November 13, 2001. In addition, among other tasks, I assisted the Staff in preparing the "NRC Staff's Response to the Applicant's Motion for Partial Summary Disposition of Contention Utah K and Confederated Tribes Contention B," filed on July 22, 1999, and the "NRC Staff's Response to Applicant's Motion for Summary Disposition of Contention Utah K and Confederated Tribes B," dated January 30, 2001; and in responding to various discovery requests that had been submitted by the State of Utah.

Q4. What is the purpose of this testimony?

A4. The purpose of this testimony is to provide the NRC Staff's views concerning Contention Utah K/Confederated Tribes B. In particular, the following issues are addressed herein: (a) crashes involving F-16 aircraft transiting Skull Valley from Hill Air Force Base (HAFB) to the Utah Test and Training Range (UTTR); (b) potential F-16 ordnance impacts at the PFS site; (c) potential F-16 crashes at the PFS site due to air-to-air combat training over the UTTR; (d) potential aircraft crashes at the PFS site from aircraft returning to the HAFB from UTTR South on the Moser Recovery Route (MRR); (e) potential crashes at the PFS site involving aircraft flying to and from Michael Army Air Field (AAF) at Dugway Proving Ground (DPG), using airway IR-420; and (f) the cumulative hazard to the PFS facility posed by aircraft crashes, as discussed in SER Supplement No.1.

Q5. Are you familiar with Utah Contention K/Confederated Tribes B?

A5. Yes. Utah Contention K/Confederated Tribes B, as admitted and revised by the Licensing Board, states as follows:

> The Applicant has inadequately considered credible accidents caused by external events and facilities affecting the ISFSI, including the cumulative effects of military facilities in the vicinity.

Q6. Please identify the Commission's requirements related to external events impacting an away-from-reactor ISFSI.

A6. (KMC) The Commission has established siting evaluation factors for evaluating site characteristics that may directly affect the safety of an ISFSI. Proposed sites for an ISFSI must be examined, *inter alia,* with respect to the frequency and severity of external man-induced events that could affect the safe operation of the ISFSI, and the existence of man-made facilities and activities that might endanger the proposed facility or affect the facility design, as more fully set forth in 10 C.F.R. Part 72, Subpart E, Sections 72.90, 72.94, and 72.98.

The regulations further provide that design basis external events must be determined with respect to each proposed ISFSI site and design. 10 C.F.R. § 72.90(c). Design bases are defined, in 10 C.F.R. § 72.3, in pertinent part, as follows:

> **§72.3 Definitions.**
> *Design bases* means that information that identifies the specific functions to be performed by a structure, system, or component of a facility or of a spent fuel storage cask and the specific values or ranges of values chosen for controlling parameters as reference bounds for design. These values may be restraints derived from generally accepted state-of-the-art practices for achieving functional goals or requirements derived from analysis (based on calculation or experiments) of the effects of a postulated event under which a structure, system, or component must meet its functional goals. The values for controlling parameters for external events include--
>
> * * *
>
> (2) Estimates of severe external man-induced events to be used for deriving design bases that will be based on analysis of human activity in the region, taking into account the site characteristics and the risks associated with the event.

In accordance with 10 C.F.R. § 72.24, an application for an ISFSI under Part 72 must include a Safety Analysis Report describing the proposed ISFSI, which must contain, *inter alia*, "a description and safety assessment of the site on which the ISFSI . . . is to be located, with appropriate attention to the design bases for external events," as well as information concerning the design of the ISFSI, including identification of the design criteria, design bases, and "the relation of the design bases to the design criteria." Further, the design and performance of structures, systems and components important to safety ("SSCs") must be analyzed for those events that are considered to be within the design bases for the facility, including consideration of "the adequacy of structures, systems, and components provided for the prevention of accidents and the mitigation of the consequences of accidents, including . . . manmade phenomena and events." 10 C.F.R. § 72.24.

The Commission has established general design criteria for an ISFSI, as set forth in 10 C.F.R. Part 72, Subpart F. Pursuant to 10 C.F.R. § 72.120(a), an application to store spent fuel in an ISFSI "must include the design criteria for the proposed storage installation," which "establish the design, fabrication, construction, testing, maintenance and performance requirements for structures, systems, and components important to safety as defined in § 72.3." Minimum requirements for an ISFSI's design criteria include, *inter alia*, "protection against environmental conditions and natural phenomena," whereby SSCs must be designed to accommodate the effects of, and to be compatible with, site characteristics and environmental conditions associated with normal operation, maintenance, and testing of the ISFSI . . . and to withstand postulated accidents." 10 C.F.R. § 72.122(b)(1). Events that do not constitute credible accidents need not be included within the design bases of the facility.

In particular, the Commission has accepted the methodology of the "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants," NUREG–0800, Section 2.2.3, "Evaluation of Potential Accidents," and Section 3.5.1.6, "Aircraft Hazards," as applicable for reviewing and evaluating aircraft hazards with respect to an ISFSI. The Commission has specifically determined that the Staff's consideration of the formulas in NUREG-0800 for calculating air crash probability with respect to a Part 72 facility is appropriate.

Q7. Please explain the staff's approach to determining the aircraft crash hazards at a facility.

A7. As described in NUREG-0800, Section 3.5.1.6, "Aircraft Hazards," the Staff uses probabilistically based screening criteria in determining the acceptability of an aircraft hazard with respect to a nuclear facility site. The Staff reviews an applicant's assessment of aircraft hazards to the facility and determines whether those hazards should be incorporated into the facility's design basis. A site location is deemed to present a low risk of public exposure if the probability of aircraft accidents resulting in radiological consequences greater than 10 C.F.R. Part 100 exposure guidelines is less than about 10^{-7} per year for nuclear power reactors. The Staff has adopted the NUREG-0800 methodology with respect to away-from-reactor ISFSIs and accepts a probability of aircraft accidents resulting in radiological consequences greater than 10 C.F.R. Part 100 exposure guidelines of 10^{-6} per year for these facilities. In practice, only the annual probability of occurrence of an aircraft crash is calculated, as if a conservative assumption was made that the crash would cause the Part 100 guidelines to be exceeded (*i.e.,* as if the probability of exceedance is 1). The Commission specifically approved the use of a 10^{-6} annual probability of occurrence standard for away-from-reactor ISFSIs, in *Private Fuel Storage, L.L.C.* (Independent Spent Fuel Storage Facility), CLI-01-22, 54 NRC ___ (Nov. 14, 2001).

For situations where federal airways or aviation corridors pass through the vicinity of a site, NUREG-0800 states that the probability per year of an aircraft crashing into a facility should be estimated. The probability of a crash is determined on the basis of air traffic density, expected crash rates by type of aircraft and flight mode, effective target area for the site, as well as specific characteristics associated with airways, airports, or other air-identifiable aircraft activities in the vicinity of a site.

This probability may be calculated as follows:

$P = C \times N \times A/W$

where, C is the in-flight crash rate per mile for aircraft using airway, W is the width of airway in miles, N is the number of flights per year along the airway, and A is the effective area of the facility in square miles. The total aircraft hazard probability at the site equals the sum of the individual probabilities obtained.

Q8. Please identify the types of air activity that should be considered in arriving at an analysis of flight crash impacts for a facility.

A8. In accordance with the review guidelines described in NUREG–0800, Section 3.1.5.6, "Aircraft Hazards," the Staff reviews all potential aircraft activity in the vicinity of a nuclear facility such as a reactor or away-from-reactor ISFSI site. This includes the consideration of general, commercial, and military aviation. The review covers specific aviation aspects such as nearby airways and airports, taking into account aircraft types, air traffic density, and specific airway and airport characteristics.

Q9. With respect to the PFS facility, describe the types of aircraft activities in the vicinity of the proposed facility for which the Staff evaluated crash probabilities?

A9. With respect to the PFS facility, the Staff evaluated crash probabilities with respect to numerous military and civilian sources, as set forth in SER Supplement No. 1, at 1-2. Those sources were considered both with respect to their individual hazard contribution as well as cumulatively, as discussed below.

Q10. Has the Staff completed its evaluation of the aircraft crash potential for the PFS facility?

A10. Yes. The Staff reviewed the Applicant's aircraft crash hazard analyses for the PFS facility and carried out confirmatory and sensitivity analyses in selected areas. The Staff's initial review was published in the SER dated September 29, 2000. Following the Staff's receipt of additional information subsequent to publication of the SER, the Staff published an updated, revised aircraft crash hazard evaluation, in section 15.1.2.11 of SER Supplement No. 1, issued on November 13, 2001. The evaluation presented in SER Supplement No. 1 supersedes the evaluation set forth in section 15.1.2.11 of the Staff's SER of September 2000.

The Staff's evaluation of the specific issues raised in Contention Utah K/ Confederated Tribes B that remain for litigation in this proceeding is set forth below.

I. <u>F-16 Aircraft Transiting Skull Valley</u>

Q11. Did the Staff evaluate the probability of F-16 aircraft crashing onto the PFS facility while transiting from Hill Air Force Base to the Utah Test and Training Range?

A11. Yes. The Staff evaluated the Applicant's analysis of the probability of F-16 aircraft crashing onto the PFS facility while transiting from Hill Air Force Base to the Utah Test and Training Range. Additionally, the Staff carried out sensitivity and confirmatory analyses in order to verify independently the validity of PFS estimates of the likelihood of aircraft impacting the facility.

Q12. What was your conclusion with respect to this evaluation?

A12. The Staff concluded that the likelihood of F-16 aircraft impacting the facility while transiting Skull Valley from Hill Air Force Base to the Utah Test and Training Range would not pose undue hazards to the PFS facility. The Staff determined the estimated annual probability of crashes per year from this activity to be 2.5 to 3.1×10^{-7}.

Q13. Did the Applicant use the probability formula set forth in NUREG-0800 for calculating the annual probability of crashes per year?

A13. Yes. The Applicant followed the NUREG-0800 formula. The Applicant, further, modified the probability calculation to reflect the potential for a pilot to direct the aircraft away from a fixed ground site, such as the proposed ISFSI, as discussed below.

Q14. Please describe the general location of the proposed facility with respect to F-16 aircraft transiting Skull Valley.

A14. The proposed PFS facility site is located beneath the Sevier B Military Operating Area (MOA). At the facility location, the Sevier B MOA extends approximately 2 miles to the west of the site and 10 miles to the east. The Sevier B MOA has a ceiling of 9,500 feet above mean sea level, which is approximately 5,000 feet above ground level at the facility location. F-16s typically fly between 3,000 and 4,000 feet above ground level.

The Sevier D MOA overlies the Sevier B MOA and is used to transit Skull Valley during large force exercises at the Utah Test and Training Range (UTTR) South area, as the narrow width of Skull Valley with mountain ranges on either side does not provide adequate airspace for 12 or more aircraft. Both the Sevier B and Sevier D MOAs are approximately 145 miles long and extend more than 100 miles south of Skull Valley. The predominant route followed by F-16s is through the eastern side of Skull Valley along the edge of the Stansbury Mountains, which are approximately 5 statute miles east of the PFS Facility. This preference for flying through the eastern side of Skull Valley is due to the superior terrain masking features in that area; in addition, this tendency is due to the funnel effect of the Sevier B MOA as the aircraft travel through Skull Valley, as discussed in response to Question 50 below.

Number of Flights (N)

Q15. Is the number of aircraft flying near the site in a year a factor that must be included in the calculation?

A15. Yes.

Q16. How was the number of flights determined?

A16. PFS used the average number of F-16 sorties through Skull Valley for FY 1999 and FY 2000. PFS also provided a separate calculation using data for FY 2000 alone. For FY 1999, the U.S. Air Force identified 4,250 F-16 flights through Sevier B and 336 F-16 flights through Sevier D, for a total of 4,586 flights. In FY 2000, there were 5,757 F-16 flights through Sevier B and 240 F-16 flights through Sevier D, for a total of 5,997 flights. The Applicant also accounted for additional flights resulting from an additional 12 F-16 aircraft that were assigned to the 388th Fighter Wing in the third quarter of FY 2001. An increase in aircraft stationed at Hill Air Force base would result in a proportional increase in the number of sorties flown. A total of 69 F-16 aircraft were stationed at Hill Air Force Base through FY 2000, and the additional 12 F-16 aircraft increases the number of F-16 aircraft stationed at HAFB to 81, which represents a 17.4% increase.

Q17. Was the Applicant's determination of the number of flights acceptable?

A17. Yes. Based on information from Hill Air Force Base, up to 10 percent of flights in the Sevier B MOA do not transit through Skull Valley. Therefore, considering the traffic through the MOAs as equivalent to flights through Skull Valley is conservative. The Staff used the upper bound data - - the FY 2000 data for the combined Sevier B and D MOAs (5,997 F-16 flights) and increased it by 17.4% to account for additional HAFB F-16 assignments. The estimated annual number of F-16 flights is 7041.

Q18. Are there any other conservatisms with respect to this factor?

A18. Yes. 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 the exception. Solo flights occur 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 foot lateral separation between the leader and the wingman in a two-ship formation. Consequently, at least one of the aircraft in a two-ship formation will not be in a position from which it can strike the PFS 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 generally consists of two, two-ship formations in a staggered pattern), only one aircraft may point at the PFS facility. Therefore, for estimating the crash hazard from aircraft transiting Skull Valley, approximately half of the flights have a negligible potential for striking the PFS facility. This was not reflected in the Applicant's analysis, but was accounted for by the Staff in SER Supplement No. 1 by reducing the number of flights by a factor of 2.

<u>In-flight Crash Rate Per Mile (C)</u>

Q19. Is the in-flight crash rate per mile for F-16s transiting Skull Valley a factor that must be included in the NUREG-0800 calculation?

A19. Yes.

Q20. How did the Applicant derive the crash rate?

A20. First, the Applicant considered the data provided in "Data Development Technical Support Document for the Aircraft Crash Risk Analysis Methodology (ACRAM) Standard," Kimura, et. al (1996) (ACRAM study). The DOE ACRAM study provides F-16 crash rate data for the period from 1975 through 1993. The ACRAM study categorizes the crash rate data by mode of flight --

(*i.e.* take off, landing, normal flight, and special operation). PFS used the "normal" flight mode as representative of the conditions in which F-16s transit Skull Valley.

Next, PFS updated the DOE ACRAM study normal flight crash rate with data from the U.S. Air Force from FY 1994 to FY 1998. The U.S. Air Force data provides "mishap" rates for each type of aircraft. The U.S. Air Force typically presents mishap rate data as the number of crashes per 100,000 hours of flight. PFS estimated the crash rate on a per mile basis by dividing the time rate (crashes per hour) by the average speed of the aircraft (miles per hour).

PFS modified the normal crash rate developed in the DOE ACRAM study by updating the data from 1975 to 1993 with the U.S. Air Force data from FY 1994 to FY1998. F-16 crash data from the U.S. Air Force shows 142 Class A mishaps and 20 Class B mishaps. The total of Class A and Class B mishaps, therefore, is 162, out of which 139 aircraft were destroyed.

Q21. What is the difference between a Class A mishap and a Class B mishap?

A21. The U.S. Air Force defines a Class A mishap as one that results in total property damage at or above $1 million, a destroyed aircraft, or a fatality. A Class B mishap results in total property damage between $200,000 and $1 million.

Q22. Please continue with your description of the Applicant's calculation.

A22. PFS made the assumption that the average speed or the flight miles per flight hour remains constant over the years at 471.85. The total flight hours in FY 1989 through FY 1998 was 4,016,311. Hence, the estimated total flight miles in FY 1989 through FY 1998 is 471.85 $\times$ 4,016,311, or 1.895×10^9. PFS made the assumption that the ratio of normal flight miles to total flight miles remains constant at 47.18% during FY 1989 through FY 1998. Hence, the estimated normal flight miles in FY 1989 through FY 1998 is $0.4718 \times 1.895 \times 10^9$, or 8.941×10^8. PFS made the assumption that the ratio of normal flight mishaps to total mishaps also remains constant during FY 1989 through FY 1998 at 15.09%. Hence, the estimated number of mishaps in normal flight phase is 0.1509 x 162, or 24.45. Based on the above assumptions, PFS adjusted the crash rate of F-16 in normal in-flight mode during FY 1989 through FY 1998.

The adjusted crash rate in normal in-flight mode in FY 1989 through FY 1998 is $24.45 / 8.941 \times 10^8$, or 2.736×10^{-8} mishaps per flight mile.

Q23. The State has asserted that bird strikes, in which a bird collides into an aircraft during flight, should be accounted for when estimating the crash rate for F-16s. Do you believe this assertion presents a valid concern with respect to the reliability of the aircraft crash rate for F-16s that has been utilized by PFS?

A23. No. The F-16 crash rates are based on actual crash data. Hence the effects of bird strikes are included in the overall F-16 crash rate data base.

In addition, the Staff specifically examined the potential for bird strikes in Skull Valley to determine whether they may affect the reliability of the estimated crash rate for F-16 aircraft in estimating accident probabilities in Skull Valley. According to the Bird Avoidance Model of the U.S. Air Force, no bird strikes occurred in Skull Valley from 1985 through June 25, 2000, the period for which the data are available. There is no large body of water within 20 miles of the PFS facility site to attract a flock of large birds. All bird strikes within 50 statute miles of the PFS facility site that are included in the Bird Avoidance Model database occurred below 800 feet above ground level. Approximately 70 percent of all bird strikes occur at or below 1,000 feet above ground level. In contrast, the Sevier B MOA is at least 1,000 feet above ground level.

The U.S. Air Force database on wildlife strikes of all types involving aircraft show that the windshield was penetrated in only 0.3 percent of incidents. 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 historically the likelihood of a damaging bird strike occurring in Skull Valley has been so low that it is normally not a part of mission planning. The policy of the Hill Air Force Base in the event that pilots returning from sorties report bird sightings, is that flight mission planners would take appropriate measures to avoid bird strikes, such as the selection of alternate altitudes. Therefore, the Staff has concluded that the overall F-16 crash rate accounts for the bird strike phenomenon; that the possibility of a damaging bird strike in Skull Valley is remote; and that the possibility of a bird strike in Skull Valley does not affect the reliability of the F-16 crash rate in estimating F-16 accident probabilities in Skull Valley.

Q24. The State has asserted that aircraft age effects can create a "bathtub" curve for crash rates versus time. On this basis, the State has asserted that for a given aircraft type, such as the F-16, crash rates may be greater toward the beginning and end of the operational life of the aircraft. Do you believe this assertion presents a valid concern with respect to the reliability of the aircraft crash rate for F-16s that has been utilized by PFS?

A24. No. The Staff has considered the potential for a "bathtub" curve for F-16 failure as a function of time, with crash rates being greater toward the beginning and end of the operational life of the aircraft. The Staff's review concluded that the data shows there is no discernible "bathtub" effect. Approximately 50 percent of all crashes of F-16 aircraft are due to operation-related causes. Hence, F-16 crashes due to causes such as pilots undergoing gravity-induced loss of consciousness (GLOC), mid-air collisions, bird strikes, running out of fuel, pilot errors, or weather-related causes would not be expected to contribute to the "bathtub" effect. It is reasonable to separate these operation-related mishaps from the crash database to determine whether the crash rate shows any "bathtub" behavior. Engine-related mishaps for all F-16 aircraft produce a straight line with a slope less than 1.0, indicating a decreasing crash rate with time. Therefore, the Staff found no "bathtub" effect present in the engine-related F-16 crash data.

As a conservatism, the Staff additionally examined the overall crash data with existing analytical procedures for testing the presence of "bathtub" behavior. These procedures are identified in "Modeling the Failure Data of a Repairable Equipment with Bathtub Type Failure Intensity," by G. Pulcini, published in Reliability Engineering & System Safety (2000). The results, as described in the SER Supplement No. 1, indicate that there is no discernible "bathtub" effect. This supports the Staff's conclusion that there is no basis for expecting higher F-16 crash rates at either the beginning or end of the service life of the F-16 aircraft that are attributed to the "bathtub" effect.

On the basis of the above conclusions, the Staff finds it reasonable to expect that the crash rates for the next generation aircraft would not exhibit a significant "bathtub" effect. Moreover, the expectation is that newer aircraft would exhibit a decreasing trend in crash rates, in agreement with historically observed decreasing crash rates for a given type of aircraft.

<u>Modification of Calculation Based on Pilot Avoidance</u>

Q25. In response to Question 13 above, you indicated that the Applicant followed the NUREG-0800 formula, and, further, modified the probability calculation to reflect the potential for a pilot to direct the aircraft away from a fixed ground site, such as the proposed ISFSI, in the event of an accident. Please explain how PFS modified the calculation method to account for this potential?

A25. The Applicant divided the probability that an F-16 would crash into the facility in two categories and applied the formula set forth in NUREG-0800 to each. For the first category, the Applicant determined the probability that the crash is of the type such that the pilot retains control of the aircraft but is unable to direct the aircraft away from the Facility. For the second category, the Applicant determined the probability that the crash is of the type that the pilot does not retain control of the aircraft and is unable to direct the aircraft away from the Facility before ejecting.

The formula is resolved in two components, as follows:

$$P = P_1 + P_2$$

where, P_1 is the probability of an F-16 crashing on the facility as a result of engine failure or other malfunction with the pilot retaining control of the aircraft, and P_2 is the probability of an F-16 crashing on the facility due to engine failure or other malfunction with the pilot not retaining control of the aircraft.

Q26. How is the NUREG-0800 formula modified by PFS to reflect the resolution of the probability in two components?

A26. The NUREG-0800 formula was modified as follows:

$$P = NC \frac{A}{W} R_1 \quad + \quad NC \frac{A}{W} R_2$$

where, N, C, A, and W remain as previously designated; and R_1 is the 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. R_1 is the product of the probability that the pilot retains control of the aircraft for a time that is sufficient to direct the aircraft away from the facility ($P_{ABLE\ TO\ AVOID}$) 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 $P_{ABLE\ TO\ AVOID} \times P_{HIT}$.

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

Q27. How did the Applicant determine the probability that the pilot retains control of the aircraft for a time that is sufficient to direct the aircraft away from the Facility (*i.e.* $P_{ABLE\ TO\ AVOID}$)?

A27. The Applicant obtained 126 F-16 aircraft Class A accident reports for the period from FY 1989 to FY 1998 from the U.S. Air Force. These reports addressed mishaps involving 121 destroyed aircraft. PFS used the reports involving destroyed aircraft because these accidents best represented the result of an accident in which an F-16 aircraft impacts the Canister Transfer Building or the spent fuel storage casks.

Three experienced U.S. Air Force pilots and former U.S. Air Force wing commanders analyzed the F-16 accident reports for the 121 destroyed aircraft to estimate the percentage of accidents in which the pilot would be able to avoid the PFS facility. For each destroyed aircraft reported, the expert team considered: 1) the cause of the accident; 2) whether the pilot was able to remain in control of the aircraft following the initiating incident; 3) the phase of flight at the time of the accident (*i.e.* take off, landing, normal flight or special operation); 4) whether the accident could have occurred in Skull Valley; and 5) whether the accident could have occurred in the flight environment in which F-16s transit the Sevier B MOA near the proposed facility.

Q28. What factors did the Applicant's expert team consider with respect to the ability of pilots to avoid a fixed facility on the ground?

A28. To determine the ability of the pilot to avoid a fixed ground site, the team considered:

1. the nature of the initiating event (such as engine or other mechanical failure, gravity induced loss of consciousness (GLOC), spatial disorientation)
2. the altitude of the aircraft at which the initiating event occurred
3. weather at the time of the initiating event
4. speed of the aircraft at the time of initiating event
5. pilot retaining control of the aircraft based on the initiating event.

Q29. What did the expert team find?

A29. The team found that 48% of all the 121 destroyed aircraft mishaps were caused by the failure of F-16 engines. The panel found that all engine failures left the pilots with time and capability to avoid a fixed site on the ground. In addition to engine failure, there were 11 other mishaps, not caused by engine failure, that would have allowed the pilot sufficient time and capability to avoid a ground site. PFS concluded that in 69 out of 121 mishaps, the pilot would have been able to avoid the proposed facility.

Q30. What was the Applicant's finding with respect to Skull Valley type flight conditions?

A30. PFS determined that many of the mishaps in the original accident data set did not occur under Skull Valley type flight conditions (F-16 pilots transit Skull Valley without engaging in high-stress maneuvering activities, such as air-to-air combat training, etc.). Only 61 out of the 121 destroyed aircraft mishaps were assessed as Skull Valley type events. PFS estimated that in 59 mishaps out of 61 Skull Valley type events (irrespective of mode of flight) the pilots had sufficient control and time to avoid a ground site. This equated to a 97% avoidance rate (59 out of 61 mishaps).

Q31. What flight conditions were considered to be representative of Skull Valley type events?

A31. The conditions considered to be representative of Skull Valley type events were those that were not unique to high-stress, aggressive maneuvering or unique to takeoff and landings. The screening criteria excluded accidents such as mid-air collisions and GLOC, that may occur during high-stress, aggressive maneuvering of "special operations" combat training. PFS did, however, include in this data set accidents occurring during the special operation phase of flight that did not involve high-stress, aggressive maneuvering, such as accidents caused by engine failure; and PFS included in this subset those mishaps that occurred during take off and landing that were not attributable to the unique circumstances associated with these events.

Q32. What is your understanding as to why the Applicant considered normal mode of flight conditions in Skull Valley and Sevier B MOA conditions as separate data groups?

A32. The analyses of the separate, smaller data groups, more tailored to Skull Valley characteristics, were conducted to compare the results of these data groups to the larger Skull Valley type event category in order to determine the validity of the larger data set results.

Q33. What was the Applicant's finding with respect to Skull Valley type events in the normal mode of flight conditions?

A33. By eliminating mishaps occurring in other flight phases, the number of mishaps relevant to Skull Valley while in a normal flight mode, or ACRAM Flight Phase, is 19. In 17 of these mishaps, the pilot was able to avoid a ground site. Therefore, the probability of avoiding the facility was estimated to be 89%. This finding is comparable to the Skull Valley avoidance rate.

Q34. What was the Applicant's finding with respect to Sevier B MOA conditions?

A34. The Applicant's expert panel concluded that only 9 mishaps fell under the Sevier B MOA flight environment. Of the nine, only one mishap involved loss of avoidance ability. Therefore, in 8 out of 9 mishaps the pilot was able to control the aircraft. Therefore, the probability was estimated to be 89%. This is comparable to the Skull Valley avoidance rate.

Q35. Was the PFS methodology in considering the ability of the pilot to avoid the facility acceptable?

A35. Yes. The Staff reviewed the information and analysis regarding the fraction of potential mishaps in which the pilot would have sufficient control and time to direct an aircraft experiencing trouble while transiting Skull Valley, away from a fixed ground site. The PFS analysis indicated that a pilot, whose aircraft was experiencing a malfunction, would have sufficient time to avoid the PFS facility approximately 90 percent of the time. This value is based on the consideration of mishap histories for the normal 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. On the basis of its review and since the ACRAM Flight Phase data subset produces the lower bound estimate, the Staff considered that the data subset representing mishaps that took place in normal in-flight mode (or the data subset referred as the ACRAM Flight Phase by PFS) is representative of Skull Valley conditions.

Q36. How does this data feed back into the modified NUREG-0800 formula?

A36. $P_{ABLE\ TO\ AVOID}$ is assigned a value of 90 percent or 0.90.

Q37. Did the Applicant determine the probability that the crash is of the type such that the pilot retains control of the aircraft but is unable to glide the aircraft away from the Facility (*i.e.* P_{HIT})?

A37. Yes. PFS judged that a pilot with sufficient control and time available would be able to avoid striking the facility 95% of the time.

PFS calculated the probability 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 the consideration of flight related aspects, such as standard procedures followed by F-16 pilots in emergencies at 5,000 feet above ground level or lower, actions required by the pilot to avoid the site, the available time for directing an aircraft away from the facility, insights obtained from analysis of U.S. Air Force accident reports by the expert panel, and other factors that may affect a pilot's capability to avoid the site. On the basis of its analyses, PFS judged that a pilot with sufficient control and time available would be able to avoid striking the PFS facility at least 95 percent of the time. Consequently, the probability that the pilot would not be able to avoid the facility with sufficient control and time is 0.05.

Q38. How does this data feed back into the modified NUREG-0800 formula?

A38. P_{HIT} is assigned a value of 0.05.

Q39. Did the Staff perform a sensitivity analysis with respect to F-16 mishaps where a pilot had adequate control of the aircraft in addition to sufficient time to direct the aircraft away, yet failed to avoid the surface facility?

A39. Yes. The Staff conducted a sensitivity analysis that showed that a 20 times increase in the likelihood of failure to avoid striking the PFS facility (from 0.01 to 0.20) increases the overall crash probability by approximately a factor of 2.5. Consequently, the overall crash probability for F-16s transiting Skull Valley is not highly sensitive to the assumed likelihood of 0.05 for the avoidance failure. However, as a conservatism, the Staff used a value of 0.10 in its evaluation presented in SER Supplement No. 1.

Q40. Did the Applicant estimate the probability that the crash is of the type that the pilot does not retain control of the aircraft and is unable to guide the aircraft away from the Facility before ejecting?

A40. Yes. PFS determined that a pilot would retain control of the aircraft with sufficient time to direct the plane away in 90 percent of F-16 crashes. Therefore, in only 10 percent of all F-16 crashes, the pilot would have to eject immediately.

Q41. The State has argued that lack of knowledge of the location of the facility on the ground may decrease a pilot's ability to avoid the facility. Do you agree with the State's assertion?

A41. Yes. The Staff, however, reviewed to what extent knowledge of the location of the PFS facility would affect the probability of a pilot avoiding a strike onto a fixed ground structure, such as the PFS facility. In addition, the Staff reviewed the effect of using the proposed facility for pilotage or for updating navigational equipment on the avoidance probability.

The Area Planning Guide of the U.S. Department of Defense (DOD) provides guidance to planners of military training routes regarding location and avoidance 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 the military flight planners and pilots would be aware of its location on the Reservation of the Skull Valley Band of Goshute Indians.

Q42. What is the effect of the use of the proposed facility for pilotage or for updating navigational equipment on the avoidance probability?

A42. Some of the pilots may use the proposed facility, which would be the largest man-made structure in Skull Valley, as a navigational steer point or pilotage point. Alternatively, the pilots may elect to correct the drift error of the Inertial Navigation System (INS), the parallax error of the imaging infrared sensor mounted on the navigational pod of the Low Altitude Navigation and Targeting Infrared for Night (LANTIRN) system, or manually adjust the focus of the targeting pod of the LANTIRN system using the structures of the PFS facility. In view of the above, there is a reasonable expectation that pilots would be aware of the location of the proposed facility.

Q43. The State has asserted that weather phenomena, such as cloud cover that reduces the ability of the pilot to visually locate the proposed Facility, will affect the ability of pilot to avoid the facility. Do you believe this assertion presents a valid concern?

A43. No. The Staff reviewed to what extent air-to-ground visibility of the PFS facility would affect the probability of a pilot avoiding a strike onto a fixed ground structure, such as the PFS facility. Typically, weather in Skull Valley area is well-suited for Visual Flight Rules (VFR) flight conditions. For example, based on Air Weather Service data, 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. 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. Consequently, VFR flight is possible in the Sevier D MOA about 270 days in a year.

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, Tactical Air Navigation System (TACAN), Global Positioning System (GPS), if available). Additionally, F-16s are equipped with an onboard Horizontal Situation Indicator which 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.

Pilots, as a general rule, rely on visual references if the visibility and cloud cover permit and reinforce them with the onboard systems. Prominent terrain features, such as the Cedar Mountains, the Stansbury Mountains, Deseret Peak, and two peaks bounding Johnson Pass southeast of the PFS facility site are particularly useful in maintaining positional and situational awareness by the pilots. 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 is reasonable to assume that the weather in the UTTR South area, especially in the nearby restricted airspaces, would be similar. As most of the aggressive maneuvering in combat training requires VFR conditions, PFS notes that it is reasonable to expect that training would be suspended if extensive vertical and horizontal cloud covers are present in the range. If weather in some restricted airspaces of the UTTR South area does permit VFR flight activities, there are five other standard routes besides Skull Valley that are typically used to enter the UTTR South area.

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. In such cases, the pilot must request and secure an IFR clearance from air traffic controllers at Clover Control. 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 PFS facility, will be able to guide the pilot in case of emergencies. 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. 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. Accordingly, it is likely that the pilots will be aware of the PFS Facility.

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 PFS facility.

Q44. The State has asserted that the level of experience of the pilot contributes to the ability of the pilot to avoid the facility. Do you believe this assertion presents a valid concern with respect to the applicability of the crash rate data in Skull Valley?

A44. No. The Staff reviewed information on the potential effects of pilot experience on the probability of avoiding a surface facility if the aircraft engine experiences a problem in flight. It is reasonable to postulate that pilot experience may have some influence on aircraft emergency control performance. For example, pilots with lesser experience may be expected to be more challenged in carrying out aircraft control and ejection procedures. However, historical data do not show any significant effect. PFS did not find any indications in 126 F-16 aircraft accident reports that a pilot's limited experience had resulted in failure to direct the aircraft away from an inhabited area. No correlation was observed between the pilots' flight experience levels and the mishaps.

In all cases in which avoidance of inhabited areas was necessary, pilots were able to direct the aircraft away from those areas. The F-16 mishaps with respect to Skull Valley type events involved pilots with various levels of experience. PFS concluded that the estimated 5 percent of the time when pilots with sufficient time and control of the aircraft would fail to avoid a surface facility bounds any differences among pilots' experience levels.

Q45. Did the Staff conduct any sensitivity analyses in this regard?

A45. Yes. The Staff conducted a sensitivity analysis with a range of probabilities (1 to 20 percent) that a pilot with adequate control of the aircraft and time available would not be able to direct the aircraft away from a fixed surface facility. The results did not show any appreciable difference in the estimated crash probabilities.

<u>Width of Airway</u>

Q46. Is the width of the airway a factor that must be included in the NUREG-0800 calculation?

A46. Yes. A factor that needs to be considered when estimating the likelihood of an aircraft flying through Skull Valley crashing onto the proposed PFS facility is the airspace width in the vicinity of the facility. For a given annual number of sorties, the airspace width determines the lateral traffic density in the vicinity of the proposed facility. The narrower the width, the higher the traffic density. The traffic density, in turn, affects the onsite strike probability.

Q47. How was the width of the airspace in the vicinity of the proposed PFS facility determined?

A47. The width of both the Sevier B and Sevier D MOAs at the latitude of the proposed PFS facility is 12 miles. PFS and the Staff used 10 miles 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 rising terrain of the Stansbury Mountains. F-16s must fly below 9,500 feet mean sea level and above 1,000 feet above ground level, and therefore cannot fly within the easternmost two miles of the Sevier B MOA.

Q48. Does the Staff consider the Applicant's approach acceptable?

A48. Yes. Additionally, the Staff carried out a sensitivity analysis assuming 8 and 9 mile widths for the Sevier B MOA. A full 12 mile width was assumed by the Staff in the analysis for the Sevier D MOA, in that it does not have the physical restrictions that affect the Sevier B MOA.

Q49. The State has asserted that the width of the airway should be 5 miles in light of the fact that pilots would point their aircraft at the PFS facility in order to update their navigational equipment. Do you agree with the State's assertion?

A49. No.

Q50. What is the basis for your conclusion in this regard?

A50. The Staff reviewed information on the potential use of the PFS facility as a steer point for navigation and for updating the onboard navigational equipment, in addition to the formation of flights of F-16s while transiting Skull Valley for a possible reduction of the navigational width of the MOA.

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 site if the PFS facility is selected as a turning point. However, if the PFS 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 PFS facility typically 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. 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. 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. 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. Consequently, the operational utility of the airspace west of Skull Valley Road decreases significantly toward the southern part of Skull Valley.

Additionally, F-16s using the Stansbury Mountains for practicing terrain masking maneuvers fly down the eastern part of the MOA. Moreover, a pilot using the PFS facility for updating onboard instruments would still need to remain cognizant of the restricted airspace to the south and west of the proposed site and fully aware of the location of the PFS facility. 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 PFS facility. Accordingly, analytical use of a 10-mile width as the effective width of the airway, thereby increasing the number of aircraft assumed to fly closer to the PFS facility, is conservative.

Effective Area

Q51. Is the effective area of the facility in square miles a factor that must be included in the NUREG-0800 calculation?

A51. Yes.

Q52. How was the effective area of the facility in square miles determined?

A52. PFS estimated the effective area of the facility by 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 STD-3014-96. The DOE standard is consistent with the guidelines given in NUREG-0800, Section 3.5.1.6, "Aircraft Hazards." Therefore, the Staff finds the PFS estimation of the effective area to be acceptable.

Q53. How does this feed back into the NUREG-0800 calculation?

A53. The total effective area for the PFS facility at full capacity is 0.13371 square miles. This value was then input to the NUREG-0800 calculation.

Summary

Q54. Please summarize the Applicant's calculation of the annual probability of an F-16 transiting Skull Valley en route from HAFB to the UTTR impacting the facility?

A54. PFS estimated the crash probability of F-16s transiting Skull Valley, using the average number of flights in FY 1999 and FY 2000 through the Sevier B MOA after adjusting for 12 additional F-16s, to be equal to 3.11×10^{-7} per year. Additionally, PFS carried out a sensitivity analysis to estimate the crash hazard using only FY 2000 flight information after adjusting for 12 additional F-16s. This yielded an estimated crash probability of 3.58×10^{-7} per year. The Applicant's analysis was reviewed by the Staff, as discussed in SER Supplement No. 1.

Q55. Please describe the Staff's conclusions with respect to F-16 aircraft crashes with respect to the PFS Facility.

A55. The Staff conducted a thorough review of the Applicant's analysis, as described in SER Supplement No. 1. In addition, the Staff performed a confirmatory analysis of the potential crash hazard of F-16s transiting Skull Valley using flights through both the Sevier B and Sevier D MOAs in FY 2000, after adjusting for 12 additional F-16s stationed at Hill Air Force Base. Additionally, 50 percent of the flights were assumed to have negligible crash potential on the PFS facility, since the aircraft fly in formation. As summarized in SER Supplement No. 1, and in Table 15-10 thereof, the results indicate that the estimated crash probability for the PFS Facility due to F-16s transiting the Sevier B and D MOAs is on the order of 10^{-7} per year.

II. Potential F-16 Ordnance Impacts

Q56. Did the Staff evaluate the potential of F-16 ordnance impacts at the PFS site?

A56. Yes. The Staff evaluated the applicant's analysis of the potential hazard to the PFS facility from ordnance carried onboard an F-16 aircraft while transiting Skull Valley. Additionally, the Staff carried out confirmatory analyses with alternative assumptions.

Q57. What was your conclusion with respect to this evaluation?

A57. The Staff concluded that potential ordnance carried onboard an F-16 aircraft while transiting Skull Valley from Hill Air Force Base to the Utah Test and Training Range would not pose undue hazards to the PFS facility. The Staff determined the estimated annual probability of jettisoned military ordnance impacting the facility to be 4.4×10^{-8}. The Staff determined the estimated annual probability of jettisoned military ordnance creating an explosion nearby the facility to be 7.1×10^{-10}. The sum of these two probabilities is approximately 4.5×10^{-8}.

Q58. With respect to the probability of jettisoned military ordnance impacting the facility, did the Applicant use the probability formula set forth in NUREG-0800 to calculate this probability?

A58. Yes. The Applicant followed the NUREG-0800 formula. The Applicant further modified the formula to determine the individual probabilities of jettisoned ordnance striking the Canister Transfer Building and of jettisoned ordnance striking the cask storage area.

Q59. How was the NUREG-0800 formula modified to reflect the resolution of the probability in two components?

A59. The NUREG-0800 formula was modified as follows:

$$P = N \times C \times e \times f_0 \times W_{sa}/W \times d_{sa} + N \times C \times e \times f_0 \times W_{ctb}/W \times d_{ctb}$$

where, N is the number of sorties per year, C is the F-16 crash rate per mile, e is the fraction of crashes initiated by engine failure, f_0 is the fraction of F-16s carrying jettisonable ordnance, W is the width of Skull Valley, W_{sa} is the width of the cask storage area, d_{sa} is the length of the cask storage area, W_{ctb} is the width of the Canister Transfer Building, and d_{ctb} is the length of the Canister Transfer Building.

Q60. Please describe the circumstances in which jettisoned ordnance may strike the facility?

A60. The U.S. Air Force has stated that almost all of the aircraft that transit Skull Valley en route to the UTTR South area are F-16s. An F-16 pilot experiencing engine trouble may intentionally jettison the onboard ordnance and other external stores, such as external fuel tanks. This is done typically to lighten the aircraft in order to reduce drag so as to gain altitude.

The U.S. Air Force notes that the ordnance would be in a "safe" unarmed mode while transiting Skull Valley. F-16s carry different types of ordnance that include inert and live bombs. Inert ordnance does not contain explosive and will not explode. The U.S. Air Force states that the possibility of explosion of unarmed live ordnance carried onboard a crashing aircraft is remote. Therefore, the potential hazard to the facility from inert and live ordnance is generally from the dead weight impact of the ordnance.

Q61. How did the Applicant consider the number of sorties per year?

A61. As discussed in response to Questions 16-18 above, PFS estimated the probability assuming the annual number of sorties through Skull Valley (in the Sevier B MOA) to be 5,870. The assumed annual number of sorties was estimated on the basis of the average number of flights in FY 1999 and FY 2000 with an additional increase of 17.4 percent to account for 12 additional F-16s stationed at Hill Air Force Base. PFS also carried out another analysis using only the annual number of sorties for FY 2000 (5,757) and the 17.4 percent increase. Based on its analysis, PFS calculated the number of sorties to be 6,759 per year.

Q62. Did the Staff evaluate the Applicant's estimated number of sorties per year in estimating the probability of ordnance striking the PFS facility?

A62. Yes. The Staff carried out an independent estimation of the probability of jettisoned ordnance striking the PFS facility using three different values for the annual number of sorties. In the first case, the number of F-16 flights assumed is 4,086, which corresponds to the number of flights going through both the Sevier B and Sevier D MOAs in FY 1998. A second case was analyzed with 5,997 flights, which is equal to the number of F-16 flights in FY 2000 through both the Sevier B and Sevier D MOAs. In the third case, the number of F-16 flights assumed is 7,041, which includes flights through both the Sevier B (5,757) and Sevier D (240) MOAs in FY 2000, as well as assumed flights due to the anticipated 17.4 percent increase in future flight activities from 12 additional F-16s stationed at the Hill Air Force Base (1,044).

Q63. How did the Applicant consider the fraction of crashes initiated by engine failure?

A63. The Applicant used a value of 0.90 for the fraction of crashes initiated by engine failure. As discussed above, the Applicant's expert team evaluated the cause of accidents with respect to U.S. Air Force accident reports for 121 destroyed aircraft. Of those accidents which could have taken place under Skull Valley type conditions, accidents related to engine failure represented 84% of the total number of accidents.

Q64. Did the Staff evaluate the Applicant's estimated fraction of crashes initiated by engine failure?

A64. Yes. Based on a 0.84 fraction of mishaps that reasonably could take place in Skull Valley that were caused by engine failure, the Staff utilized an assumption of *e* equal to 0.9 as bounding.

Q65. How did the Applicant consider the fraction of F-16s carrying jettisonable ordnance?

A65. The Applicant used data from the U.S. Air Force regarding ordnance carried by F-16s from FY 1998 - FY 2000. In FY 1998, the 388th Fighter Wing flew 678 sorties to the UTTR South area carrying ordnance. In FY 2000, 128 such sorties were flown. The U.S. Air Force states that the number of sorties carrying ordnance in FY 1999 is similar to that of FY 2000.

The Applicant considered the sorties flown by the 419th Fighter Wing that carried ordnance during the same time period. Based on information from the U.S. Air Force, the Applicant considered that the 419th Fighter Wing would fly sorties with ordnance at the same rate and using the same munitions as the 388th Fighter Wing. Thus, the ordnance usage has been updated to incorporate the proportional increase in flights attributable to the 419th Fighter Wing, taking into account 54 F-16s assigned to the 388th Fighter Wing, and 15 F-16s assigned to the 419th Fighter Wing.

Q66. Did the Staff evaluate the Applicant's estimated fraction of F-16s carrying jettisonable ordnance?

A66. Yes. The Staff applied the fraction of F-16s carrying jettisonable ordnance to the three cases considered above. The Staff considered that in Case 1 (the total number of F-16 sorties through Sevier B and Sevier D MOAs in FY 1998), the fraction of F-16s carrying jettisonable ordnance is 11.8 percent. In Case 2 (the total number of F-16 sorties through the Sevier B and Sevier D MOAs in FY 2000), the fraction of F-16s carrying jettisonable ordnance is 2.3 percent. In Case 3 (the total number of F-16 flights through Sevier B and Sevier D MOAs in FY 2000, including the 17.4 percent increase in the number of sorties based on the 12 additional F-16 aircraft to be stationed at HAFB), the fraction of F-16s carrying jettisonable ordnance is 2.3 percent.

Q67. How did the Applicant evaluate the width of Skull Valley?

A67. In its estimate, the Applicant considered the effective width of Skull Valley to be 10 miles.

Q68. Did the Staff evaluate the Applicant's value for the effective width of Skull Valley?

A68. Yes. As discussed above, the Staff considered that a 10 mile effective width is reasonable. The Staff, nevertheless, considered a conservative effective width of 8 miles for Skull Valley.

Q69. How did the Applicant evaluate the length and width of the cask storage area and the Canister Transfer Building?

A69. The Applicant used the actual dimensions (length or depth and width) of the cask storage area and the Canister Transfer Building in the calculations.

Q70. Did the Staff evaluate the Applicant's value for the length and width of the cask storage area and the Canister Transfer Building?

A70. Yes. The Staff considered the Applicant's estimation of the cask storage area acceptable. With respect to the Canister Transfer Building, however, the Staff increased the size of the effective area calculated by the Applicant, by using the length and width of the CTB at its widest point.

Q71. What is your overall conclusion with respect to the Applicant's calculation of the probability of jettisoned ordnance striking the Canister Transfer Building and the cask storage area?

A71. The Staff considered that, based on the application of the modified NUREG-0800 calculation, the estimated annual probabilities for the three cases described in response to Question 66 above are 1.3×10^{-7}, 3.7×10^{-8}, and 4.4×10^{-8}, respectively. The Staff concluded that there is reasonable assurance that jettisoned ordnance from F-16s hitting the facility would not pose a significant hazard to the facility.

Q72. With respect to the probability of jettisoned military ordnance impacting the ground near the facility so as to cause damage to the facility, did the Applicant use the probability formula set forth in NUREG-0800 to calculate this probability?

A72. Yes. The Applicant followed the NUREG-0800 formula. PFS assessed the potential hazards to the facility from explosion of ordnance jettisoned near the facility or onboard an F-16 crashing near the facility. The U.S. Air Force has stated that the Utah Test and Training Range has never experienced "an unanticipated munitions release outside of designated launch/drop/ shoot boxes." Therefore, the likelihood of an inadvertant release of armed ordnance is judged to be extremely low. Consequently, the principal source of explosion-induced air overpressure is assumed to be unarmed ordnance that either was jettisoned from an aircraft, or was onboard when the aircraft crashed. PFS analyzed both these cases.

The Applicant modified the NUREG-0800 formula to determine the individual probabilities of the two events: 1) the probability of an F-16 with exploding live, onboard ordnance crashing sufficiently close to the facility so as to exceed the design-basis air overpressure of the facility; and 2) the probability of an F-16 jettisoning live ordnance that impacts the ground sufficiently close to the facility so as to exceed the design-basis air overpressure of the facility.

Q73. How was the NUREG-0800 formula modified by PFS to reflect the resolution of the probability with respect to the first of the two events involving exploding ordnance?

A73. The NUREG-0800 formula was modified as follows:

$$P = N \times C \times A_{nm1}/W \times f_{lo} \times P_e$$

where, N is the number of flights per year, C is the F-16 crash rate per mile, W is the width of Skull Valley, A_{nm1} is the 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} is the fraction of F-16s crashing with live ordnance, and P_e is the probability that an unarmed ordnance onboard a crashing F-16 will explode.

Q74. How was the NUREG-0800 formula modified by PFS to reflect the resolution of the probability with respect to the second of the two events involving exploding ordnance?

A74. The NUREG-0800 formula was modified as follows:

$$P = N \times C \times A_{nm2}/W \times fj_{lo} \times P_e$$

where, N is the number of flights per year, C is the F-16 crash rate per mile, W is the width of Skull Valley, A_{nm2} is the area in which the aircraft could impact the ground and cause damage to structures, f_{lo} is the fraction of F-16s crashing with live ordnance, and P_e is the probability that an unarmed ordnance will explode.

Q75. Please describe the Applicant's analysis with respect to these two events.

A75. PFS obtained information on ordnance carried onboard by F-16 aircraft of the 388th Fighter Wing in FY 2000 from the U.S. Air Force. Ordnance carried by 419th Fighter Wing was accounted for by assuming 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 this approach. PFS conservatively assumed in its estimation of probability of design-basis air overpressure from exploding ordnance that all ordnance were MK-84 2000 pound bombs, although only approximately 3 percent in FY 2000 were actually MK-84 and the remainder of the ordnance flown in FY 2000 was of a lesser explosive inventory. PFS concluded that the aggregate probability of live ordnance exploding while either carried onboard a crashing aircraft or jettisoned from a crashing aircraft at the PFS Facility is about 3.25×10^{-10} per year. PFS concluded that a simultaneous explosion of multiple ordnance would not increase the risk to a significant level, as the risk would increase by only $2^{1/3}$ or approximately 25 percent.

Q76. Did the Staff evaluate the Applicant's analysis of this matter?

A76. Yes. The Staff performed a confirmatory calculation assuming Minol-2 as the representative explosive for MK-84 bombs with a conservative air overpressure limit for both the storage casks and the Canister Transfer Building. The assumption of Minol-2 is conservative since it will give the maximum equivalent amount of TNT explosive, although the bomb may contain other types of explosives with lower TNT equivalents. Additionally, the Staff assumed that all F-16 aircraft with jettisonable ordnance carried two MK-84 bombs. The Staff estimated the aggregate probability to be about 7.1×10^{-10} per year, approximately a factor of two higher than the PFS estimate.

III. <u>F-16 Aircraft Conducting Air-to-Air Training on the UTTR</u>

Q77. Did the Staff evaluate the probability of an F-16 conducting to air-to-air combat training over the Utah Test and Training Range crashing onto the facility?

A77. Yes. The Staff evaluated the Applicant's analysis of the potential of F-16 aircraft crashing onto the PFS facility while engaged in air-to-air combat training over the Utah Test and Training Range.

Q78. What was your conclusion with respect to this evaluation?

A78. The Staff concluded that the likelihood of a crash of an F-16 aircraft at the PFS Facility while engaged in air-to-air combat training over the Utah Test and Training Range would not pose an undue hazard to the facility. The Staff estimated the annual probability of crashes per year from this activity at the PFS Facility to be less than 1×10^{-8}.

Q79. Please explain the basis for your conclusion in this regard.

A79. The Staff reviewed the analyses and information presented by PFS with respect to potential hazards of aircraft conducting air-to-air combat training operations in the UTTR South area. The PFS Facility site is located about 2 miles outside the restricted airspace. PFS has assumed a 3-mile wide interior buffer zone within the edge of the UTTR South area restricted airspaces near the facility, where aircraft training activities are limited.

Based on the information provided by PFS, five types of mishaps are possible in which the pilot would not be able to maintain control of the aircraft during air-to-air combat training: (1) Midair Collision, (2) Departed Controlled Flight, (3) Spatial Controlled Flight, (4) Collision with Ground, and

(5) Gravity-Induced Loss Of Consciousness. All these types of mishaps occur during aggressive maneuvering within a range. As a safety precaution, training requiring such aggressive maneuvering is deliberately carried out near the centers of the restricted ranges. The Staff reviewed the PFS analysis of F-16 aircraft crashes during aggressive maneuvering training and concluded that a cut-off radius of 5 miles is a reasonable approximation. A distance of 5 miles would provide at least 45 seconds for the pilots to take necessary actions to avoid an occupied site, which would provide sufficient time for pilots to take action to direct the aircraft away from the Facility.

In summary, the Staff reviewed the PFS assessment of mishaps during aggressive maneuvering training and concluded that this type of aircraft activity within the UTTR South area would pose a negligible crash hazard to the facility. The Staff concluded that the probability of an on-site crash from aircraft flying within the restricted airspaces of the UTTR South area would be less than 1×10^{-8} per year.

IV. Aircraft Departing the UTTR via the Moser Recovery Route

Q80. Did the Staff evaluate the potential for an aircraft crash on the PFS site from aircraft returning to Hill Air Force Base from the Utah Test and Training Range South on the Moser Recovery Route?

A80. Yes. The Staff evaluated the Applicant's analysis of the potential for F-16 aircraft crashing onto the PFS facility while returning to Hill Air Force Base from the Utah Test and Training Range on the Moser Recovery Route. Additionally, the Staff carried out confirmatory analyses with alternative assumptions.

Q81. What was your conclusion with respect to this evaluation?

A81. The Staff concluded that the likelihood of a crash of F-16 aircraft while returning to Hill Air Force Base from the Utah Test and Training Range using the Moser Recovery Route would not pose an undue hazard to the PFS facility. The Staff estimated the annual probability of crashes per year from this activity to be 2.5×10^{-8}.

Q82. Please describe the activities associated with F-16 aircraft transiting the Moser Recovery Route.

A82. The Moser Recovery Route may be used by aircraft returning from the UTTR to HAFB. The Moser Recovery Route passes about 2 to 3 miles north of the proposed facility site at an altitude of 15,000 feet above mean sea level and is an instrument recovery route. This recovery route is only used at night or in marginal weather conditions at HAFB or when Runway 32 at HAFB is active. However, pilots train on the UTTR South area mostly during daytime and in good weather conditions and, as a result, the Moser Recovery route is seldom used.

Q83. Did the Applicant follow the NUREG-0800 formula for calculating the annual probability of an aircraft crash onto the facility from an F-16 transiting the Moser Recovery route?

A83. Yes. The Applicant followed the NUREG-0800 formula. The Applicant further modified the probability to reflect the potential for a pilot to direct an F-16 away from a fixed ground site. The modified formula is similar to that discussed above with respect to F-16s transiting Skull Valley from HAFB to the UTTR South area.

Q84. How did the Applicant determine the estimated annual number of flights?

A84. The Applicant, on the basis of air traffic controllers' information, determined that less than five percent of aircraft returning to HAFB from the UTTR South use the Moser Recovery route.

The Applicant updated this information to account for an increase of sorties in the UTTR South area due to an additional 12 F-16 aircraft stationed at HAFB in FY2001. The Applicant used the average FY 1999 and FY 2000 data for sorties transiting Skull Valley, which the Applicant assumed to be the same as for the Sevier B MOA.

Q85. Did the Staff evaluate the Applicant's estimate of the number of F-16 flights transiting the Moser Recovery route?

A85. Yes. The Staff, however, considered that the UTTR South area sortie data, rather than the Skull Valley flight information used by the Applicant in its most recent analysis, is more appropriate for estimating the annual number of F-16s flying through the Moser Recovery route. The Staff carried out an independent analysis to estimate the crash hazard onto the PFS facility from aircraft flying through Moser Recovery route using FY 2000 sorties from the UTTR South area to estimate the probability of crash. The Staff adjusted the number to account for an additional 12 F-16 aircraft stationed at HAFB.

Q86. Has the use of the Moser Recovery route significantly increased, such that the Applicant's estimate of 5% of returning F-16s using the Moser Recovery route understates its use? For example, do pilots use the Moser Recovery route more frequently due to the introduction of the use of night vision goggles?

A86. No. Pilots use this recovery route only at night or in marginal weather conditions at Hill Air Force Base. On the basis of information from air traffic controllers, less than 5 percent of aircraft to Hill Air Force Base from the UTTR South area use this route. 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 Route. Therefore, this development does not affect the assumption made by PFS about the number of flights through the Moser Recovery.

Q87. How did the Applicant determine the in-flight crash rate per mile?

A87. The Applicant used the in-flight crash rate per mile as discussed above for F-16s transiting Skull Valley, *i.e.*, 2.736×10^{-8}. Since the F-16s returning to HAFB via the Moser Recovery route do not engage in any high-stress maneuvers, the aircraft are in the normal in-flight mode.

Q88. Did the Applicant consider the width of the airway and the effective area of the facility?

A88. Yes. The Applicant used the same data for these factors as it did with respect to the analysis for F-16s transiting Skull Valley.

Q89. Did the Staff evaluate the Applicant's analysis with respect to the width of the airway and the effective area of the facility?

A89. Yes. The Staff's analysis is similar to that with respect to the analysis for F-16s transiting Skull Valley.

Q90. How did the Applicant determine the probability that a crashing F-16 pilot would be able to avoid the facility?

A90. The Applicant used the same value for the probability that a crashing F-16 pilot would be able to avoid the facility as it did with respect to F-16s transiting Skull Valley, discussed above.

Q91. Did the Staff evaluate the Applicant's estimation of the ability of the pilot to avoid the facility?

A91. Yes. The Staff, however, used the value of 10 percent for the probability that a pilot with sufficient control of the crashing aircraft would still not be able to guide the aircraft away from the facility. This is twice the value of 5 percent used by PFS. On this basis, the estimated annual crash probability, after accounting for 12 additional F-16 aircraft at Hill Air Force Base, is estimated by the Staff to be 2.5×10^{-8}. Additionally, the pilots flying through the Moser Recovery route will be under the control of air traffic controllers at Clover control, as this is an instrument flight route. This provides additional conservatism to the estimation of crash probability not accounted for in the analysis.

V. Aircraft From Michael Army Air Field on Airway IR-420

Q92. Did the Staff evaluate the potential for aircraft from Michael Army Air Field at Dugway Proving Ground on airway IR-420 to crash into the PFS facility?

A92. Yes. The Staff evaluated the Applicant's analysis of the likelihood of an aircraft crashing onto the PFS facility while flying to and from Michael Army Air Field at Dugway Proving Ground on airway IR-420.

Q93. What was your conclusion with respect to this evaluation?

A93. The Staff concluded that the likelihood of an aircraft crashing into the PFS Facility while flying to and from Michael Army Air Field at Dugway Proving Ground on airway IR-420 would not pose an undue hazard to the PFS facility. The Staff determined the estimated annual probability of crashes per year from this activity to be 3×10^{-9}.

Q94. Please describe the flight activities on airway IR-420.

A94. Military airway IR-420 runs northeast to southwest over the proposed PFS Facility site to Michael Army Airfield at Dugway Proving Ground. It is 11.5 statute miles (10 nautical miles) wide and terminates at the northern boundary of the Sevier B MOA. According to Michael Army Airfield, 89 percent of flight operations at the airfield involve aircraft from Hill Air Force Base. 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.

Q95. Did the Applicant follow the NUREG-0800 formula?

A95. Yes.

Q96. How did the Applicant determine the annual in-flight crash rate per mile for aircraft using military airway IR-420?

A96. PFS determined the crash rate based on military transport and large aircraft similar to commercial civilian aircraft. PFS analyzed U.S. Air Force accident reports for mishaps involving large military cargo aircraft during FY 1989 through FY 1998. PFS concluded that no destroyed aircraft mishaps took place under circumstances representative of flying in airway IR-420.

In addition, the Applicant considered that the use of the U.S. Air Force Class A and Class B data would greatly overstate the crash rate for military cargo aircraft that have multiple engines. Large multi-engine aircraft can 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, in 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. Therefore, the Applicant used the crash rate of 4×10^{-10} per mile for commercial airlines, as set forth in NUREG-0800. Data for F-16 aircraft using airway IR-420 were not included in this evaluation, inasmuch as those aircraft were considered separately, as discussed in response to Question 98 below.

Q97. Did the Staff evaluate the Applicant's estimation of the in-flight crash rate for these aircraft?

A97. Yes. The Staff determined that the use of the commercial airliner crash rate, as stated in NUREG-0800, to be reasonable for application as the crash rate of large military cargo aircraft. The Staff conducted a confirmatory analysis to evaluate the acceptability of this assumption. The Staff's confirmatory analysis determined that based on the U.S. Air Force data for destroyed aircraft from FY 1989 to FY 1998, the crash rate per mile of flight would be 3.66×10^{-9}. Because all of the crashes reported did not involve conditions found on IR-420, the Staff considered that the actual crash rate would be much less. Therefore, the Staff considered the use of the NUREG-0800 value of 4×10^{-10} to be appropriate.

Q98. The State of Utah has asserted that the Applicant's consideration of the crash rate is incorrect because most of the aircraft flying on IR-420 are F-16s. Do you agree with this assertion?

A98. No. The Applicant assumed that all aircraft traffic, except for F-16s flying to and from Michael Army Airfield in the vicinity of the PFS facility site, use IR-420. F-16s using Michael Army Airfield often fly directly from the UTTR South area ranges without using route IR-420 and have already been considered in the analysis 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.

Q99. How did the Applicant determine the effective area of the facility and the width of the airway?

A99. The Applicant used the DOE standard, discussed above, to evaluate the effective area of the facility, and used an airway width of 11.5 miles for IR-420.

Q100. How did the Applicant estimate the number of flights per year?

A100. The Applicant estimated the number of flights per year in IR-420 on the basis of data provided by the U.S. Army. Specifically, the U.S. Army indicated in an April 2, 1997 letter to Stone & Webster Engineering Corporation that a total of approximately 414 flights per year fly along IR-420. According to the Applicant, neither the U.S. Air Force nor the U.S. Army were able to provide updated IR-420 traffic information for FY 2000. However, the Applicant provided a basis for assuming that the 414 flights per year continues to be a reasonable estimate.

According to Michael Army Air Field (MAAF), there were 1,929 flight operations conducted at MAAF in FY 2000. An operation is defined as a flight action in association with an airport. Actions constituting an operation include landings, takeoffs, approaches, or flights through the airport traffic area. Hence, a single flight to MAAF may involve more than one flight operation.

Thus, for example, the maximum number of flights associated with 1,929 flight operations can be as high as 1,929 flights. In practice, depending on the average number of flight operations conducted, the number of flights associated with FY 2000 operations at MAAF may be considerably less than 1,929.

In any event, MAAF has indicated that only 89% of the 1,929 flight operations (*i.e.,* 1,717 flight operations) correspond to aircraft originating at HAFB. Hence, the maximum potential number of flights in FY 2000 along IR-420 would not exceed 1,717. Most of these aircraft were F-16s and, hence, their presence on IR-420 would have been accounted for in the number of F-16 flights through Skull Valley. Thus, even though the number of IR-420 flights associated with the 1,717 MAAF flight operations is not known, it has been effectively accounted for by PFS.

If the remaining 212 MAAF flight operations that originated from other airfields were to be assumed as flights along airway IR-420, this would represent the maximum number of flights along IR-420 for FY 2000 that have not been accounted for elsewhere in the Applicant's analyses. Therefore, an estimate of 212 flights along IR-420 in FY 2000 would be conservative. On this basis, the Applicant's use of 414 flights (from the 1997 data) for IR-420 is reasonable.

Q101. Did the Staff evaluate the Applicant's estimation of the number of flights per year?

A101. Yes. As indicated in A.100 above, the Applicant provided a description of the FY 2000 MAAF operations data and how they relate to IR-420 traffic. The Staff views the Applicant's description to be reasonable and considers the use of the estimated 414 flights per year along IR-420 to be conservative.

VI. Cumulative Hazard

Q102. Did the Staff evaluate the cumulative hazard with respect to aircraft crashes at the PFS site?

A102. Yes. The Staff evaluated the cumulative aircraft crash hazard for the PFS Facility. This was done by summing the crash probabilities estimated for each individual type of aircraft activity in the vicinity of the proposed PFS facility.

Q103. What was your conclusion?

A103. As set forth in SER Supplement No. 1, the Staff concluded that the estimated cumulative aircraft crash hazard to the PFS facility is acceptably low. The Staff found that the estimated cumulative aircraft crash hazard to the PFS facility is within the regulatory guidelines as described in NUREG–0800 Sections 2.2.3 and 3.1.5.6. The data supporting this conclusion are set forth in SER Supplement No. 1 and Table 15-10 thereof.

Q104. Please explain the basis for your conclusion in this regard.

A104. The Staff reviewed the Applicant's description of past and present activities in connection with potential hazards from the crash of both civilian and military aircraft flying in the vicinity of the PFS facility site. The activities reviewed 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. The Staff also reviewed the potential hazards associated with jettisoned ordnance and ordnance carried onboard an aircraft crashing in Skull Valley. In addition to the review of the Applicant's submitted information, the Staff performed various sensitivity and confirmatory analyses.

Independent confirmatory analyses carried out by the Staff provided a measure of the conservatism inherent in the Applicant's analyses. For example, the Staff conservatively utilized the annual sortie data for FY 2000, increased by the 12 additional F-16 aircraft stationed at HAFB in FY 2001, thus obtaining the maximum number of sorties in the data. 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 PFS). Taking formation flights into account yields the result that about 50 percent of the flights would not be in a position to pose a crash hazard to the proposed PFS 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 PFS 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 conservatism and robustness of the analyses and estimates presented by PFS.

The Staff also reviewed the PFS estimated projected growth of civilian and military flights based on the Federal Aviation Administration (FAA) long-range forecast. The FAA estimates 66 percent growth of commercial aviation and 14 percent growth in general aviation traffic in the United States, by 2025. These factors were used to project the estimated crash probability of commercial and general aviation aircraft, accordingly.

The FAA predicts that the military air traffic would not increase appreciably, if at all, in the foreseeable future. Use of constantly improving flight simulators is enabling the pilots to advance flying proficiency with reduced actual flying hours. 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. Additionally, 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. The crash rates of newer aircraft are decreasing relative to those of their predecessors.

Based on the above projections and trends, the increase in cumulative crash hazard to the proposed PFS facility, taking into account commercial, general aviation, and military aircraft, would be insignificant (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 conclusions above concerning the aircraft crash hazard for the PFS facility based on current information would still be valid for the foreseeable future, assuming the projection of future air traffic, as discussed above, remains valid. Finally, it should be noted that if the flight activities near the PFS 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.

In summary, the Staff found the Applicant's methods of analysis and the results of its analyses to be reasonable. The estimated crash probability with respect to the proposed PFS facility was found to be within the regulatory guidelines as described in NUREG–0800, Sections 2.2.3 and 3.1.5.6. The Staff's review of the Applicant's analyses, and the Staff's independent confirmatory and sensitivity analyses, support the conclusion, as stated in section 15.1.2.11 of SER Supplement No. 1, 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.

Q105. Does this conclude your testimony?

A105. Yes.

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Ph.D., Nuclear Engineering, Purdue University

Post-Graduate Courses and Training
- Rensselaer Polytechnic Institute (Mathematics)
- Massachusetts Institute of Technology (Nuclear Power Plant Operations)
- Babcock & Wilcox (Nuclear Power Plant Operations)
- U. S. Nuclear Regulatory Commission
  - System Reliability and Safety Analysis
  - BWR Fundamentals
  - PWR Fundamentals
  - Fault Tree Analysis
  - Radiological Accident Assessment
  - Fundamentals of Inspection
  - Supervision and Management

Experience:

U. S. Nuclear Regulatory Commission (formerly U. S. Atomic Energy Commission), 1972 - Present

Currently serve as a technical staff member of the Probabilistic Safety Assessment Branch. Responsible for performing safety assessments of nuclear power plant facilities. Safety evaluations include thermal hydraulic analyses of containment response to design basis accidents involving loss of coolant events. In addition, performs safety reviews of risks posed to nuclear facilities by external man-made hazards. These include assessment of risks associated with aircraft activity as well as other modes of transportation (e.g., railroads, highways, navigable waterways, and pipelines).

Prior to his present position, Dr. Campe was assigned to the Analytic Support Group, which provided analytic services to the technical branches within the Division of Systems Safety and Analysis. As a technical staff member of this group, he primarily performed thermal hydraulic analyses of nuclear power plant transients and design basis accidents using advanced nuclear analysis codes. Part of his duties within the group involved code development and maintenance activities. In addition, he provided analytic support in other areas, such as spent fuel pool thermal analysis code work.

Before joining the Analytic Support Group, Dr. Campe was employed as Section Chief in the Risk Applications Branch. His responsibilities within the branch were to supervise and participate in the administrative and technical activities of the Reliability Applications Section. This involved the planning, coordinating, and directing risk evaluations with respect to the design and operation of nuclear power plants. Specifically, using a diverse background of systems engineering and risk assessment, Dr. Campe supervised the development and application of systems reliability and plant risk analysis for the purpose of identifying significant contributors to risk. As Section Chief, he also performed technical evaluations and provided expert consultation in the area of man-made hazards.

Prior to the Risk Applications Branch, Dr. Campe held the positions of Section Leader in the Plant Systems Branch and the Site Analysis Branch. His principal responsibilities were the technical and administrative supervision of licensing actions relating to plant systems design and operation, external hazards, and site suitability determinations.

Before accepting the position of Section leader, Dr. Campe was employed as Senior Site Analyst, Site Analyst, and Nuclear Engineer. He was responsible for performing licensing reviews, principally in the areas of man-made external hazards associated with toxic, flammable, or explosive substances, as well as missile impacts. In addition, he performed reviews of tornado and turbine missile risks, and control room habitability systems with respect to design basis accidents.

His activities in generic studies included technical contract management, computer code development, drafting of Regulatory Guides, and participating in Fission Product Release and Foreign Reactor Safety Research Groups. Specifically, he has prepared most of the technical input for Regulatory Guide 1.115 on turbine missiles. He has also prepared the following sections of the Standard Review Plan, NUREG-0800 (formerly NUREG-75/087): Standard Review Plan § 3.5.1.3, "Turbine Missiles"; Standard Review Plan § 2.2.1-2.2.2, "Identification of Potential Hazards in Site Vicinity"; Standard Review Plan § 2.2.3, "Evaluation of Potential Accidents"; Standard Review Plan § 3.5.1.5, "Site Proximity Missiles (Except Aircraft)"; and Standard Review Plan § 3.5.1.6, "Aircraft Hazards."

Hittman Associates, Inc., Columbia, MD, 1966 - 1972

As Section Chief for radiation analysis and special projects, Dr. Campe was responsible for radiation analysis of systems which either use or interface with radioisotopes.

In this capacity, he has performed numerous parametric studies on the radiation shielding characteristics of conceptual polonium, promethium, and plutonium fueled heat sources, and was responsible for detailed analysis of the radiation fields and the radiation shielding requirements of radioisotope thermoelectric generators for spacecraft. He also performed radiation analyses for implanted medical devices.

Dr. Campe also was active in reactor physics analysis, performing calculations and developing advanced computer codes for analyzing water moderated reactor lattices.

Pratt and Whitney, CANEL, Middletown, CT, 1960 - 1962 (plus summer of 1963)

As Analytical Engineer, Dr. Campe worked in the Analytic Physics Group on problems associated with the design of a nuclear propulsion reactor for an aircraft. This involved extensive reactor physics analyses of a liquid metal fast fission spectrum reactor.

AMITAVA GHOSH

Principal Engineer
Center for Nuclear Waste Regulatory Analyses
Southwest Research Institute
San Antonio, TX

Education:

B.Tech., Mining Engineering, Indian Institute of Technology, Kharagpur, India; 1978
M.S., Mining Engineering, University of Arizona, Tucson, Arizona; 1983
Ph.D., Mining Engineering, University of Arizona, Tucson, Arizona; 1990

Experience:

Dr. Ghosh has over 20 years of experience in conducting both academic and industrial research, consulting, and teaching in mining, geological, and geotechnical engineering with special emphasis on numerical simulations, field and laboratory experiments, rock mechanics and rock engineering, explosives and blasting, soil mechanics, rock fracture mechanics, and application of probabilistic methods, theory of fractal geometry, geostatistics, and artificial intelligence. Since joining the Center for Nuclear Waste Regulatory Analyses, he provides technical support to the U.S. Nuclear Regulatory Commission on the design and experimental programs for site characterization of the proposed repository, spent fuel project, and reclamation of active mill tailings sites.

He is the principal investigator for developing the Private Fuel Storage Facility Safety Evaluation Report. He is the technical lead for preclosure activities of the proposed high-level nuclear waste repository at Yucca Mountain and is currently involved with probabilistic risk assessment; identification of hazards and initiating events; and repository design. He was the principal investigator for modeling rock joint response under cyclic, pseudostatic, and earthquake loads, evaluating rock joint constitutive models and their implementation in UDEC code for the proposed repository at Yucca Mountain. He led a multi-disciplined team for developing the Centralized Interim Storage Facility Assessment Report. He has developed a part of the Standard Review Plan for reclamation of active mill tailings sites under Title II of the Uranium Mill Tailings Radiation Control Act. He was part of the team developing a module for Total-system Performance Assessment code to assess the risk associated with waste package disruption from fault slippage at Yucca Mountain using probabilistic methodology.

Dr. Ghosh worked as a postdoctoral research fellow at the University of Nevada, Reno. He quantified the utilization of explosive energy in blasting from the energy required to crush the blasted fragments. Dr. Ghosh was awarded the Rocha Medal in 1992 by the International Society for Rock Mechanics in a worldwide competition for his PhD research on the application of fractal geometry and numerical methods to examine fracture formation and propagation in rock using explosives. A paper based on the application of fractal geometry to quantify the effects of natural fractures on rock blasting won the Society of Mining Engineers Outstanding Student Paper contest in Graduate Division in 1989. He worked as a Technical Services Engineer at IDL Chemicals Ltd. with emphasis on ground vibration and air blasts from blasting. Dr. Ghosh has taught several courses at the University of Arizona. He has published more than 35 technical papers and 15 research reports. He has reviewed papers for several journals and rock mechanics symposiums and chaired the session of Rock Fragmentation from Blasting at the 35th U.S. Symposium on Rock Mechanics, and the session on Waste Repositories at the 38th U.S. Symposium on Rock Mechanics.

Professional Chronology:

Technical Services Engineer, IDL Chemicals Ltd., 1978–1981; Graduate Assistant/Associate, University of Arizona, 1982–1990; Postdoctoral Fellow, University of Nevada, Reno, 1990–1992; Research Engineer, Southwest Research Institute, 1992–1994; Senior Research Engineer, Southwest Research Institute, 1994–1999; Principal Engineer, 1999–Present.

Memberships:

International Society for Rock Mechanics; American Rock Mechanics Association; International Association for Mathematical Geology; American Geophysical Union; Society for Mining, Metallurgy, and Exploration, Inc.

Staff Exhibit D

Skull Valley Elevation Profile at PFSF Latitude