RESPONSES TO NUCLEAR REGULATORY COMMISSION

POTENTIAL AIRCRAFT CRASHES AT THE PFSF

OCTOBER 22, 1999

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I. AIRCRAFT CRASH RATES FOR F-16S IN SKULL VALLEY

NRC Comment 1 – The NRC raised questions about PFS's use of "normal" rather than "special operations" aircraft crash rates from DOE-STD 3014-96 for the F-16s flying down Skull Valley and requested further justification from PFS for its use of the normal crash rate.

PFS Response

As PFS has previously stated, the maneuvers conducted by F-16s transiting through Skull Valley are limited to clearing turns, G-awareness maneuvers and terrain masking. These maneuvers fall within the parameters of "normal" flight operations and would not be categorized as "special" operations as those terms are used in the Data Development Technical Document for the Aircraft Crash Risk Analysis Methodology (ACRAM), August 1, 1996. We have talked to the authors of the ACRAM study, specifically, Richard W. Mensing, who was responsible for analyzing the military crash data set forth in the study. He advised us that the term "special" operations describes the high stress, violent maneuvers that occur in simulated air-to-air combat and air-to-ground weapons deliveries which significantly increase the potential for air crashes. The low stress maneuvers undertaken by the F-16s flying through Skull Valley, as described below, would be considered part of "normal" operations, not "special" operations as defined by the study. Therefore, he agreed that it is proper to use the "normal" crash rate to calculate the probability of F-16s crashing as they transit Skull Valley.

The former commander of the 388th Fighter Wing at Hill AFB, Col. Ronald E. Fly, USAF (Ret.), who has flown F-16s in Skull Valley, states in the memorandum at Tab A that "[t]ypical maneuvering in Skull Valley is in the administrative and routine categories, both of which are low risk phases of flight." This further confirms that the F-16 maneuvers in Skull Valley do not involve the high stress, violent maneuvers of simulated training activities and therefore belong in the "normal" category.

Specifically, clearing turns simply involve shallow banking turns looking for other aircraft that could possibly be in the area. The "G-awareness" maneuver simply involves a sharp turn of relatively short duration for the purpose of subjecting the aircraft and pilot to the G forces of a sharp turn sufficient to activate the pilot's G-suit and to confirm that it will work properly during the high stress violent maneuvering that will take place later on the range. The Chief of Safety of Air Combat Command for the U.S. Air Force confirms in Tab B that G-awareness turns are "merely a warm-up exercise" that are accomplished as part of normal operations before entering a range.

Terrain masking simply involves flying at a constant altitude above the terrain while staying below an altitude that would allow radar tracking by a potential enemy. As the terrain rises, the aircraft climbs. As the terrain falls away, the aircraft descends. This is neither an unusual nor special maneuver. For this flying activity, the F-16s fly on the eastern side of Skull Valley in the radar "shadow" of the Stansbury Mountains. The minimum altitude for flying in Skull Valley is 1,000 ft above ground level (AGL), although most aircraft according to the Air Force fly at 3,000 ft to 4,000 ft AGL. In areas other than Skull Valley, 500 ft AGL is the normal altitude for such maneuvers, and, as confirmed by the Chief of Safety of Air Combat Command in Tab B, flying these maneuvers at this altitude is not considered high risk.

Further, clearing turns, "G-awareness" maneuvers, and terrain masking are not confined to Military Operating areas (MOAs) and Restricted Area Ranges. They are regularly performed on Visual Routes and Instrument Routes en-route to the ranges. Thus, in addition to being normal, standard, low risk, and non-violent, these maneuvers are not confined to range areas as are those that are termed "special operations." Consequently, they appropriately fall in the "normal operations" category. The authors of the ACRAM study and the U.S. Air Force agree with this assessment.

In sum, the "special" operations category in the ACRAM study was intended to cover the high stress violent maneuvers involved in combat training exercises and does not include the routine and administrative flight maneuvers of the F-16s flying down Skull Valley, which are appropriately part of "normal" operations as that term is used in the ACRAM study. Thus, PFS appropriately used the normal crash rate for F-16s flying down Skull Valley.

II. USE OF AN AVERAGE AREA FOR THE PFSF CASK STORAGE AREA

NRC Comment 2 – The NRC questioned PFS's approach of using a time-weighted average area for the cask storage area when calculating the air crash impact hazard to the PFSF instead of evaluating the hazard on an annual basis.

PFS Response

A. Overview and Summary

Although as set forth in its August 13 submission PFS believes that it is appropriate to assess the air crash hazard to the PFSF using probabilities averaged over the lifetime of the facility, PFS has performed an alternate analysis utilizing an annual probability based on the maximum filled capacity of the PFSF of 4000 casks. This alternate analysis is based on new additional information that PFS has obtained since its August 13 submission which enables it to better determine and quantify some of the many conservatisms in PFS's August 13 calculations. Specifically, PFS has conferred with Colonel Ronald E. Fly, USAF (Ret.), former commander of the 388th Fighter Wing at Hill AFB and an F-16 pilot who has recently flown in Skull Valley, to better understand both the emergency procedures employed by pilots in the event of an engine failure (by far the most common cause of an F-16 crash in the normal operations mode) and the related flight characteristics of the crashing F-16. PFS has also obtained more specific data concerning the percentage of F-16 crashes attributable to engine failure. Based on this new information, PFS has been able to more realistically calculate the risks of aircraft crashes to the PFSF and has found that, even using the maximum area of the cask storage area filled with 4000 casks, the air crash risk to the PFSF remains well within NRC acceptable limits in defining a non-credible accident.

As set forth in PFS's August 13 submission (pages 1-5) and as discussed in the October 7 telephone conference, PFS believes that the applicable NRC regulatory limit for determining credible design basis events for which a facility performing waste storage and handling, such as the PFSF, must be designed is 1×10^{-6} per year. Specifically, in December 1996, the Commission amended its 10 C.F.R. Part 60 rules for geologic repository operations area – including surface operations and storage – to establish a probability bound for Category 2 design basis events of 1×10^{-6} per year. Disposal of High-Level Radioactive Wastes in Geologic Repositories; Design Basis Events, Final Rule, 61 Fed. Reg. 64,257 (Dec. 4, 1996).[1] "[E]vents with probabilities of occurrence lower than 1×10^{-6} per year could be screened from further consideration due to their negligible contribution to individual risk." Id. at 64,261. In promulgating this standard for repository operations area, the Commission stated its intent to make the design basis for 10 C.F.R. Part 60 repositories comparable to that for 10 C.F.R. Part 72 facilities "[b]ecause operations at the repository are expected to be similar to operations at . . ." 10 C.F.R. Part 72 facilities. Id. at 64,262. The Commission stated that the rulemaking on Part 60 design basis events "will harmonize part 60 with part 72" because "part 72 applies to those facilities (MRS installations) most similar to the surface facilities of a repository and for which the kinds of design basis events are also expected to be similar." Id. at 64,265. Further, the Commission expressly confirmed that Part 60 Category 2 events were equivalent to "design basis accident[s]" under 10 C.F.R. § 72.106 and that the difference in terminology between Part 60 and Part 72 "is not intended to be one of substance." Id.

Thus, it is appropriate to apply the same probability bound to exclude from design basis accidents under 10 C.F.R. § 72.106 accident events less probable than 1×10^{-6} per year. In fact, such a standard is conservative when applied to the PFSF in that the risks associated with the PFSF will be less than that associated with the above ground facilities at a repository because no fuel processing or repackaging will take place at the PFSF.

[1] Category 2 design basis events are "[o]ther natural and man-induced events that are considered unlikely but sufficiently credible to warrant consideration, taking into account the potential for significant radiological impacts on public health and safety." 10 C.F.R. § 60.2.

Further, in promulgating a probability bound of 1 x 10^{-6} per year for Part 60 repositories (and Part 72 ISFSI facilities), the Commission specifically distinguished the risks of such facilities from the risks associated with operating nuclear reactors. The Commission found that in comparison with nuclear reactors "the primary activities [of] waste receipt, handling, storage, and emplacement" at a repository resulted in a "relatively simple facility" that did not "require the variety and complexity of active systems necessary to support an operating nuclear power plant." 61 Fed. Reg. at 64,266. In addition, the "conditions are not present at a repository to generate a radioactive source term of a magnitude that, however unlikely, is potentially capable at a nuclear power plant (e.g., from a postulated loss of coolant event)." Id. The same holds true for a Part 72 ISFSI, such as the PFSF, at which the primary activities are waste receipt, handling and storage. Because the NUREG-0800 guidance was established for operating nuclear power plants – which the Commission specifically distinguished in establishing the probability bound of 1 x 10^{-6} per year for Part 60 repositories (and Part 72 ISFSI facilities) – the 1 x 10^{-6} per year probability bound, and not the NUREG guidance, is the applicable regulatory standard here.

As set forth below, quantifying some of the conservatisms in the August 13 calculations shows that the calculated probability for aircraft hazards for a fully loaded 4,000 cask facility is well below the 1 x 10^{-6} per year standard enunciated by the Commission. Specifically, PFS has calculated that the annual probability of an air crash impacting the cask storage area, assuming it were fully loaded, would be approximately 2.59 x10^{-7} and the annual probability of an air crash impacting the Canister Transfer Building (CTB) is 2.61 x 10^{-8}, which results in an overall calculated annual probability for the facility of 2.85 x 10^{-7}. Furthermore, by virtue of the significant conservatisms still remaining in the calculation, the realistic probability even for a fully loaded facility is less than 1 x 10^{-7}, and therefore PFS fully meets the NUREG-0800 standard as well even assuming that standard were applicable here.[2]

B. PFS's Revised Calculations

1. Summary of the August 13, 1999 Calculations

As part of its August 13 calculations, PFS calculated the time-weighted average effective area of the PFSF cask storage area with respect to the F-16s transiting Skull Valley to be 0.063 sq. mi. (August 13 submission, at 16). The effective area for a fully loaded cask storage area is 0.1222 sq. mi. (August 13 submission, Tab F). Thus, the effect of using the peak cask storage area would be to increase the calculated air crash impact probability for that area (but not for the canister transfer building, which does not change in area) by a factor of 1.94 (0.1222/0.063). The change in the other calculated air crash impact probabilities for the cask storage area, on page 43 of the August 13 response, would be essentially the same.[3] Therefore, the annual probability of an air crash impacting the cask storage area, assuming it were fully loaded, using the methodology of the August 13 calculations, would be approximately 1.31×10^{-6}. Together with the calculated annual probability of 1.26×10^{-7} for the Canister Transfer Building, the overall August 13 calculated an-

[2] The Standard Review Plan for nuclear power reactors, NUREG-0800, uses an "NRC staff objective of approximately 10^{-7} per year" for determining design basis events for which such reactors should be designed. However, NUREG-0800 goes on to state that "because of the low probabilities of the events under consideration, data are often not available to permit accurate calculation of probabilities. Accordingly, the expected rate of occurrence of potential exposures in excess of the 10 CFR Part 100 guidelines of approximately 10^{-6} per year is acceptable if, when combined with reasonable qualitative arguments, the realistic probability can be shown to be lower." NUREG-0800 at 2.2.3-2 (emphasis added)

[3] The change from an average cask storage area to the full cask storage area increases the effective area of the PFSF by a factor of precisely 1.94 with respect to the F-16s transiting Skull Valley and flying on the UTTR. With respect to other aircraft, the PFSF effective area increases by a slightly smaller or slightly larger amount, in that the effective area includes the physical area of the cask storage area, plus some skid area or shadow area that is fixed in depth by the skid distance or impact angle of the aircraft. For aircraft with a longer skid distance (e.g., airliners), the factor of effective area increase is slightly less than 1.94; for aircraft with shorter skid distances (e.g., general aviation aircraft), the factor of effective area increase is slightly greater than 1.94. For ease of calculation, PFS has applied the 1.94 factor throughout this analysis.

nual probability for the facility would be 1.44 x 10^{-6}, only slightly above the 1 x 10^{-6} per year standard enumerated by the Commission for above-ground repository facilities under Part 60 and ISFSIs under Part 72, such as the PFSF. As shown below, however, quantification of only some of the major conservatisms in the August 13 PFS calculation brings this number well below the 1 x 10^{-6} regulatory standard.

2. PFS's Revised Calculation for F-16s Transiting Skull Valley

PFS's August 13 calculation of the probability that an F-16 transiting Skull Valley would crash, impact the PFSF, and cause a radioactive release was conservative for a number of reasons. First, in its calculation PFS assumed that crashing F-16s would fall to the ground randomly somewhere within the aircraft's glide range from the point at which the precipitating event occurred, assuming the pilot remained with the plane but took no action to avoid the facility. This is a highly conservative assumption in that PFS took no credit for the likely potential that the pilot could retain control of the aircraft during the accident and hence would be able to guide the aircraft away from the PFSF. Second, PFS's calculated probability assumed that all crash impacts would occur at high velocity and nearly perpendicular to the side of a storage cask or the wall of the canister transfer building (CTB), such that the aircraft would have the most favorable conditions to penetrate the cask or the CTB upon impact. PFS took no credit in its calculation for the much more likely potential for crash impacts at lower velocities and at angles such that the aircraft would not penetrate the cask or the CTB and hence would not cause a radioactive release. Third, PFS assumed that the F-16s were evenly distributed across Skull Valley rather than concentrated toward the eastern side of the valley, where their predominant route of flight is located and from whence it would be less likely that a crashing aircraft would impact the PFSF site. Further, PFS made additional conservative assumptions in its calculation, such as using the 10 year crash rate rather than the more recent lower five year crash rate.

On the basis of new information obtained since August 13, PFS can now quantify some of the above conservatisms and provide more a accurate – but still conservative – calculation of the probability that an F-16 transiting Skull Valley would crash, impact the PFSF, and cause a radioactive release. The quantification of just two of the principal conservatisms in the probability risk calculation for F-16s transiting Skull Valley greatly reduces the calculated risk that crashing F-16s pose to the PFSF facility.

The first principal conservatism is the assumption inherent in the August 13 calculation that all F-16s transiting Skull Valley that experienced problems that would lead to crashes would fall to the ground in random directions somewhere within the aircraft's glide range from the points at which the problems occurred. (August 13 submission, at 10, 17-19) In fact, if an F-16 experiences a problem which leaves the pilot in control of the direction of the aircraft – such as the loss of its engine – the aircraft will not fall in a random direction. Instead, the pilot, as he has been trained, will fly the aircraft in a chosen direction in an unpowered glide. Pilots of disabled aircraft will make every reasonable effort to avoid gliding toward populated areas or buildings, such as the PFSF, in order to avoid the possibility that their aircraft would hit such areas if they were forced to eject from the aircraft. Therefore, it is highly unlikely that an F-16 experiencing an engine failure, which would leave the pilot in control of the aircraft (albeit without thrust), would strike any built up area, including the PFSF, particularly where, as in Skull Valley, there are many open areas towards which the pilot could direct a crashing F-16.

To more fully address this accident scenario, PFS now divides potential F-16 crashes in Skull Valley into two categories: 1) crashes precipitated by engine failure in which the pilot will retain control of the aircraft and 2) all other crashes in which it is assumed that the pilot does not retain control of the aircraft. PFS addresses engine failures below and addresses all other crashes as it did in its August 13 submission. U.S. Air Force data show that virtually all F-16 crashes during normal operations are attributable to engine failure. Because such failures leave the pilot in control of the plane and capable of avoiding the PFSF site, the effect of this analysis is to reduce the calculated probability that an F-16 would impact the PFSF (full cask storage area or CTB) by 95 percent to 4.96 x 10^{-8} per year. This calculated probability is further reinforced by the fact that the emergency procedures taken by the pilot greatly reduce the speed of the aircraft such that it would not penetrate the storage casks even assuming the plane were to strike the facility, which is the second principal conservatism that PFS quantifies in its analysis here.

As set forth in the memorandum at Tab A from Col. Ronald Fly, USAF (Ret.), a former F-16 flight instructor and former Wing Commander at Hill Air Force Base, F-16 pilots are trained to follow a specific procedure upon experiencing an engine failure when flying below 5000 feet AGL.[4] First, the pilot will climb and trade excess airspeed for altitude in order to gain more time to respond to the incident (e.g., attempt to restart the engine) and jettison external ordnance and stores, if applicable. Climbing will reduce his airspeed to that which will enable him to stay aloft the longest and will give him more altitude to lose before he must eject from the aircraft. The pilot will initiate a climb to a 30-degree nose-high attitude and when the aircraft has decelerated to 250 knots indicated air speed (KIAS), the pilot will lower the nose of the aircraft and begin to glide at about 210 KIAS, which allows the F-16 to stay aloft for a longer recovery period. Then the pilot would attempt to restart his engine and maneuver to land if a suitable airstrip were available (which would not be the case in Skull Valley).

If he is able to start the jet fuel starter on the F-16, he would reduce his glide speed further to about 170 KIAS giving him longer time in the air but a shorter glide distance. If the pilot had not restarted his engine by the time he reached 2,000 ft. AGL, he would

[4] F-16 pilots are regularly tested on the procedure after receiving their training as well. Conference with Col. Ron Fly, USAF (ret.), October 16, 1999.

eject from the aircraft. While gliding in the aircraft, the pilot would, time and circumstances permitting, ensure that upon ejecting from the aircraft it would not be pointed in the direction of any built up area. Moreover, the F-16 possesses a flight control computer that will hold the aircraft on the flight path set by the pilot even after he ejects. The computer will attempt to keep the aircraft flying at a constant altitude by raising the nose of the aircraft as it decelerates. Once the aircraft reaches a 25-degree nose-high attitude, the computer will hold that attitude as the aircraft descends. The aircraft will most likely impact the ground at a velocity between 170 and 210 KIAS at a point some distance along the flight path from the point of pilot ejection.[5]

Thus, in the event of an engine failure, the pilot would most likely be able to direct the aircraft away from a built up area like the PFSF and the aircraft would continue flying in that direction even after the pilot ejected. Therefore, it would be highly unlikely that the aircraft would strike the PFSF. Thus, PFS can reasonably exclude from its risk calculation the fraction of the F-16s that were assumed to hit the site in the August 13 submission as a result of an engine failure but in fact would crash without affecting the PFSF. On the other hand, PFS conservatively calculates the probability of an F-16 impacting the PFSF because of a crash not precipitated by engine failure the same way as it did in the August 13 submission, i.e., the aircraft is assumed to impact the ground at a random point within the glide distance of the aircraft from the point at which the aircraft experiences the problem leading to the crash. All such crashes are conservatively assumed to be events in which the pilot does not retain control of the aircraft and ejects without maneuvering to avoid the site.

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[5] This information concerning the flight computer in the F-16 and its ability to maintain flight control of the aircraft after the pilot ejects is new information provided by Col. Fly not previously known by PFS. Therefore, in an engine failure scenario, the F-16 will not go out of control upon ejection of its pilot as PFS previously was led to believe and stated in its earlier responses filed with the NRC.

Air Force data on F-16 crashes occurring in the last 10 years indicates that of those crashes that occurred in the "normal" mode of flight, over 95 percent were precipitated by engine failure. (Tab C) This data is supported by Col. Fly's professional judgment that engine-related failures would be by far the leading cause of F-16 crashes in Skull Valley.[6] Therefore, the risk posed to the PFSF cask storage area by F-16s transiting Skull Valley calculated in the August 13 submission (assuming a maximum area for the cask storage area) can be reduced by at least 95 percent to 4.53×10^{-8} per year.[7] Similarly the risk posed by F-16s transiting Skull Valley to the CTB calculated in the August 13 submission can be reduced by 95 percent to 4.29×10^{-9} per year, and the combined calculated risk of impact to either the cask storage area or the CTB can be reduced to 4.96×10^{-8} per year.

The second principal conservatism to be quantified with respect to PFS's probability calculation for F-16s transiting Skull Valley – which directly reinforces the above reduction in calculated risk – is the assumption that all air crashes that impact the PFSF will result in a radioactive release in excess of that allowed under 10 C.F.R. § 72.106. This is ex-

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[6] Conference with Col. Ron Fly, USAF (ret.), October 16, 1999; (Tab A).

[7] In its August 13 submission, PFS calculated the air crash impact probability for F-16s transiting Skull Valley using the NUREG-0800 and Kimura methodologies. (August 13 submission at 9-21) In NUREG-0800, the impact probability is given as P = N x C x A/W, where N is the number of flights, C is the crash rate per mile, A is the site effective area, and W is the width of the valley. Id. at 9-18. However, because 95 percent of all F-16s crashing in Skull Valley would do so because of an engine failure and would miss the PFSF, the impact probability may be reduced by 95 percent (i.e., the number of crashing aircraft, N x C, may effectively be reduced by 95 percent). The resulting number is further reduced by 30 percent per PFS's original calculation because only 70 percent of the planes crashing for reasons other than engine failure could reach the site. Thus, $P = 3871 \times 2.736 \times 10^{-8} \times (.05) \times (.70) \times (.1222) \div 10$ or 4.53×10^{-8} per year. This probability can also be computed directly from the annual average probability that PFS provided in its August 13 submission, by multiplying the annual average probability calculated in the August 13 response by the 1.94 factor of effective area increase (to arrive at the probability assuming a maximum area for the cask storage area before any reduction due to engine failures) multiplied by .05 to reflect the 95 percent reduction due to engine failure (the 30 percent reduction already being included in PFS's August 13 calculation). For ease of computation, the subsequent probabilities set forth in these responses will be derived by making the appropriate adjustments to the annual average probabilities set forth at page 43 of PFS's August 13 submission.

tremely conservative in that, as shown in PFS's August 13 submission, an F-16 impacting at a velocity less than 340 knots perpendicular to the spent fuel storage cask would not penetrate the cask. (August 13 submission, Tab H). As shown above, an F-16 that crashed after an engine failure would impact the ground between 170 and 210 KIAS (approximately 185 to 230 knots true airspeed) at some angle with the horizontal. Thus, it will not penetrate a cask even assuming the pilot does not direct the plane away from the site.

Moreover, even assuming that the flight control computer failed to maintain the attitude of the aircraft after the pilot ejected at 2000 ft. AGL, the crash impact velocity from a glide at that altitude would not be significantly higher than 210 KIAS. Further, the aircraft would impact the ground at some angle with the vertical, which would reduce its ability to penetrate a spent fuel storage cask or the canister transfer building. The data developed in the DOE ACRAM Data Development Technical Support Document shows that 95 percent of the crashes of small military aircraft (which includes the F-16) on take-off and landing (which would be analogous to the F-16 crash-after-glide scenario considered here) would have a horizontal impact velocity of less than 237 knots (true airspeed). (Tab D) This velocity is significantly less than the 340 knots necessary to penetrate the spent fuel storage casks. Thus, quantification of the impact velocities for F-16 crashes caused by engine failure shows that the horizontal velocities of the crashing F-16s would be insufficient to penetrate the spent fuel storage casks.[8]

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[8] An impact velocity below 197 knots perpendicular to the CTB would not penetrate it. (Tab E). While a gliding F-16 might therefore penetrate the CTB, it would not penetrate both the CTB <u>and</u> a cask inside. Accordingly, the only time spent fuel inside the CTB might be vulnerable would be when a canister was outside a cask during a canister transfer operation. Because PFS will receive or ship about 200 canisters per year (PFS SAR at 7.4-2) and each canister will be outside a storage or shipping cask only 3.4 hours per transfer operation (PFSF SAR at Tables 7.4-1 and 7.4-2), the period of vulnerability would be 680 hours per year or less than 8 percent of the time.

Furthermore, assuming an F-16 crashing into the site might cause the fuel tank to rupture and the fuel to spill out and potentially burn, the resulting fire would not cause a radioactive release. (Tab F) The F-16 carries approximately 1,000 gallons of fuel internally.[9] If the fuel were released and ignited, it would collect around the concrete storage pads, which are designed to be self-draining and which are arranged in rows 30 ft. apart. PFSF SAR at Fig. 1.2-1. If such a fire was assumed to cover an area of 30 ft. x 60 ft., approximately the area of a storage pad (i.e., conservatively assuming the fuel did not spread out farther in a direction parallel to the rows of storage pads), it would burn for no more than six minutes and would produced a maximum temperature of less than 1,100 °F. PFS has shown that the spent fuel storage casks to be used at the site could withstand a fire with a maximum temperature of 1,475 °F for more than 15 minutes. PFS SAR at 8.2-28. Thus, even a fuel fire resulting from an F-16 crash into the site would not cause a radioactive release.

This second conservatism in the probability risk calculation for F-16s transiting Skull Valley – the lack of sufficient speed of F-16s crashing as a result of engine failure to penetrate the casks – reinforces the first conservatism (that those F-16s will not even hit the site) discussed above. Even in the highly unlikely event that the pilot of an F-16 suffering from engine failure were unable to direct it away from the site and the plane were to strike the facility, it will not breach or cause failure of the storage casks, and would most likely not breach the CTB and any cask located inside.[10] The result, therefore, of the quantification of these two conservatisms is that it is not credible for an F-16 flying in Skull Valley that experienced an engine failure to crash into the PFSF and cause a release of radioactivity. Either it would miss the site altogether or would not cause a release even if it hit the site.

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[9] Conference with Col. Ron Fly, USAF (Ret.), October 16, 1999.

[10] See supra note 8.

Thus, as stated above, the combined calculated risk to the cask storage area and the CTB (assuming a maximum area for the cask storage area) for F-16s transiting Skull Valley is 4.96×10^{-8} per year. Other conservatisms in the PFS calculation only further reduce the risk from its already extremely low probability.

3. PFS's Revised Calculation for F-16s on the Moser Recovery Route

As set forth in PFS's August 13 calculations, a small number of the F-16s (conservatively assumed to be 5 percent of the 3,871 aircraft from Hill AFB that use the UTTR South Area per year) return to Hill AFB on the Moser Recovery Route. (August 13 submission at 35-36). These returning F-16s are in the normal operation mode and the same two conservatisms quantified for the F-16s transiting Skull Valley can similarly be quantified in the same manner with respect to the F-16 flights on the Moser Recovery Route. Therefore, consistent with the above revisions for F-16s transiting down Skull Valley, the calculated risk posed by F-16s flying the Moser Recovery Route to the cask storage area of the PFSF (assuming a maximum area for the cask storage area) can be reduced by 95 percent to 2.8×10^{-9}. The calculated risk posed to the CTB can also be reduced by 95 percent to 2.7×10^{-10} per year, and the combined calculated risk to either the storage area or the CTB is reduced to 3.1×10^{-9} per year.

4. PFS's Revised Calculation for Aircraft on the UTTR

Consistent with the above revisions, PFS has also revised its August 13 calculation of the hazard posed to the PFSF by air combat training flights on the UTTR. (August 13 submission at 22-34) PFS stated that its calculation was highly conservative in that: 1) PFS assumed that disabled aircraft would glide to and strike the PFSF without the pilot taking action to avoid it and 2) PFS assumed that the density of air operations was the same at the edge of the restricted area as in the center (i.e., PFS assumed a uniform distribution across each restricted area). In this reassessment, on the basis of information that PFS did not possess as of August 13, PFS quantifies the first of these two conservatisms to produce a somewhat more realistic, albeit still highly conservative, estimate of the crash impact hazard to the PFSF posed by operations on the UTTR. Although PFS has obtained additional information which shows that air operations at the edges of the restricted areas is substantially reduced from that in the center, it has not at this time attempted to quantify this conservatism.

First, as previously stated, an aircraft on the UTTR experiencing an engine failure would not merely crash in a random direction but rather it would glide under the control of the pilot until the pilot restarted the engine or decided to eject from the aircraft at relatively low altitude. By its very purpose, the UTTR itself presents a significant safe area to receive a descending aircraft, therefore, an aircraft experiencing an engine failure would not glide across the Cedar Mountains and to the PFSF in the middle of Skull Valley – which is off the range – and impact it while under a pilot's control. As is also the case with engine-related crashes of F-16s transiting Skull Valley, even if an aircraft from the UTTR experiencing an engine failure struck the PFSF, it would not breach and cause failure of the storage casks because of the relatively low velocity at which it would impact. Therefore, as it did for the F-16s transiting Skull Valley, PFS divides potential UTTR crashes into two categories: 1) crashes precipitated by engine failure in which the pilot will retain control over the airplane (addressed below) and 2) all other crashes, in which it is conservatively assumed that the pilot does not retain control of the aircraft (addressed as before in PFS's August 13 calculation).

Crashes caused by engine failure would not impact the site or cause a release of radioactivity even if they were to impact the site for the same reasons stated above with respect to F-16s transiting Skull Valley. U.S. Air Force data on F-16 crashes occurring in the last 10 years indicates that 44 percent of all F-16 crashes occurring during "special operations" result from engine failure. (Tab C) Therefore, those potential crashes may be excluded from the PFS air crash hazard calculation and the calculated hazard posed by air crashes on the UTTR may be reduced by 44 percent.[11]

Second, the density of air operations in the restricted areas on the UTTR is higher toward the center of the UTTR than toward the edges.[12] Thus, the expected aircraft crash rate is also higher toward the center than toward the edges. Pilots engaged in air combat training in restricted areas do not fly outside those areas and thus they conduct their high-speed, violent maneuvering toward the center of the restricted areas on the UTTR rather than at their edges.[13] While conducting training on the UTTR, pilots seldom fly within two miles of the edges of the restricted areas. On the east side of the UTTR, pilots use the Cedar Mountains as a visual reference while maneuvering to stay inside the restricted area boundaries.[14] Thus, they do not conduct high-risk maneuvers east of the Cedars (in restricted areas R-6406B and R-6402B, see August 13 submission, Tab A), which they would have to cross to reach the PFSF. Furthermore, Clover Control will provide warning calls to pilots flying within three to five miles of the range boundary to ensure that they stay inside the restricted area.[15] Finally, pilots on the UTTR also do not conduct combat training over Dugway Proving Ground (ranges R-6402A and R-6402B) because of the facilities present and the ground activities conducted there.[16] Thus, the assumption used in PFS's August 13 UTTR calculation that the density of high risk combat training

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[11] While fighter aircraft other than F-16s conduct air combat training on the UTTR, PFS applied the F-16 engine-related crash rate to all fighters to be consistent with PFS's conservative assumption in its August 13 submission that all fighters engaging in air combat training on the UTTR would crash at the more conservative F-16 rate. (See August 13 submission, Table 3).

[12] Conference with Col. Ron Fly, USAF (Ret.), October 16, 1999.

[13] Id.

[14] Id.

[15] Id.

[16] Id.

operations within each restricted area of the UTTR was uniform across the area is highly conservative.

A more realistic approach to calculating air crash hazards posed by aircraft on the UTTR would be to exclude aircraft crashes precipitated by engine failures and to assign a lower density and a lower crash rate to air operations on the edge of the restricted areas near the PFSF, i.e., inside the "cutout area," in which it was assumed, in PFS's August 13 submission, that an aircraft could experience a problem leading to a crash and impact the PFSF. (See August 13 submission at 30-31). It would also be more realistic to account for the fact that crashes not caused by engine failure are mostly caused by pilot error by assuming that aircraft crashing on the UTTR will impact the ground inside the restricted areas where they conduct their maneuvering. PFS has not attempted to quantify these effects here except to reduce the expected crash rate of aircraft by 44 percent to reflect the occurrence of engine-related crashes. Thus, more realistically, but still highly conservative, the calculated probability that an aircraft from the UTTR would crash and strike the PFSF (assuming a fully loaded facility) is equal to 1.91×10^{-7} (1.74×10^{-7} for the cask storage area and 1.68×10^{-8} for the CTB).

5. Other Air Crash Hazards

PFS has not attempted to quantify the conservatisms in its August 13 submission regarding the aircraft crash impact hazards posed by general aviation aircraft and aircraft on airways J-56, V-257 and IR-420. The calculated impact probabilities for these aircraft are already extremely low and realistically the fraction of the risk posed to the PFSF by these aircraft is immaterial. Similar to the F-16s transiting Skull Valley, a general aviation aircraft or an aircraft on an airway that experienced an engine failure would likely remain in control of the pilot, who, if the aircraft did not possess an ejection seat or parachutes, would attempt to make an emergency landing. Thus, he or she would guide the aircraft toward a suitable site, away from built up areas such as the PFSF. Likewise, for a significant portion of the crashes, particularly for general aviation, the horizontal impact velocities would be insufficient to penetrate the casks. PFS's August 13 submission did not quantify these effects and hence the actual air crash hazard probabilities for those aircraft are lower than those calculated.

6. Summary

The quantification of only some of the above conservatisms greatly reduces the calculated risk to the PFSF from aircraft crashes. As shown in the table below, quantifying these conservatisms reduces the calculated risk to the cask storage area, assuming a fully loaded facility, from 1.31×10^{-6} to 2.59×10^{-7} and reduces the calculated risk to the canister transfer building from 1.26×10^{-7} to 2.61×10^{-8}, for a total aircraft crash calculated risk to the facility of 2.85×10^{-7}.

Calculated Aircraft Crash Impact Probabilities		
Aircraft	**Peak Probability**	
	Cask Storage Area	**Canister Transfer Building**
Skull Valley F-16s	3.92 to 4.63×10^{-8} (Kimura) 4.53×10^{-8} (NUREG)	3.7 to 4.4×10^{-9} (Kimura) 4.29×10^{-9} (NUREG)
Aircraft Using the Moser Recovery	1.2×10^{-9} (Kimura) 2.8×10^{-9} (NUREG)	1.2×10^{-10} (Kimura) 2.7×10^{-10} (NUREG)
UTTR Aircraft	1.74×10^{-7}	1.68×10^{-8}
Aircraft on Airway J-56	1.63×10^{-8}	2.2×10^{-9}
Aircraft on Airway V-257	1.03×10^{-8}	1.4×10^{-9}
General Aviation Aircraft	7.8×10^{-9}	7.1×10^{-10}
Aircraft on Airway IR-420	2.5×10^{-9}	3.9×10^{-10}
Cumulative Probability	2.59×10^{-7} (NUREG)	2.61×10^{-8} (NUREG)

In addition, there remain numerous other, yet unquantified, conservatisms in the calculation such that the realistic risk to the facility is less than 10^{-7}, even with a fully loaded facility. Some of the major yet unquantified conservatisms include the following.

- The calculated probabilities conservatively assume that all crashes not precipitated by engine failure result in the aircraft going out of control and striking the ground randomly within the glide range of the aircraft from the point at which the precipitating event occurred. This is particularly conservative with respect to crashes of aircraft training on the UTTR, in that the cause of such a crash, if it were not engine failure, would likely be pilot error (see Tab A), which would most likely result in a ground impact inside the range restricted area where the aircraft was maneuvering.

- The calculated probabilities also conservatively assume that all crash impacts not precipitated by an engine failure (on the UTTR or otherwise) occur at high velocity and at an angle nearly perpendicular to the side of a cask or the wall of the CTB such that penetration of the storage cask and/or the CTB would occur.

- The calculated probability for UTTR aircraft assumes that the density of high risk air combat training operations is the same at the edge of the restricted area as in the center (i.e., PFS assumed a uniform distribution across each restricted area sector), which is highly conservative based on new additional information that PFS has received.

- The calculated probability for the F-16s transiting Skull Valley assumes that the F-16s are evenly distributed across the valley rather than concentrated toward the eastern side, where their predominant route of flight is located.

A further conservatism in the above risk numbers is that they are for a fully loaded facility, which would be the situation for only a short period of time. The annual calculated risk would be less for virtually the entire life of the facility, even assuming full use of its licensed capacity, and on average over the expected 40 year life of the facility the calculated risk would be approximately 1.6×10^{-7} per year.

In short, the bottom line is that the calculated risk for the facility is well below the regulatory standard as defined by the Commission of 1×10^{-6} per year even for the worst case fully loaded cask storage area.

III. INDEPENDENT TREATMENT OF THE CANISTER TRANSFER BUILDING AND THE CASK STORAGE AREA

NRC Comment 3 – The NRC raised questions about PFS's analyzing the air crash impact hazards for the cask storage area and the canister transfer building independently and requested PFS to provide further justification for such independent treatment or for PFS to alternatively treat the cask storage area and the canister transfer building together.

PFS Response

PFS presented the probabilities that an aircraft crash would impact the PFSF cask storage area and the canister transfer building (CTB) separately in its August 13 submission to facilitate the treatment of analytical factors that may affect the two facilities differently (e.g., the likelihood of penetration). In fact, the cumulative probability that an aircraft crash would impact either the cask storage area or the CTB is equal to the sum of the probabilities that an aircraft would impact each facility individually, minus the probability that an aircraft would impact both facilities at once. In these responses, PFS presents the sum of the probabilities that each facility would be struck and penetrated individually. The likelihood that an aircraft crash would affect both facilities at once is low and represents a small conservatism for which PFS does not take credit and has not calculated.

IV. THE EFFECT OF ORDNANCE CARRIED BY F-16S

NRC Comment 4 – In light of its above questions, the NRC also questioned the overall likelihood of an air craft crash impacting the PFSF, and the NRC requested PFS, should it be unable to show the lack of any credible hazard from aircraft crashes, to identify the type and quantity of live ordnance carried by F-16s flying down Skull Valley and assess the potential consequences of an F-16 carrying live ordnance crashing at or nearby the PFSF. Also, to further support the Air Force's statement of no inadvertent release of ordnance, the NRC requested PFS to show, if possible, how many flights on the UTTR have taken place without an inadvertent release of ordnance.

PFS Response

A. Inadvertent Ordnance Releases from Non-Crashing Aircraft

In response to an 18 December 1998, FOIA request, the U.S. Air Force specifically stated that " No aircraft flying over Skull Valley are allowed to have their armament switches in a release capable mode. All switches are "SAFE" until inside DOD land boundaries. The UTTR has not experienced an unanticipated munitions release outside of designated launch/drop/shoot boxes." (Tab G) During FY 1998 there were 13,367 total sorties in the UTTR with 5,083 in the North and 8,284 in the South. In earlier years, during the Cold War, the sortie rate was higher; e.g., 27,000 sorties were flown on the UTTR in FY1988.[17] All were accomplished with obviously no inadvertent munitions releases outside of designated launch/drop/shoot boxes. Consequently, an inadvertent weapons release impacting or affecting the PFSF is not a credible event and it is reasonable to assign a subjective probability of zero to such an event.

[17] Preliminary Draft Environmental Impact Study, Electronic Combat Test Capability Utah Test and Training Range, United States Air Force (July 1989), at 4.11-27.

B. Ordnance from Crashing Aircraft

Based on the calculations set forth in response to Comment 2, it is clear that the potential risk of radiological accidents at the PFSF caused by aircraft crashes is well below the regulatory standard of 1×10^{-6} per year. Therefore, they do not pose a credible hazard to the PFSF. Accordingly, PFS is not required to assess the potential consequences of an F-16 carrying live ordnance crashing at or nearby the PFSF. Nevertheless, to provide further conservatism, PFS intends to analyze the potential for impacts of ordnance at the PFSF once PFS receives information in response to its Freedom of Information Act request concerning the type and numbers of ordnance carried by F-16s transiting Skull Valley.

V. AIRCRAFT IMPACT VELOCITY

NRC Comment 5 – The NRC raised questions about the speeds at which crashing aircraft would impact the spent fuel storage casks and requested PFS to clarify and further address, if possible, this issue.

PFS Response

In its August 13 submission, PFS did not incorporate into its probability calculations the effect of aircraft impact velocity on the likelihood that an aircraft impact would cause a radioactive release from the PFSF. PFS, however, did calculate the velocity at which an F-16 would have to impact a spent fuel storage cask in order to penetrate it and compared this calculated penetration velocity to the velocity at which F-16s transit Skull Valley to show that the PFS probability calculation was highly conservative, in that a significant fraction of the F-16s would not penetrate a cask even if they did impact it. (August 13 submission, Tab H). In these responses, PFS has addressed this issue further and has quantitatively shown that the physical protection provided by the spent fuel storage casks and the CTB is indeed significant considering the velocities at which crashing aircraft would hit the PFSF.

Specifically, based on the U.S. Air Force data (Tab C), 95% percent of the crashes involving F-16s while transiting Skull Valley or returning to Hill AFB via the Moser Recovery Route would be caused by engine failure. As indicated in PFS's response to Comment 2, in the event of an engine failure, the pilot would pull up to gain altitude and decrease airspeed; jettison external ordnance and stores, if applicable; and attempt an airstart, if feasible. (See also Tab A). During this process, the aircraft's airspeed would decrease to approximately 170 KIAS to 210 KIAS. Since performing an engine out landing in Skull Valley is an unattractive and unlikely option, the pilot will most likely slow toward 170 KIAS maximum endurance airspeed in preparation for ejection. After the pilot ejects, the F-16 flight control computer would keep the aircraft relatively stable in wings level 1 G flight as it slowly loses altitude and settles straight ahead. (Tab A). Thus, the aircraft's ground impact velocity would be in the 170 KIAS to 210 KIAS range (approximately 185 to 230 kts true airspeed) – significantly less than the 340 knots perpendicular velocity necessary to penetrate a storage cask. (August 13 submission, Tab H) Further, as set forth in PFS's response to Comment 2, even if the flight computer did not maintain the attitude of the aircraft, the crash impact velocity from a glide at 2,000 ft. AGL, the point of pilot ejection, would not be significantly higher than 210 KIAS[18] and would remain substantially less than the 340 knots perpendicular velocity necessary to penetrate a storage cask. Therefore, an F-16 crashing into a cask at these relatively low airspeeds would not be sufficient to cause a release of radioactivity.[19]

Thus, 95% of all crashes of F-16s transiting Skull Valley or returning to Hill AFB via the Moser Recovery Route would have impact velocities insufficient to penetrate the storage casks and to cause the release of radiation. Similarly, as set forth in PFS's response to Comment 2, at least 44% of the UTTR crashes potentially affecting the PFSF would be attributable to engine failure and would likewise have impact velocities insufficient to penetrate the storage casks and to cause a release of radiation.

In addition to the foregoing, the spent fuel storage casks and CTB would also provide substantial physical protection against many other aircraft crashes which makes PFS's crash risk calculation conservative. This would include other crashes that impact the storage casks at velocities less than 340 knots as well as many higher speed impacts. While a high speed impact greater than 340 knots directly perpendicular to a cask could

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[18] As set forth in the response to Comment 2, data in the DOE ACRAM Data Development Technical Support Document shows that 95 percent of the crashes of small military aircraft (which includes the F-16) on takeoff and landing (which would be analogous to the F-16 crash-after-glide scenario considered here) would have a horizontal impact velocity of less than 237 knots (true airspeed). (Tab D)

[19] An F-16 crash into the CTB at these relatively low velocities would also not penetrate both the CTB walls and a spent fuel storage cask. See supra note 8.

penetrate it, an impact at an angle or a glancing impact may well not have sufficient perpendicular velocity to do so. For example, an aircraft impacting a cask at an angle of 30 degrees from the vertical would have a horizontal velocity half that of an aircraft impacting perpendicular to the side of the cask ($\sin(30^\circ) = 0.5$) and thus would require an impact velocity of 680 knots to penetrate the cask. This effect reduces the already extremely low risk to the PFSF from potential high-speed F-16 crashes. And it reduces even further the impact hazard posed by crashes of commercial airliners and general aviation aircraft, in that such aircraft do not fly as fast as F-16s. PFS's air crash hazard calculation is thus conservative in that it does not reflect the substantial reductions in risk provided by the storage casks against crash impacts (other than those attributable to F-16 engine failure).

Tab A

Memorandum Concerning the Private Fuel Service October 21, 1999

This memorandum was written in response to questions posed during an October 19th phone call with representatives of the Shaw Pittman law firm. Most of this material was covered during a meeting the weekend prior in Washington, DC.

Please state your personal qualifications with respect to the F-16 and the Utah Test and Training Range.

I am a command pilot with approximately 2,800 hours of total flying time of which more than 1,250 hours were in the F-16. I had two assignments as a formal course F-16 instructor pilot where my primary duty was to teach other pilots how to fly the F-16. I have flown a variety of fighter aircraft, starting with the F-4 in 1975. I have also flown the F-5 and AT-38. I first flew the F-16 in 1981 at MacDill AFB, FL and last flew it in 1998 at Hill AFB, UT. During my assignment at Hill AFB I was the commander of the 388th Fighter Wing and the Utah Test and Training Range.

In your opinion, please state the most likely causes of F-16 accidents.

I would place the causes of F-16 accidents into two major categories, pilot error and material failure.

Those involving pilot error normally occur during high demand phases of flight. For example, air-to-air combat training where closure rates can be in excess of 1,200 knots (over 2,000 feet per second), the situation is very fluid and changes rapidly. The pilots may be maneuvering very aggressively, often at very high G loads. The low altitude environment (500' above ground level) and air-to-ground bombing patterns can also be very unforgiving due to the close proximity to the ground and planned maneuvers to increase the effectiveness of the bombs and reduce the exposure time to enemy weapons. The margin for error goes down with the aircraft's altitude and inversely with the aircraft's speed. In addition, a number of accidents have occurred during takeoff and landing.

With respect to material failure, engine related accidents are by far the leading cause of F-16 accidents. Other accidents caused by material failure are infrequent enough that I do not believe any of them would be of sufficient number to be categorized as a group.

Describe a pilots actions in the event of an engine failure when operating below 5,000' AGL.

F-16 pilots are trained to follow Critical Action Procedures (CAPs) in the event of low altitude (below 5,000') engine failure. The first two steps are 1) Zoom 2) Stores Jettison.

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Zoom. The pilot will initiate a climb to either 30⁰ nose high or 250KIAS, whichever comes first. This serves two purposes; first, it gets the pilot and aircraft away from the ground, and second, it trades airspeed for altitude which gives the pilot more time to analyze the situation and take appropriate actions.. At 250KIAS the pilot will initiate a push over maneuver to establish a slightly nose low attitude and maintain approximately 210KIAS while he accomplishes other steps to help restart the engine and look for a place to land. If he is successful in starting the JFS (jet fuel starter) the pilot will slow to approximately 170KIAS (maximum endurance airspeed) to increase his time aloft.

Stores Jettison. The pilot pushes the Emergency Stores Jettison button (commonly known as the panic button) to jettison external stores. This sends a signal through the jettison circuitry which will energize all installed jettison cartridges causing the stores to separate from the aircraft. Although individual F-16 unit commanders have some authority to choose which stations have ejection cartridges (normally referred to as "carted"), the following items are generally carted: external fuel tanks, heavy weight bombs (real or concrete). Practice bombs such as the 25 pound BDU-33 and the suspension equipment upon which they are stored are not normally carted.

The pilot will go through a series of steps in an attempt to restart the engine. In addition, he will maneuver for a flame out landing if a suitable airstrip is available. In the event the pilot can not restart the engine or maneuver for a landing, he will eject at a minimum altitude of 2,000' AGL in accordance with published directives. If time and circumstances permit, the pilot can be expected to point the aircraft toward an uninhabited area prior to ejection.

If live ordnance (real bombs) are jettisoned, they separate from the airplane in a "safe" condition. The fuse does not arm and the bomb should not explode upon impact.

What normally happens to the aircraft if the pilot ejects after an engine failure.

The aircraft will continue to fly until ground impact. Normal ejection conditions would be at 2,000' with airspeed in the 170-210KIAS range, depending on whether the JFS started and how precise the pilot was with airspeed control under stressful conditions. If the airplane was in a normal, trimmed condition it will continue to go straight ahead and maintain slow speed flight with a shallow descent gradient until impact.

Due to the relatively low speed and shallow descent angle at impact, the aircraft normally remains essentially intact.

How do F-16s use the airspace above Skull Valley?

F-16s use it primarily as a transition corridor to the South UTTR. Typically F-16s will start a descent into the low altitude arena (below 5,000'), if that's part of the mission, and spread out in a tactical formation which may be 2-3 nautical miles across and several miles deep. Formations vary depending upon the number of aircraft in the flight, meteorological

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conditions, mission objectives, etc. In addition, they may accelerate to above 400KIAS and perform two 90° G Awareness turns. Typical maneuvering in Skull Valley is in the administrative and routine categories, both of which are low risk phases of flight.

Ronald E. ~~Fly, Colonel~~ USAF (Retired)

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Tab B

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR COMBAT COMMAND
LANGLEY AIR FORCE BASE, VIRGINIA

15 Oct 99

MEMORANDUM FOR BGEN JACK COLE, USAF (RET.)

FROM: HQ ACC/SE
175 Sweeney Blvd
Langley AFB VA 23665-2700

SUBJECT: G-Awareness Turns and Low Level Flying

Sir

I spoke with my flight guys and they agree that G Awareness turns are not high risk, but merely a warm-up exercise to check your equipment and body tolerance for that particular day. These are normal operations accomplished before range entry.

Also, low level flying at 500 feet or above (except for obstacles and birds) is not generally considered high risk. There are good low-level step-down training programs to ensure a pilot does not fly at a low altitude until he/she is ready. The lower a pilot flies, of course, the more demanding the mission, but 500 feet is not too tough...I've flown at 500 feet many times and never broke a sweat. Obstacles and birds do require more vigilance, and flying low is higher risk in war due to modern air defense weaponry. In addition to my duties as Air Combat Command Chief of Safety, I currently fly F-16CJs at Shaw AFB, SC.

If you need more information, please don't hesitate to call.

Greg Alston

GREG ALSTON, Colonel, USAF
Chief of Safety

Tab C

Probability of an F-16 Crash Being Caused by Engine Failure

PFS has calculated the fraction of F-16 crashes caused by engine failure in normal and special operations (as defined in the ACRAM study) based on F-16 engine related failure data that PFS has recently received from the U.S. Air Force following the August 13, 1999 submittal to the NRC. See Attached Data . The calculation has been performed using the data for the period of 1989 to 1998, the same period PFS used to calculate the overall crash rate for the F-16 (August 13 submission at 12).

In the 10 years from 1989 to 1998, the F-16 experienced 142 Class A mishaps. (August 13 submission, Table 1). Based on the data received from the U.S. Air Force Safety Center and Air Combat Command, of the 142 Class A mishaps, 64 were "engine related," i.e., caused by a loss of engine thrust. See Attached Data .

Analysis of the attached Air Force data concerning the 64 F-16 crashes precipitated by engine failures for fiscal years 1989 to 1998 shows that engine-related Class A mishaps in "normal" flight operations totaled 21. Engine-related mishaps in "special" flight operations totaled 31 while the remaining 12 occurred on takeoff, landing, or on the ground. Consistent with the definitions used in the ACRAM Data Development Document (pp. 4-4 to 4-5, 5-4 to 5-6), where "normal" flight operations are defined to include the "Climb to Cruise," "Cruise," and "Cruise Descent" phases of flight, the analysis assigned engine failures identified as occurring during those phases of flight to the "normal" category. Engine related failures identified as occurring during the "Cruise Maneuvering" and "Cruise Low Level" phases of flight, which the attached data identify as involving activities that occur on Restricted area ranges such as Basic Fighter Maneuvers, Air Combat Tactics, attacks, close air support, and Dissimilar Air Combat Training, were assigned to "special operations."

To determine the fraction of crashes that were precipitated by engine failure for each phase of flight (normal or special operations), PFS compared the totals above to the total number of F-16 Class A mishaps that occurred in normal flight, special operations, and on takeoff or landing from 1989 to 1998. According to the ACRAM Data Development Document, the F-16 experienced 212 crashes as of 1993 (pp. 4-12 to 4-13). Thirty two crashes occurred during "normal" flight (15 percent), 104 crashes occurred during "special operations" (49 percent), and the remaining 76 crashes occurred on takeoff or landing (36 percent). Applying these percentages to the 142 crashes that occurred between 1989 and 1998, 21 crashes occurred during normal flight, 70 occurred during special operations, and 51 occurred on takeoff or landing. Comparing the engine-related crashes to the overall Air Force crash data, 21 out of 21 crashes in normal flight were engine-related (100 percent), 31 out of 70 crashes in special operations were engine-related (44 percent), and 12 out of 51 crashes on takeoff or landing were engine-related (24 percent). This data is summarized in the table below.

F-16 Class A Mishaps
FY 1989 – FY 1998
(1 Oct 88 through 30 Sep 98)

Total Class A Mishaps	Engine Related Class A Mishaps	Engine Related Class A Mishaps in Takeoff/Approach/ Landing Operations	Engine Related Class A Mishaps in "Normal" Flight Operations	Engine Related Class A Mishaps in "Special" Flight Operations
142	64	12	21	31

Although the data indicate that 100 percent of the F-16 crashes in normal flight from 1989 to 1998 were caused by engine failure, PFS has conservatively assumed (on the basis that hypothetically a crash could be caused by something other than engine failure) that 95 percent of the potential crashes in Skull Valley (normal flight) would be engine-related. PFS has taken directly from the calculation above (since the UTTR data already include a significant number of non-engine related crashes) that 44 percent of the potential crashes on the UTTR (special operations) would be engine-related.

Category	*Cls*	*Cmd*	*Accountable Command*
Operations	A	AFE	US AIR FORCES IN EUROPE
Logistics	A	AFE	US AIR FORCES IN EUROPE
Logistics	A	AFE	US AIR FORCES IN EUROPE
Logistics	A	AET	AIR EDUCATION & TRAINING COMMAND
Logistics	A	AET	AIR EDUCATION & TRAINING COMMAND
Logistics	A	AET	AIR EDUCATION & TRAINING COMMAND
Logistics	A	AET	AIR EDUCATION & TRAINING COMMAND
Logistics	A	AET	AIR EDUCATION & TRAINING COMMAND
Logistics	A	ANG	AIR NATIONAL GUARD
Logistics	A	PAF	PACIFIC AIR FORCES
Logistics	A	MTC	AIR FORCE MATERIEL COMMAND
Operations	A	TAC	
Logistics	A	TAC	
Operations	A	LOG	
Logistics	A	ANG	AIR NATIONAL GUARD
Logistics	A	ANG	AIR NATIONAL GUARD
Logistics	A	PAF	PACIFIC AIR FORCES
Logistics	A	MTC	AIR FORCE MATERIEL COMMAND
Logistics	A	AFE	US AIR FORCES IN EUROPE
Logistics	A	PAF	PACIFIC AIR FORCES
Logistics	A	TAC	
Logistics	A	TAC	
Operations	A	TAC	
Logistics	A	TAC	
Logistics	A	TAC	
Logistics	A	TAC	
Logistics	A	TAC	
Logistics	A	TAC	
Logistics	A	TAC	
Logistics	A	ANG	AIR NATIONAL GUARD
Logistics	A	AFE	US AIR FORCES IN EUROPE
Logistics	A	TAC	
Logistics	A	TAC	
Logistics	A	TAC	
Logistics	A	TAC	
Logistics	A	AFE	US AIR FORCES IN EUROPE
Logistics	A	TAC	
Logistics	A	TAC	
Logistics	A	PAF	PACIFIC AIR FORCES
Logistics	A	ACC	AIR COMBAT COMMAND
Logistics	A	TAC	
Operations	A	ANG	AIR NATIONAL GUARD
Logistics	A	PAF	PACIFIC AIR FORCES
Logistics	A	ANG	AIR NATIONAL GUARD
Logistics	A	TAC	
Logistics	A	ANG	AIR NATIONAL GUARD
Operations	A	ANG	AIR NATIONAL GUARD
Logistics	A	ANG	AIR NATIONAL GUARD

Logistics	A	ANG	AIR NATIONAL GUARD
Logistics	A	AFE	US AIR FORCES IN EUROPE
Logistics	A	ANG	AIR NATIONAL GUARD
Logistics	A	AFR	HQ AIR FORCE RESERVE
Logistics	A	ACC	AIR COMBAT COMMAND
Logistics	A	PAF	PACIFIC AIR FORCES
Logistics	A	TAC	
Logistics	A	PAF	PACIFIC AIR FORCES
Logistics	A	TAC	
Logistics	A	ANG	AIR NATIONAL GUARD
Maintenance	A	ACC	AIR COMBAT COMMAND
Logistics	A	ACC	AIR COMBAT COMMAND
Maintenance	A	ACC	AIR COMBAT COMMAND
Logistics	A	ANG	AIR NATIONAL GUARD
Maintenance	A	ANG	AIR NATIONAL GUARD
Logistics	A	AFE	US AIR FORCES IN EUROPE
Logistics	A	TAC	
Logistics	A	TAC	
Logistics	A	ANG	AIR NATIONAL GUARD
Logistics	A	AFE	US AIR FORCES IN EUROPE
Logistics	A	ACC	AIR COMBAT COMMAND
Logistics	A	ACC	AIR COMBAT COMMAND
Operations	A	ANG	AIR NATIONAL GUARD
Logistics	A	ANG	AIR NATIONAL GUARD
Logistics	A	ANG	AIR NATIONAL GUARD
Logistics	A	ANG	AIR NATIONAL GUARD
Logistics	A	ANG	AIR NATIONAL GUARD
Logistics	A	ACC	AIR COMBAT COMMAND
Logistics	A	TAC	
Logistics	A	ACC	AIR COMBAT COMMAND
Logistics	A	PAF	PACIFIC AIR FORCES
Logistics	A	AFE	US AIR FORCES IN EUROPE
Logistics	A	TAC	
Logistics	A	TAC	
Logistics	A	AFE	US AIR FORCES IN EUROPE
Logistics	A	ANG	AIR NATIONAL GUARD
Logistics	A	AFR	HQ AIR FORCE RESERVE
Logistics	A	TAC	
Logistics	A	AFE	US AIR FORCES IN EUROPE
Operations	A	ACC	AIR COMBAT COMMAND
Operations	A	TAC	
Logistics	A	TAC	
Logistics	A	PAF	PACIFIC AIR FORCES
Logistics	A	ACC	AIR COMBAT COMMAND
Logistics	A	TAC	
Logistics	A	TAC	
Logistics	A	SYS	
Logistics	A	SYS	
Logistics	A	ACC	AIR COMBAT COMMAND

Logistics	A	ANG	AIR NATIONAL GUARD
Logistics	A	ANG	AIR NATIONAL GUARD
Logistics	A	AFE	US AIR FORCES IN EUROPE
Logistics	A	ACC	AIR COMBAT COMMAND
Logistics	A	ACC	AIR COMBAT COMMAND
Logistics	A	AET	AIR EDUCATION & TRAINING COMMAND
Logistics	A	AFR	HQ AIR FORCE RESERVE
Logistics	A	TAC	
Logistics	A	TAC	
Logistics	A	TAC	
Logistics	A	TAC	
Logistics	A	ANG	AIR NATIONAL GUARD
Logistics	A	AFE	US AIR FORCES IN EUROPE
Logistics	A	TAC	
Logistics	A	TAC	
Logistics	A	AFE	US AIR FORCES IN EUROPE
Logistics	A	AET	AIR EDUCATION & TRAINING COMMAND
Operations	A	TAC	
Logistics	A	TAC	

Evt Cost Af Dmg SUM	Evt Date	Day/Night	Dstr Ind	FY	Mds Acct
17430866	08-OCT-1993	Day	+	1994	F016C
11300000	27-AUG-1987	Day	+	1987	F016D
2406523	16-FEB-1994	Day		1994	F016C
15000000	21-AUG-1995	Day	+	1995	F016C
15000000	21-DEC-1995	Day	+	1996	F016C
16200000	29-JAN-1997	Day	+	1997	F016C
19644343	26-MAR-1999	Day	+	1999	F016C
19302385	03-FEB-1999	Day	+	1999	F016C
18911921	18-JUN-1999	Day	+	1999	F016D
8201000	24-JAN-1984	Night	+	1984	F016A
13402000	22-AUG-1997	Day	+	1997	F016B
12738024	09-AUG-1979	Day	+	1979	F016B
8161000	04-MAY-1982	Day	+	1982	F016A
8557009	16-MAR-1990	Day	+	1990	F016A
8201000	08-JUN-1991	Day	+	1991	F016B
9497000	21-APR-1993	Day	+	1993	F016A
9107325	22-MAR-1987	Day	+	1987	F016A
8201000	30-OCT-1992	Day	+	1993	F016A
11800000	12-OCT-1988	Day	+	1989	F016C
10300000	30-JAN-1989	Day	+	1989	F016C
7541518	25-JUN-1980	Day	+	1980	F016A
8201000	18-NOV-1983	Day	+	1984	F016A
8201000	16-AUG-1989	Day	+	1989	F016A
8161000	08-JUN-1982	Day	+	1982	F016A
8201000	01-MAY-1984	Day	+	1984	F016A
10592000	25-JUL-1988	Day	+	1988	F016C
8201000	25-JUL-1983	Day	+	1983	F016B
8089714	11-FEB-1985	Day	+	1985	F016A
13711544	24-APR-1992	Day	+	1992	F016C
8201000	27-NOV-1991	Day	+	1992	F016A
8161000	20-JAN-1983	Day	+	1983	F016A
738450	17-FEB-1987	Day		1987	F016A
9557021	22-JUN-1987	Day	+	1987	F016A
1258543	29-NOV-1988	Day		1989	F016A
8201000	17-NOV-1989	Day	+	1990	F016A
8201000	17-DEC-1987	Day	+	1988	F016A
8254860	11-SEP-1986	Day	+	1986	F016A
11133000	13-SEP-1988	Day	+	1988	F016C
10500000	03-APR-1990	Day	+	1990	F016C
15962000	02-FEB-1994	Day	+	1994	F016C
7525570	23-JUL-1980	Day	+	1980	F016B
8201000	11-MAR-1988	Day	+	1988	F016A
10500000	26-DEC-1989	Day	+	1990	F016C
12299072	19-FEB-1993	Day	+	1993	F016A
8161000	27-MAR-1981	Day	+	1981	F016B
11087639	13-JUL-1995	Day	+	1995	F016A
8201000	26-JAN-1991	Day	+	1991	F016A
15000000	07-FEB-1994	Day	+	1994	F016C

17281564	07-JUN-1996	Day	+	1996	F016C
14526757	22-OCT-1992	Day	+	1993	F016C
8201000	31-AUG-1992	Day	+	1992	F016A
9767750	21-MAY-1992	Day	+	1992	F016A
13167890	01-SEP-1992	Day	+	1992	F016C
13710000	07-MAY-1991	Night	+	1991	F016C
13700000	20-SEP-1990	Day	+	1990	F016D
21465309	24-AUG-1998	Day	+	1998	F016C
8161000	20-MAY-1982	Day	+	1982	F016A
1388888	05-MAY-1992	Day		1992	F016A
12000000	23-FEB-1993	Night	+	1993	F016C
16200000	12-MAY-1997	Day	+	1997	F016C
20000000	08-JAN-1998	Day	+	1998	F016C
24067755	05-FEB-1995	Day	+	1995	F016C
17281564	09-NOV-1993	Day	+	1994	F016C
16172319	18-OCT-1988	Day	+	1989	F016C
12540000	26-MAR-1980	Day	+	1980	F016A
13710000	16-DEC-1991	Dusk	+	1992	F016C
8390000	27-AUG-1993	Day	+	1993	F016A
13100000	18-APR-1988	Day	+	1988	F016C
19200000	25-OCT-1994	Day	+	1995	F016C
19500000	11-JUL-1996	Day	+	1996	F016C
16462700	20-JAN-1996	Day	+	1996	F016C
16575053	17-NOV-1998	Day	+	1999	F016C
8201000	11-SEP-1993	Day	+	1993	F016A
16200000	19-MAR-1996	Day	+	1996	F016C
13300000	21-NOV-1996	Night	+	1997	F016A
23109226	19-NOV-1998	Day	+	1999	F016C
14171922	31-MAY-1992	Day	+	1992	F016C
16200000	03-AUG-1996	Day	+	1996	F016C
10554000	02-SEP-1988	Day	+	1988	F016C
14501000	17-SEP-1987	Day	+	1987	F016C
8201000	20-MAY-1988	Day	+	1988	F016A
10464628	03-SEP-1990	Day	+	1990	F016C
16172319	29-JUN-1988	Day	+	1988	F016C
8603484	13-JAN-1991	Day	+	1991	F016A
9179356	02-OCT-1986	Day	+	1987	F016A
14406565	17-FEB-1991	Dusk	+	1991	F016C
14547990	11-AUG-1993	Day	+	1993	F016C
17000000	27-OCT-1992	Day	+	1993	F016C
884785	06-APR-1981	Day		1981	F016A
13700110	07-AUG-1990	Day	+	1990	F016D
14060000	17-JUL-1991	Day	+	1991	F016D
18962745	12-JUL-1999	Day	+	1999	F016C
8201000	27-APR-1986	Day	+	1986	F016A
13085000	28-JAN-1991	Day	+	1991	F016C
8161000	23-MAR-1982	Day	+	1982	F016B
253000	24-JUN-1976	Day	+	1976	YF016A
18917099	22-JUL-1998	Day	+	1998	F016C

8201000	15-MAY-1995	Day	+	1995	F016B
17281564	25-JUN-1995	Day	+	1995	F016C
23500000	13-JAN-1995	Day	+	1995	F016D
16200000	21-APR-1997	Day	+	1997	F016C
18578731	04-DEC-1998	Day	+	1999	F016D
22776045	07-JAN-1999	Day	+	1999	F016D
16238033	04-FEB-1997	Night	+	1997	F016D
8201000	11-JUL-1983	Day	+	1983	F016B
8326360	27-FEB-1986	Day	+	1986	F016A
8201000	19-JUN-1984	Day	+	1984	F016A
8161000	16-JUN-1982	Day	+	1982	F016A
8201000	07-FEB-1985	Day	+	1985	F016A
8201000	30-JUL-1985	Day	+	1985	F016A
8201000	10-FEB-1988	Day	+	1988	F016A
10606192	25-JUL-1987	Day	+	1987	F016C
18846153	20-FEB-1991	Day	+	1991	F016C
16380042	15-DEC-1998	Day	+	1999	F016C
11925316	11-FEB-1986	Day	+	1986	F016C
30245	19-JAN-1983	Day		1983	F016A

Type Mishap 1	*Owning Command*
PILOT INDUCED ENGINE MALFUNCTIONS.	US AIR FORCES IN EUROPE
ENGINE FAILURES.	US AIR FORCES IN EUROPE
ENGINE FAILURES.	US AIR FORCES IN EUROPE
ENGINE FAILURES.	AIR EDUCATION & TRAINING COMMAND
ENGINE FAILURES.	AIR EDUCATION & TRAINING COMMAND
ENGINE FAILURES.	AIR EDUCATION & TRAINING COMMAND
ENGINE FAILURES.	AIR EDUCATION & TRAINING COMMAND
ENGINE FAILURES.	AIR EDUCATION & TRAINING COMMAND
ENGINE FAILURES.	AIR NATIONAL GUARD
ENGINE FAILURES.	PACIFIC AIR FORCES
ENGINE FAILURES.	AIR FORCE MATERIEL COMMAND
PILOT INDUCED ENGINE MALFUNCTIONS.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
PILOT INDUCED ENGINE MALFUNCTIONS.	AIR FORCE LOGISTICS COMMAND
AIRCRAFT FUEL SYSTEM.	AIR NATIONAL GUARD
ENGINE FAILURES.	AIR NATIONAL GUARD
ENGINE FAILURES.	PACIFIC AIR FORCES
AIRCRAFT FUEL SYSTEM.	AIR FORCE MATERIEL COMMAND
ENGINE FAILURES.	US AIR FORCES IN EUROPE
ENGINE FAILURES.	PACIFIC AIR FORCES
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
PILOT INDUCED ENGINE MALFUNCTIONS.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	AIR NATIONAL GUARD
ENGINE FAILURES.	US AIR FORCES IN EUROPE
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	US AIR FORCES IN EUROPE
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	PACIFIC AIR FORCES
ENGINE FAILURES.	AIR COMBAT COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
PILOT INDUCED ENGINE MALFUNCTIONS.	AIR NATIONAL GUARD
ENGINE FAILURES.	PACIFIC AIR FORCES
ENGINE FAILURES.	AIR NATIONAL GUARD
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	AIR NATIONAL GUARD
PILOT INDUCED ENGINE MALFUNCTIONS.	AIR NATIONAL GUARD
ENGINE FAILURES.	AIR NATIONAL GUARD

ENGINE FAILURES.	AIR NATIONAL GUARD
AIRCRAFT FUEL SYSTEM.	US AIR FORCES IN EUROPE
ENGINE FAILURES.	AIR NATIONAL GUARD
ENGINE FAILURES.	HQ AIR FORCE RESERVE
ENGINE FAILURES.	AIR COMBAT COMMAND
ENGINE FAILURES.	PACIFIC AIR FORCES
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	PACIFIC AIR FORCES
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	AIR NATIONAL GUARD
ENGINE FAILURES.	AIR COMBAT COMMAND
ENGINE FAILURES.	AIR COMBAT COMMAND
ENGINE FAILURES.	AIR COMBAT COMMAND
ENGINE FAILURES.	AIR NATIONAL GUARD
ENGINE FAILURES.	AIR NATIONAL GUARD
AIRCRAFT FUEL SYSTEM.	US AIR FORCES IN EUROPE
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
AIRCRAFT FUEL SYSTEM.	AIR NATIONAL GUARD
ENGINE FAILURES.	US AIR FORCES IN EUROPE
ENGINE FAILURES.	AIR COMBAT COMMAND
ENGINE FAILURES.	AIR COMBAT COMMAND
PILOT INDUCED ENGINE MALFUNCTIONS.	AIR NATIONAL GUARD
ENGINE FAILURES.	AIR NATIONAL GUARD
ENGINE FAILURES.	AIR NATIONAL GUARD
ENGINE FAILURES.	AIR NATIONAL GUARD
ENGINE FAILURES.	AIR NATIONAL GUARD
ENGINE FAILURES.	PACIFIC AIR FORCES
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	AIR COMBAT COMMAND
ENGINE FAILURES.	PACIFIC AIR FORCES
ENGINE FAILURES.	US AIR FORCES IN EUROPE
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	US AIR FORCES IN EUROPE
ENGINE FAILURES.	AIR NATIONAL GUARD
ENGINE FAILURES.	HQ AIR FORCE RESERVE
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	US AIR FORCES IN EUROPE
PILOT INDUCED ENGINE MALFUNCTIONS.	AIR COMBAT COMMAND
PILOT INDUCED ENGINE MALFUNCTIONS.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	PACIFIC AIR FORCES
ENGINE FAILURES.	AIR COMBAT COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	AIR FORCE SYSTEMS COMMAND
ENGINE FAILURES.	AIR FORCE SYSTEMS COMMAND
ENGINE FAILURES.	AIR COMBAT COMMAND

ENGINE FAILURES.	AIR NATIONAL GUARD
ENGINE FAILURES.	AIR NATIONAL GUARD
ENGINE FAILURES.	US AIR FORCES IN EUROPE
ENGINE FAILURES.	AIR COMBAT COMMAND
ENGINE FAILURES.	AIR COMBAT COMMAND
ENGINE FAILURES.	AIR EDUCATION & TRAINING COMMAND
ENGINE FAILURES.	HQ AIR FORCE RESERVE
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	AIR NATIONAL GUARD
ENGINE FAILURES.	US AIR FORCES IN EUROPE
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND
ENGINE FAILURES.	US AIR FORCES IN EUROPE
ENGINE FAILURES.	AIR EDUCATION & TRAINING COMMAND
PILOT INDUCED ENGINE MALFUNCTIONS.	TACTICAL AIR COMMAND
ENGINE FAILURES.	TACTICAL AIR COMMAND

Flt Activity1	*Flt Clearance*	*Obj Flt Time SUM*
FINAL	Local IFR	3.6
	Local VFR	1.3
	Local IFR	2
AIR COMBAT TACTICS	Local IFR	0.5
BASIC FIGHTER MANEUVERS	Local IFR	0.4
BOMBS	Local IFR	0.6
LOW LEVEL	Local IFR	0.4
	Local IFR	0.8
	Local IFR	0.5
FORMATION	Local VFR	1.9
LOW LEVEL	Local IFR	2.9
	Local IFR	1.5
	Local VFR	0.3
FORMATION	Local IFR	0.4
FORMATION	Local IFR	1.5
FUNCTIONAL CHECK FLIGHT	Local VFR	0.1
JOIN/REJOIN	Local VFR	
FORMATION	Local IFR	0.1
LOCALIZER ONLY ILS	Pnt-to-pnt IFR - airways	1.4
AIR COMBAT TACTICS	Local VFR	0.7
ATTACKING		0.7
FORMATION	Local VFR	1.9
FORMATION	Local VFR	15
GCA PRECISION APPROACH	Local VFR	1.5
INTERCEPT	Local VFR	0.4
INTERCEPT	Local VFR	0.5
INTERCEPT	Local VFR	0.8
LOW LEVEL	Local VFR	
SIMULATED FLAMEOUT PATTERN	Local VFR	0.1
TACTICAL FORMATION	Local IFR	0.6
TACTICAL FORMATION	Local VFR	0.7
	Local VFR	0.8
	Local VFR	0.9
	Local VFR	
	Pnt-to-pnt IFR - airways	0
	Local VFR	0.1
	Local VFR	0.5
	Local VFR	0.1
BASIC FIGHTER MANEUVERS	Local IFR	0.5
DISSIMILAR AIR COMBAT TRAINING	Local IFR	0.7
POPUP PATTERN	Local VFR	1
	Local VFR	0.7
	Local VFR	0.1
LOW LEVEL	Local VFR	
BASIC FIGHTER MANEUVERS	Local VFR	0.8
AIR COMBAT TACTICS	Local IFR	0.2
ATTACKING	Local IFR	0.4
BASIC FIGHTER MANEUVERS	Local IFR	0.6

BASIC FIGHTER MANEUVERS	Local IFR	0.1
BASIC FIGHTER MANEUVERS		0.6
DISSIMILAR AIR COMBAT TRAINING	Local IFR	0.8
DISSIMILAR AIR COMBAT TRAINING	Local VFR	0.9
FORMATION	Local VFR	0.5
FORMATION	Local VFR	0
FORMATION	Local VFR	0.6
INTERCEPT	Local IFR	1.2
INTERCEPT	Local VFR	
JOIN/REJOIN	Local VFR	1.3
LANTIRN LOW ALTITUDE TARGET AND IR NA	Local VFR	0.9
LOW LEVEL	Local IFR	0.3
LOW LEVEL	Local IFR	0.6
LOW LEVEL	Local IFR	0.5
LOW LEVEL	Local IFR	0.4
LOW LEVEL	Local VFR	1.2
LOW LEVEL AT MINIMUM ENROUTE ALTITUD	Local VFR	0.4
ROUTE FORMATION	Local VFR	0.2
SIMULATED FLAMEOUT PATTERN	Local IFR	1.5
TACTICAL FORMATION	Local VFR	0.3
	Local IFR	0.5
	Local IFR	2
	Local IFR	3
	Local IFR	0.6
	Local IFR	0.7
	Local IFR	0.5
	Local IFR	0.6
	Local IFR	0
	Local VFR	0.8
	Local IFR	0.1
TRAIL FORMATION	Local VFR	0.3
	Local VFR	0.6
TACTICAL FORMATION	Local VFR	0.4
FORMATION	Local IFR	0.1
FORMATION	Local VFR	1
FORMATION	Local VFR	1.1
DISSIMILAR AIR COMBAT TRAINING	Local VFR	
FORMATION	Local VFR	3.5
CLOSE AIR SUPPORT	Local VFR	1.7
FORMATION	Local VFR	2.6
RECOVERY	Local VFR	1.3
	Local IFR	0.9
	Local VFR	0.6
	Local IFR	0.6
AIR COMBAT MANEUVERS	Local VFR	0.3
FORMATION	Local VFR	3
	Local VFR	0.8
	Local VFR	23
AIR COMBAT MANEUVERS	Local IFR	0.4

LOW LEVEL	Local IFR	0.7
LOW LEVEL	Local IFR	0.4
LOW LEVEL	Local IFR	0.2
	Local IFR	0.4
	Local IFR	0.4
	Local IFR	0.1
	Local IFR	1
BASIC FIGHTER MANEUVERS	Local VFR	1.4
FORMATION	Local VFR	0.5
SIMULATED FLAMEOUT PATTERN	Local VFR	
TACTICAL FORMATION	Local VFR	0.7
	Local VFR	0.6
	Local VFR	
	Local VFR	0.1
	Local VFR	
FORMATION	Local VFR	0.9
LOW LEVEL	Local IFR	
TOUCH AND GO LANDING	Local VFR	1.1
	Local VFR	

G Load	MDSN	Meteorological Cond	Phase Opr
	F016	Changing: VFR/IFR or IFR/VFR	LFINL
	F016	Visual contact	CDESC
	F016	Instrument - simulated	CMANV
	F016	Instrument - simulated	CMANV
	F016	Instrument - simulated	CRUZ
	F016	Instrument - simulated	CMANV
	F016	Instrument - simulated	CMANV
	F016	Instrument - simulated	CMANV
	F016	Instrument - simulated	CRUZ
1	F016	Visual contact	CRUZ
	F016	Instrument - simulated	CRUZ
	F016	Visual contact	LFINL
1	F016	Visual contact	CRUZ
2.5	F016	Visual contact	CRUZ
	F016	Visual contact	CRUZ
	F016	Visual contact	TCLMB
1	F016	Visual contact	CDESC
	F016	Visual contact	CCLMB
0.9	F016	Changing: VFR/IFR or IFR/VFR	LFINL
1	F016	Visual contact	CMANV
1	F016	Visual contact	CMANV
1	F016	Visual contact	CDESC
1	F016	Visual contact	LFINL
1	F016	Visual contact	LFINL
1	F016	Visual contact	CMANV
1	F016	Visual contact	CMANV
1	F016	Visual contact	CRUZ
1	F016	Visual contact	CLL
1	F016	Visual contact	TCLMB
1	F016	Visual contact	CMANV
1	F016	Visual contact	CRUZ
1	F016	Visual contact	LROLL
1	F016	Visual contact	LROLL
1	F016	Visual contact	TROLL
1	F016	Visual contact	TCLMB
1	F016	Visual contact	CRUZ
1.5	F016	Visual contact	CRUZ
1.5	F016	Visual contact	TCLMB
4	F016	Instrument - actual	CMANV
4	F016	Instrument - simulated	CMANV
4	F016	Visual contact	CMANV
4	F016	Visual contact	CDESC
4	F016	Visual contact	CMANV
5	F016	Visual contact	CMANV
5.5	F016	Visual contact	CMANV
	F016	Instrument - simulated	CMANV
	F016	Visual contact	CMANV
	F016	Instrument - simulated	CMANV

F016	Instrument - simulated	TCLMB
F016		CMANV
F016	Visual contact	CMANV
F016	Visual contact	CMANV
F016	Visual contact	CMANV
F016	Visual contact	TCLMB
F016	Visual contact	CLL
F016	Instrument - simulated	CRUZ
F016	Visual contact	CRUZ
F016	Visual contact	LROLL
F016		CRUZ
F016	Instrument - simulated	CLL
F016	Instrument - simulated	CLL
F016	Instrument - simulated	CMANV
F016	Instrument - simulated	CRUZ
F016	Visual contact	CLL
F016	Visual contact	CLL
F016	Visual contact	CCLMB
F016	Instrument - simulated	CRUZ
F016	Visual contact	CMANV
F016	Instrument - simulated	CLL
F016	Instrument - simulated	CRUZ
F016	Instrument - simulated	CDESC
F016	Instrument - simulated	CLL
F016	Instrument - simulated	CMANV
F016	Instrument - simulated	CMANV
F016	Instrument - simulated	CRUZ
F016	Instrument - simulated	TCLMB
F016	Visual contact	CMANV
F016	Instrument - simulated	TCLMB
1 F016	Visual contact	CRUZ
1 F016	Visual contact	CRUZ
1 F016	Visual contact	CMANV
1.1 F016	Visual contact	CLL
4 F016	Visual contact	LPATT
5 F016	Visual contact	CRUZ
6 F016	Visual contact	CMANV
6 F016	Visual contact	CRUZ
F016	Visual contact	CRUZ
F016	Visual contact	CRUZ
F016	Visual contact	CLL
1 F016	Instrument - actual	LFINL
F016	Visual contact	CRUZ
F016	Instrument - simulated	CRUZ
2 F016	Instrument - actual	CMANV
3 F016	Visual contact	CMANV
4 F016	Visual contact	CDESC
F016	Visual contact	LFINL
F016	Instrument - simulated	CRUZ

	F016	Instrument - simulated	CMANV
	F016	Instrument - simulated	CMANV
	F016	Instrument - simulated	CLL
	F016	Instrument - simulated	CLL
	F016	Instrument - simulated	CRUZ
	F016	Instrument - simulated	TCLMB
	F016	Instrument - simulated	CMANV
1	F016	Visual contact	CMANV
1	F016	Visual contact	CMANV
1	F016	Visual contact	TCLMB
1	F016	Visual contact	CLL
1	F016	Visual contact	CRUZ
1	F016	Visual contact	TROLL
1.5	F016	Visual contact	TCLMB
3	F016	Visual contact	CRUZ
	F016	Visual contact	CRUZ
	F016	Instrument - simulated	CRUZ
	F016	Visual contact	TCLMB
	F016	Visual contact	PCHOK

Phase of Operation	Type of Mission	ALC
LANDING FINAL APPROACH	AIRCRAFT DELIVERY/FERRY	
CRUISE DESCENT	AIRCRAFT DELIVERY/FERRY	
CRUISE MANEUVERING	COMBAT	
CRUISE MANEUVERING	COMBAT CREW TRAINING	
CRUISE	COMBAT CREW TRAINING	
CRUISE MANEUVERING	COMBAT CREW TRAINING	
CRUISE MANEUVERING	COMBAT CREW TRAINING	
CRUISE MANEUVERING	COMBAT CREW TRAINING	
CRUISE	COMBAT CREW TRAINING	
CRUISE	CROSS COUNTRY	
CRUISE	DIRECT TEST SUPPORT	
LANDING FINAL APPROACH	DIRECT TEST SUPPORT	
CRUISE	FUNCTIONAL CHECK FLIGHT (FCF)	
CRUISE	FUNCTIONAL CHECK FLIGHT (FCF)	
CRUISE	FUNCTIONAL CHECK FLIGHT (FCF)	
TAKEOFF INITIAL CLIMB	FUNCTIONAL CHECK FLIGHT (FCF)	
CRUISE DESCENT	HIGHER HEADQUARTERS DIRECTED	
CRUISE CLIMB	INDIRECT MISSION SUPPORT	
LANDING FINAL APPROACH	OPERATIONAL TRAINING	
CRUISE MANEUVERING	OPERATIONAL TRAINING	
CRUISE MANEUVERING	OPERATIONAL TRAINING	
CRUISE DESCENT	OPERATIONAL TRAINING	
LANDING FINAL APPROACH	OPERATIONAL TRAINING	
LANDING FINAL APPROACH	OPERATIONAL TRAINING	
CRUISE MANEUVERING	OPERATIONAL TRAINING	
CRUISE MANEUVERING	OPERATIONAL TRAINING	
CRUISE	OPERATIONAL TRAINING	
CRUISE LOW LEVEL	OPERATIONAL TRAINING	
TAKEOFF INITIAL CLIMB	OPERATIONAL TRAINING	
CRUISE MANEUVERING	OPERATIONAL TRAINING	
CRUISE	OPERATIONAL TRAINING	
LANDING ROLLOUT	OPERATIONAL TRAINING	
LANDING ROLLOUT	OPERATIONAL TRAINING	
TAKEOFF ROLL	OPERATIONAL TRAINING	
TAKEOFF INITIAL CLIMB	OPERATIONAL TRAINING	
CRUISE	OPERATIONAL TRAINING	
CRUISE	OPERATIONAL TRAINING	
TAKEOFF INITIAL CLIMB	OPERATIONAL TRAINING	
CRUISE MANEUVERING	OPERATIONAL TRAINING	
CRUISE MANEUVERING	OPERATIONAL TRAINING	
CRUISE MANEUVERING	OPERATIONAL TRAINING	
CRUISE DESCENT	OPERATIONAL TRAINING	
CRUISE MANEUVERING	OPERATIONAL TRAINING	
CRUISE MANEUVERING	OPERATIONAL TRAINING	
CRUISE MANEUVERING	OPERATIONAL TRAINING	
CRUISE MANEUVERING	OPERATIONAL TRAINING	
CRUISE MANEUVERING	OPERATIONAL TRAINING	
CRUISE MANEUVERING	OPERATIONAL TRAINING	

TAKEOFF INITIAL CLIMB	OPERATIONAL TRAINING
CRUISE MANEUVERING	OPERATIONAL TRAINING
CRUISE MANEUVERING	OPERATIONAL TRAINING
CRUISE MANEUVERING	OPERATIONAL TRAINING
CRUISE MANEUVERING	OPERATIONAL TRAINING
TAKEOFF INITIAL CLIMB	OPERATIONAL TRAINING
CRUISE LOW LEVEL	OPERATIONAL TRAINING
CRUISE	OPERATIONAL TRAINING
CRUISE	OPERATIONAL TRAINING
LANDING ROLLOUT	OPERATIONAL TRAINING
CRUISE	OPERATIONAL TRAINING
CRUISE LOW LEVEL	OPERATIONAL TRAINING
CRUISE LOW LEVEL	OPERATIONAL TRAINING
CRUISE MANEUVERING	OPERATIONAL TRAINING
CRUISE	OPERATIONAL TRAINING
CRUISE LOW LEVEL	OPERATIONAL TRAINING
CRUISE LOW LEVEL	OPERATIONAL TRAINING
CRUISE CLIMB	OPERATIONAL TRAINING
CRUISE	OPERATIONAL TRAINING
CRUISE MANEUVERING	OPERATIONAL TRAINING
CRUISE LOW LEVEL	OPERATIONAL TRAINING
CRUISE	OPERATIONAL TRAINING
CRUISE DESCENT	OPERATIONAL TRAINING
CRUISE LOW LEVEL	OPERATIONAL TRAINING
CRUISE MANEUVERING	OPERATIONAL TRAINING
CRUISE MANEUVERING	OPERATIONAL TRAINING
CRUISE	OPERATIONAL TRAINING
TAKEOFF INITIAL CLIMB	OPERATIONAL TRAINING
CRUISE MANEUVERING	OPERATIONAL TRAINING
TAKEOFF INITIAL CLIMB	OPERATIONS (GENERAL)
CRUISE	SPECIAL EXERCISE LOCAL
CRUISE	SPECIAL EXERCISE ORI
CRUISE MANEUVERING	SPECIAL EXERCISE OTHER
CRUISE LOW LEVEL	SPECIAL EXERCISE OTHER
LANDING PATTERN	SPECIAL EXERCISE OTHER
CRUISE	SPECIAL EXERCISE OTHER
CRUISE MANEUVERING	SPECIAL EXERCISE OTHER
CRUISE	SPECIAL EXERCISE OTHER
CRUISE	SPECIAL EXERCISE OTHER
CRUISE	SPECIAL EXERCISE OTHER
CRUISE LOW LEVEL	SPECIAL EXERCISE OTHER
LANDING FINAL APPROACH	SPECIAL TAC, MAC
CRUISE	SPECIAL TAC, MAC
CRUISE	STUDENT TRAINING
CRUISE MANEUVERING	TACTICAL TRAINING
CRUISE MANEUVERING	TEST (D/I/OT&E)
CRUISE DESCENT	TEST (D/I/OT&E)
LANDING FINAL APPROACH	TEST (D/I/OT&E)
CRUISE	TRAINING

CRUISE MANEUVERING	TRAINING
CRUISE MANEUVERING	TRAINING
CRUISE LOW LEVEL	TRAINING
CRUISE LOW LEVEL	TRAINING
CRUISE	TRAINING
TAKEOFF INITIAL CLIMB	TRAINING
CRUISE MANEUVERING	TRAINING
CRUISE MANEUVERING	
CRUISE MANEUVERING	
TAKEOFF INITIAL CLIMB	
CRUISE LOW LEVEL	
CRUISE	
TAKEOFF ROLL	
TAKEOFF INITIAL CLIMB	
CRUISE	
CRUISE	
CRUISE	
TAKEOFF INITIAL CLIMB	
PARKED CHOCKS	

Eng Ccl Bld SUM	Eng Ccl Cdmx SUM	Eng Ccl Inst SUM
		61
436		415
536	21	304

548

67

326
76
76

130

Eng Ccl Ovh SUM	Evt Date	Fac Bld
	08-OCT-1993	
	27-AUG-1987	
	16-FEB-1994	
	21-AUG-1995	
	21-DEC-1995	
	29-JAN-1997	
	26-MAR-1999	
	03-FEB-1999	
	18-JUN-1999	
	24-JAN-1984	
	22-AUG-1997	
	04-MAY-1982	
	08-JUN-1991	
	21-APR-1993	
	22-MAR-1987	PWW
	30-OCT-1992	
	12-OCT-1988	
	30-JAN-1989	
	25-JUN-1980	
	18-NOV-1983	
	08-JUN-1982	
	01-MAY-1984	
	25-JUL-1988	
	25-JUL-1983	
	11-FEB-1985	
	24-APR-1992	
	27-NOV-1991	
	20-JAN-1983	
	17-FEB-1987	
	22-JUN-1987	
	29-NOV-1988	
	17-NOV-1989	PWH
	17-DEC-1987	
	11-SEP-1986	DEP
	13-SEP-1988	
	03-APR-1990	
	02-FEB-1994	
	23-JUL-1980	CIV
754	26-DEC-1989	
	19-FEB-1993	
	27-MAR-1981	CIV
	13-JUL-1995	
	07-FEB-1994	

	07-JUN-1996	
	31-AUG-1992	
	21-MAY-1992	
	01-SEP-1992	
	07-MAY-1991	
	20-SEP-1990	
	24-AUG-1998	
	20-MAY-1982	
	05-MAY-1992	
	23-FEB-1993	
	12-MAY-1997	
	08-JAN-1998	
	05-FEB-1995	
	09-NOV-1993	
	18-OCT-1988	
	26-MAR-1980	
	16-DEC-1991	
	27-AUG-1993	
	18-APR-1988	
	25-OCT-1994	
	11-JUL-1996	
	20-JAN-1996	
	17-NOV-1998	
	11-SEP-1993	
	19-MAR-1996	
	21-NOV-1996	
	19-NOV-1998	
	31-MAY-1992	
	03-AUG-1996	
	02-SEP-1988	
	17-SEP-1987	PWH
4240	20-MAY-1988	
	03-SEP-1990	
	29-JUN-1988	CIV
	13-JAN-1991	
	02-OCT-1986	
	17-FEB-1991	
	11-AUG-1993	
	27-OCT-1992	
	07-AUG-1990	SAN
	17-JUL-1991	
	12-JUL-1999	
	27-APR-1986	SAN
4198	28-JAN-1991	
	23-MAR-1982	
	24-JUN-1976	
	22-JUL-1998	

15-MAY-1995	
25-JUN-1995	
13-JAN-1995	
21-APR-1997	
04-DEC-1998	
07-JAN-1999	
04-FEB-1997	
11-JUL-1983	
27-FEB-1986	
19-JUN-1984	
16-JUN-1982	
07-FEB-1985	
30-JUL-1985	
10-FEB-1988	
25-JUL-1987	CIV
20-FEB-1991	CIV
15-DEC-1998	

Eng Hrs Manf SUM	Rstr Att	Engine
		F110-129
159	U	F110-100
		F110-100
3700	U	F100-PW-220E
5609	U	F100-PW-220E
4426	U	F100-PW-220E
	N	F100-PW-220E
	N	F100-220
	U	F100-PW-220E
		F100-200
	U	F100-200
467	U	F100-200
3140		F100-200
		F100-200
983	U	F100-200
3857		F100-200
956		F100-200
477		F110-100
110	U	F100-200
1293	U	F100-200
		F100-200
		F100-200
		F100-200
		F100-200
		F100-200
		F110-100
3828		F100-200
		F100-200
		F100-200
		F100-200
		F100-200
2798	N	F100-200
1718	U	F100-200
	U	F100-200
1846		F100-200
236	N	F110-100
196		F110-129
	U	F100-200
754	U	F110-100
3712.4		F100-200
	U	F100-200
4328	U	F100-PW-220E
1213		F100-220

1517	U	F110-100
2309	U	F100-200
2586		F100-200
3791	U	F100-200
1669	N	F110-100
1985	U	F100-200
	N	F110-100
		F100-200
2446		F100-200
1627		F110-100
1988	U	F110-100
1962	U	F110-100
1959	U	F110-100
2260		F110-100
		F110-100
		F100-200
538	U	F100-220
2815	S	F100-200
592	U	F110-100
951	U	F110-129
939	U	F110-129
2045	N	F100-220
	N	F110-100
		F100-200
3071	U	F110-100
3471	U	F100-PW-220E
	N	F110-129
		F100-220
2032	N	F110-100
450	U	F110-100
427	U	F100-200
3089	U	F100-200
1576		F100-200
281	U	F110-100
	N	F100-200
		F100-200
	U	F100-200
2919		F110-100
		F100-220
	N	F100-200
501	N	F110-100
		F110-100
1361	U	F100-200
3104		F100-200
		F100-200
231	N	F100-200
	U	F110-129

3691		F100-200
	U	F110-100
758		F110-129
1567	U	F110-100
	U	F110-100
	N	F100-PW-220E
	U	F110-100
1089	U	F100-200
		F100-200
1161	N	F100-200
		F100-200
		F100-200
		F100-200
		F100-200
998	U	F100-200
1176	U	F110-100
	U	F100-PW-220E

Eng Type Code	Event Id
XZ	36925
XY	23219
XY	37341
GV	39066
GV	39359
GV	40446
GV	42195
ZH	41992
GV	42445
X2	8670
X2	40951
X2	2346
X2	14
X2	36511
X2	21818
X2	35752
X2	26714
XY	27621
X2	2092
X2	7959
X2	2357
X2	9852
X2	26062
X2	6387
X2	13782
XY	35042
X2	34336
X2	3860
X2	21497
X2	22638
X2	27130
X2	29763
X2	24165
X2	20139
X2	26498
XY	30731
XZ	37234
X2	2108
XY	30024
X2	36233
X2	2215
GV	38965
ZH	37256

XY	39805
X2	35576
X2	35171
X2	35580
XY	33266
X2	31996
XY	41648
X2	2352
X2	35094
XY	36242
XY	40661
XY	41170
XY	38502
XY	37003
XY	26783
X2	2064
ZH	34435
X2	36794
XY	25242
XZ	38264
XZ	39893
ZH	39462
XY	41825
X2	36841
XY	39592
GV	40229
XZ	41839
ZH	35203
XY	39945
XY	26425
X2	23386
X2	25546
X2	31876
XY	25873
X2	32641
X2	20301
X2	32831
XY	36789
ZH	35733
X2	31664
XY	33661
XY	42508
X2	18875
X2	32726
X2	2327
X2	924
XZ	41555

X2	38768
XY	38888
XZ	38395
XY	40629
XY	41867
GV	41925
XY	40455
X2	6192
X2	18222
X2	10423
X2	2361
X2	13729
X2	15827
X2	24587
X2	22938
XY	32844
GV	41896

Tab D

UCRL-ID-124837

DATA DEVELOPMENT TECHNICAL SUPPORT DOCUMENT FOR THE AIRCRAFT CRASH RISK ANALYSIS METHODOLOGY (ACRAM) STANDARD

Chris Y. Kimura
Ronald E. Glaser
Richard W. Mensing
Tom Lin
Timothy A. Haley
Andrew B. Barto
Martin A. Stutzke

August 1, 1996

Lawrence Livermore National Laboratory

This is an informal report intended primarily for internal or limited external distribution. The opinions and conclusions stated are those of the author and may or may not be those of the Laboratory.
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4.3.3 CRASH VELOCITY DISTRIBUTIONS

Two other crash kinematic parameters are needed for the calculations associated with this Standard are the airspeed and horizontal velocity of the aircraft at the time of impact. Both of these parameters are necessary inputs into the structural response calculations. For purposes of describing the crash kinematics for military aviation in this Standard, the airspeed of the crashing aircraft is referred to as the crash velocity. The horizontal velocity is the crash velocity in the horizontal direction, i.e., the crash velocity adjusted by the cosine of the impact angle.

The Minuteman III WSSA database was the source of the data used in developing the distributions of the crash and horizontal velocities. The same analysis techniques as were used for the impact angle were used in selecting and estimating appropriate distributions for the velocities associated with future military aviation crashes. Lognormal distributions were selected for the crash velocity for both large and small aircraft. The logistic distribution seemed to be the best descriptor for the horizontal velocity.

Tabulated values of the cumulative probability distributions for the crash velocity and the horizontal velocity, for the four combinations of aircraft size and phase of operation, are given in Tables 4.15 and 4.16 respectively.

Impact Airspeed

Cumulative Probability	*Large Aircraft*		*Small Aircraft*	
	Landing	Takeoff	Landing	Takeoff
5%	70.70	83.75	96.00	89.05
10%	81.47	95.45	109.01	103.73
15%	89.64	104.26	118.78	114.97
20%	96.71	111.83	127.16	124.78
25%	103.23	118.77	134.82	133.85
30%	109.45	125.36	142.09	142.56
35%	115.55	131.80	149.18	151.13
40%	121.66	138.21	156.23	159.75
45%	127.87	144.71	163.37	168.55
50%	134.29	151.41	170.72	177.68
55%	141.03	158.42	178.39	187.31
60%	148.24	165.87	186.54	197.63
65%	156.07	173.94	195.36	208.90
70%	164.76	182.87	205.11	221.46
75%	174.70	193.02	216.17	235.87
80%	186.46	204.99	229.19	253.02
85%	201.18	219.89	245.37	274.60
90%	221.36	240.17	267.35	304.37
95%	255.06	273.73	303.60	354.55
100%	∞	∞	∞	∞

Table 4.15 Estimated Cumulative Distributions for Airspeed at Principal Impact

Horizontal Velocity

Cumulative Probability	*Large Aircraft*		*Small Aircraft*	
	Landing	Takeoff	Landing	Takeoff
5%	50.52	76.65	39.57	24.45
10%	71.96	90.73	64.55	49.21
15%	85.23	99.44	80.01	64.53
20%	95.23	106.00	91.66	76.07
25%	103.48	111.42	101.27	85.60
30%	110.69	116.16	109.67	93.93
35%	117.24	120.46	117.31	101.49
40%	123.37	124.48	124.45	108.57
45%	129.24	128.34	131.29	115.35
50%	135.00	132.12	138.00	122.00
55%	140.76	135.90	144.71	128.65
60%	146.63	139.76	151.55	135.43
65%	152.76	143.78	158.69	142.51
70%	159.31	148.08	166.33	150.07
75%	166.52	152.82	174.73	158.40
80%	174.77	158.24	184.34	167.93
85%	184.77	164.80	195.99	179.47
90%	198.04	173.52	211.45	194.79
95%	219.48	187.59	236.43	219.55
100%	∞	∞	∞	∞

Table 4.16 Estimated Cumulative Distributions for Horizontal Velocity at Principal Impact

Tab E

(1)

Canister Transfer Building
F-16 Engine

Determine the KE that will be absorbed as an F-16 Engine penetrates the walls and roof of the Canister Transfer Building. Determine the speed of an F-16 engine that will just penetrate the walls and roof of the Canister Transfer Building.

Inputs: The mass of an F16 engine is given as 100 slugs in Table 1, "Aircraft Engine Characteristics," of Davis, Strenge, and Mishma, October 1998. This corresponds to a weight of $(100\ slugs)(32.2\ ft/s^2) = 3,220\ lbs$; Engine Dia. = 3.0 ft

The thickness of the reinforced concrete outer walls of the Canister Transfer Building is 2.0 ft, as shown in Dwgs 0599602-EC-5-A, -6-A and -7-A, Canister Transfer Building elevations.

The thickness of the concrete roof slabs of the Canister Transfer Building is 1.0 ft, as shown in Dwgs 0599602-EC-3-A and -4-A, Canister Transfer Building roof plans at elevations 130 ft and 190 ft respectively.

The formula used to assess the potential for aircraft to penetrate concrete is given in Davis, Strenge, and Mishma, October 1998, and is as follows:

$$t_p = (U/V)^{0.25} (MV^2/Df'_c)^{0.5}$$

where:

t_p = perforation thickness of concrete (in feet) that is just great enough to allow missile to pass through with zero exit speed.

U = reference velocity (200 ft/sec)

V = missile impact velocity (aircraft impact velocity in ft/sec)

M = mass of missile (in slugs)

D = missile diameter (in feet)

f'_c = ultimate compressive strength of concrete (720,000 lb/ft²)

Manipulating the above formula to solve for V:

$$t_p = \left(\frac{U^{0.25}}{V^{0.25}}\right)\left(\frac{MV^2}{Df'_c}\right)^{0.5}$$

$$t_p = \left(\frac{U^{0.25}}{V^{0.25}}\right)\left(\frac{M}{Df'_c}\right)^{0.5} V$$

$$t_p = \frac{U^{0.25} M^{0.5} V^{0.75}}{(Df'_c)^{0.5}}$$

$$V^{0.75} = \frac{t_p (Df'_c)^{0.5}}{U^{0.25} M^{0.5}}$$

Substituting values and solving for V for the 2.0 ft thick outer concrete walls (assume the F-16 Engine is travelling horizontally when it impacts):

(2.0 ft thick outer concrete walls...) ③

$$V^{0.75} = \frac{(2.0)\left[(3.0)(720{,}000)\right]^{0.5}}{(200^{0.25})(100)^{0.5}}$$

$$V^{0.75} = \frac{(2.0)(1470)}{(3.761)(10.0)}$$

$$V^{0.75} = 78.17$$

$$V = 334.2 \text{ ft/sec}$$

$= 227$ mph

$= 198$ knots

Kinetic Energy absorbed $= \frac{1}{2} M V^2 = \frac{1}{2}(100)(334.2)^2$

$= 5.58\text{E}6$ ft-lbs

Next, determine KE absorbed and maximum initial speed of an F-16 engine that will just penetrate the 1.0 ft thick concrete slab roof (assume the F-16 engine is travelling vertically downward when it impacts):

Substituting into the above formula for velocity:

$$V^{0.75} = \frac{t_p (D f'_c)^{0.5}}{U^{0.25} M^{0.5}} = \frac{(1.0)\left[(3.0)(720{,}000)\right]^{0.5}}{(200^{0.25})(100^{0.5})}$$

$$V^{0.75} = \frac{(1.0)(1470)}{(3.761)(10.0)}$$

$$V^{0.75} = 39.09$$

$V = 132.6$ ft/sec $= 90.4$ mph $= 78.5$ knots

(1.0 ft thick concrete roof slabs...)

Kinetic Energy absorbed = $\frac{1}{2} MV^2 = \frac{1}{2}(100)(132.6)^2$

$= 8.79 E5$ ft-lbs

Tab F

Assume that the jet aircraft impacts the storage area in a near vertical direction so that a jet fuel spill is concentrated in a relatively small area. Also assume that the jet fuel collects in the area between the storage pads in a conservatively small area of 30 ft by 60 ft. The effective depth of a 1000 gallon fuel spill would be 0.89 inches.

Using the mass loss rate per unit area given in Table 21-6A of the Fire Protection Handbook (Sixteenth Edition) for JP-4 jet fuel, which equals 0.049kg/m^2-sec, and the density which equals 760 kg/m^3, the burning rate for the spilled fuel would be 0.15 in/min. Based on this burn rate, the 1000 gallons of jet fuel spread to an effective depth of 0.89 inches would burn off in approximately 6 minutes.

Figure 7-9B of the Fire Protection Handbook provides time-temperature curves for different types of fire loads in enclosed structures. Curve E in this figure is the standard time-temperature curve for occupancies where the primary hazard includes flammable liquids. This curve reaches a temperature of approximately 1100° F in 6 minutes. The temperature for the jet crash would be less because the fire would not occur in an enclosed structure.

Tab G

WEAPONS TESTING ON THE UTTR
SOUTH RANGE

1. WEAPONS SYSTEM EVALUATION PROGRAM (WSEP) Nicknamed "Combat Hammer": This program is held annually during a two week period normally in May or June. Combat Hammer is designed to evaluate weapon system combinations from buildup through impact. Aircraft from all United States Air Bases, both continental U.S. and overseas may be involved. Aircraft include F-15E, F-16, F-117, A-10, B-1 and the B-52. The May 1997 WSEP was the largest WSEP effort in history. It involved over 400 people, 226 sorties, 56 aircraft, and 167 weapon employment's.

Weapon Systems Evaluated by type and average number each year:

a. GBU -10/12/24/27	4 - 60 weapons	(inert warhead)
b. GBU-15	6 - 12 weapons	(inert warhead)
c. AGM-142	2 weapons	(inert and live warhead)
d. AGM-65	40 - 60 weapons	(Live warhead)
e. AGM-130	2 - 6 weapons	(inert warhead)
f. AGM-88	2 - 21 weapons	(inert warhead)
g. AGM-86	3 - 4 weapons	(inert warhead)
h. AGM-86C	1 - 2 weapons	(live warhead)
i. AGM-129	3 - 4 weapons	(inert warhead)

NOTE: Weapon systems indicated in bold have a Flight Termination System (FTS) installed. Weapon systems that have a capability of exceeding range boundaries are required to have an FTS installed prior to testing on the UTTR. Additional information pertaining to FTS requirements are identified in the 388RANS Supplements 1 & 2 to AFI 13-212. The FTS systems are designed to destruct the weapon and terminate the weapon flight path, on command, in the event of a weapon anomaly from the Mission Control Room at Hill AFB. Averages of three AGM-88s are destructed each year during the WSEP deployment. The UTTR has never experienced a FTS failure.

The normal range ingress is as follows:
a. Aircraft employing AGM-88s depart Hill AFB and proceed direct to the Delta VORTAC and enter the Sevier "B" MOA and then direct to R-6405 and dedicated targets located in R-6407/R-6406.

b. Aircraft employing AGM-65s depart Hill AFB and proceed direct to the Delta VORTAC and enter the Sevier "B" MOA and then enter the range via Sevier MOAs (SKULL VALLEY) to R-6406 and dedicated targets in R-6406 or direct from the Delta VORTAC to R-6405 and dedicated targets located in R-6406. Aircraft transitioning over Skull Valley include F-15, F-16 and A-10. Normal flow is eight aircraft per hour during a two hour period range period Monday-Thursday, WSEP Deployment. Each aircraft will carry a maximum of two live AGM-65 missiles. Altitude is from 5,000 to 10,000 feet above ground level.

c. Aircraft employing GBU-10/12/15/24/27s or AGM-130s depart Hill AFB and proceed direct to the Delta VORTAC and enter the Sevier "B" MOA and then enter the range via Sevier MOAs (SKULL VALLEY) to R-6406 and dedicated targets in R-6407. Aircraft transitioning over Skull Valley include F-15, F-16, F-117 and A-10. Normal flow is eight aircraft per hour during a two-hour period range period, Monday-Thursday WSEP Deployment. Each aircraft will carry a maximum of two inert GBU/AGM-130 weapons. Altitude is from 5,000 to 10,000 feet above ground level.

d. Aircraft (B-52) employing AGM-142 depart their homebase and proceed direct to the UTTR via flight plan routes and enter the range from low level flight routes terminating on entry into the range via R-6405 or R-6406.

The normal range egress is as follows:
All aircraft staging out of Hill AFB depart R-6406 direct to Hill AFB as assigned by Clover Control.
ircraft departing for home base depart R-6406 as assigned by flight plan routing.

5. AGM-86 Air Launched Cruise Missile (ALCM)
The ALCM is an autonomous guided weapon system. Flight profiles vary but generally utilize all restricted areas and MOA's in the south range. Missile profiles that transit from the south range to the north range MOA's (Lucin) exist, but are rarely flown. Flight times vary depending on profile, but generally last 3 to 3.5 hours.

6. AGM-86C Conventional Air Launched Cruise Missile (CALCM)
ALCM variant equipped with a live conventional warhead flight profiles allow it to fly only in restricted airspace and only over DOD withdrawn lands. Flight time is approximately 1.5 hours.

7. AGM-129 Advanced Cruise Missile (ACM)
Improved version of the ALCM Flight profiles vary but generally utilize all restricted areas and MOA's in the south range. Missile profiles that transit from the south range to the north range MOA's (Lucin) exist, but are rarely flown. Flight times vary depending on the profile, but generally last 4 to 5 hours.

8. "Hanging Bombs"
All weapons testing conducted on the UTTR go through a comprehensive safety review and risk anaysis. Footprints are established using guidelines in AFI 13-212, volumes I-III or as provided by the customer. The 388RANS establish Shootcones/Release boxes and all aircraft must adhere to safety parameters established. Currently all non-FTS equipped weapon Shootcones/Release boxes are within restricted airspace over Department of Defense (DOD) owned lands. "HUNG BOMB" procedures are conducted in accordance with aircraft Technical Orders (TOs) and applicable AFIs. Test procedures are contained in the 388RANS supplement to AFI 13-212.

9. Probability of an unintentional release of live ordnance at any given location in Skull Valley and at the Skull Valley Reservation.

No aircraft overflying the Skull Valley are allowed to have their armament switches in a release capable mode. All switches are "Safe" until inside DOD land boundaries. The UTTR has not experienced an unanticipated munitions release outside of designated launch/drop/shoot boxes.

10. Run-in headings for weapons testing.
Each weapon tested on the UTTR has a run-in heading established during the safety review process. Footprints, time of fall, altitude at release and release airspeed dictate the headings allowed. No run-in headings are currently over the Skull Valley area.

NOTE.
The information provided is based on our assumption that the main areas of interest would be the Southern UTTR ranges. The southern ranges consist of R-6402, R-6405, R-6406, R-6407 and the Sevier A, B, C, and D MOA's