RAI Volume 2, Chapter 2.1.1.3, First Set, Number 1, Supplemental Question: Where in the RAI response or the License Application are examples of the types of means to inform, monitor and ensure restrictions; for example, the "means to monitor annual number of flights over the flight-restricted airspace"?

1. SUPPLEMENTAL RESPONSE

Through orders of the Federal Aviation Administration (FAA) and Air Force instructions (AFI), affected organizations will be notified about flight restrictions in the airspace over Yucca Mountain. Yucca Mountain is located in the restricted area R-4808N. The first full paragraph of page two of the RAI 2.2.1.1.3-001 response (RAI Response) provided by the U.S. Department of Energy (DOE) on December 31, 2008, explains the DOE authority to specify the use of the restricted airspace R-4808N. Specifically, FAA Order 7400.8 for Special Use Airspace provides that no person may operate an aircraft within the restricted airspace R-4808N unless he/she has the advance permission of the using agency or the controlling agency. The using agency shall schedule activities and authorize transit through or flight within the restricted area. The using agency for the restricted airspace R-4808N, as identified in FAA Order 7400.8, is the DOE and there is no controlling agency. Hence, the DOE has the sole authority to schedule activities and authorize transit through or flight within the restricted area of R-4808N.

The DOE currently allows military aircraft to transit R-4808N but requires the Air Force to observe certain avoidance areas. Implementation of the specified use of the R-4808N airspace by the Air Force is through Air Force instructions. AFI 13-212, which is discussed in the third and fourth paragraphs on page two of the DOE RAI Response, is another example of the means by which notification of the flight restrictions will be made.

Examples of the means to monitor the annual number of flights and to inform affected organizations when the limit is being approached are located in the third and fourth paragraphs on page two and the top of page three of the DOE RAI Response. The National Nuclear Security Administration, Nevada Site Office is capable of monitoring flights. An example of the capability and reporting of such monitoring is shown on Page II-3 of *Frequency Analysis of Aircraft Hazards for License Application*, identified in Safety Analysis Report (SAR) Section 1.6.5 as BSC 2007c. In addition, in order to not violate Air Force instructions, Air Force monitoring of the annual number of flights is required. Although reporting of flights in the vicinity of the repository is not necessary at this time and is not currently being performed, flight monitoring sufficient to both demonstrate compliance and monitor activity limits will be implemented via one or both of those sources prior to receipt of waste.

Examples of the means to ensure that restricted activities do not occur in the flight-restricted airspace are the Air Force instructions and FAA orders described above and in the RAI Response. Restrictions such as those set forth in AFI 13-212 and Order 7400.8 will require pilots to observe aircraft operational constraints in the restricted airspace.

As mentioned in the RAI Response and SAR Section 5.8.3, prior to receipt of a license to receive and possess spent nuclear fuel and high-level radioactive waste, and in accordance with 10 CFR 63.121(c), the DOE plans to implement controls to ensure that the requirements of 10 CFR

63.111(a) and (b) are met. Flight restrictions are identified in SAR Table 1.9-10 as Procedural Safety Controls 15, 16, 17, and 18. Because restrictions for the airspace are not needed until nuclear waste forms are actually located at the repository, specific controls for the flight restrictions have not yet been fully developed. However, as discussed above and in the RAI Response, the DOE has the authority to implement the additional flight restrictions in the R-4808N airspace over Yucca Mountain and the means to do so.

2. COMMITMENTS TO NRC

None

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

RAI Volume 2, Chapter 2.1.1.3, First Set, Number 2: Supplemental Question: Where in the response is information on developing gamma-factors for aircraft mishaps based on data from the database of 282 mishaps, including gamma-factors for aircraft operations other than landings and takeoffs, and does DOE have an analysis of the effects of these "latter gamma-factors" on predicted aircraft crash frequencies? Provide the table numbers from Reference 2.2.6 of BSC 2007c referred to in the last paragraph of the response.

1. SUPPLEMENTAL RESPONSE

The *Frequency Analysis of Aircraft Hazards for License Application*, identified in SAR Section 1.6.5 and in this response as BSC 2007c, used the Solomon model, which employed γ-factors, for flights within the Beatty Corridor. The Beatty Corridor flights include military as well as commercial and general aviation flights. The data contained in the database of the 282 mishaps, which are found in Attachment III of BSC 2007c, are only for military aircraft mishaps. Therefore, γ-factors developed only from military aircraft crashes would not be representative of the aircraft evaluated in the Beatty Corridor. As such, the RAI 2.2.1.1.3-002 response (RAI Response), which was provided by the U.S. Department of Energy (DOE) on December 31, 2008, did not contain information on developing γ-factors for aircraft mishaps based on data from the database of 282 mishaps, nor did it contain an analysis of the effects of these "latter gamma-factors" on predicted aircraft crash frequencies. BSC 2007c relies on the γ-factors developed by Solomon. The RAI Response and BSC 2007c provide justification for the γ-factors developed in the Solomon model and provides justification for applying those γ-factors to the military, general aviation, and commercial aircraft in the Beatty Corridor. Specifically, the γ-factors were developed for military, commercial, and general aviation aircraft based on 31 sets of investigations and studies of aircraft accidents, including international studies. These γ-factors are not specific to one geographic location and, thus, are applicable to the Yucca Mountain area.

The last paragraph of the DOE RAI Response included a discussion concerning the feasibility of a γ-factor lower than 1.0. This discussion was specifically aimed at addressing the next to the last sentence of the second paragraph of RAI 2.2.1.1.3-002, which states in part, "a value of γ lower than 1.0 appears credible." The discussion in the last paragraph of the RAI Response was not intended to imply that the DOE developed γ-factors, but to agree with the statement in the RAI in that it may be feasible to develop a γ-factor lower than 1.0. However, the data that appear to support a γ-factor lower than 1.0 are for aircraft landings and takeoffs. These data are found in Tables B-2 through B-13 of Reference 2.2.6 of BSC 2007c. As stated in the DOE RAI Response, airport activity has been screened from consideration due to distance from the North Portal. Therefore, information based on landings and takeoffs does not apply to the aircraft activity considered in the analysis.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

RAI Volume 2, Chapter 2.1.1.3, First Set, Number 3: Supplemental Question: From the first paragraph of the response to RAI 2.2.1.1.3-003, DOE stated, "because statistically sufficient information is available to develop probabilities, there is no measurable bias introduced into the calculation that could lead to either an over or under estimate in the aircraft crash frequency, thus providing confidence in the results." Where in the RAI response or LA is the basis for the conclusion that a) DOE's data is "statistically sufficient" and b) omission of unknowns introduces "no measurable bias"? Did DOE examine the mishaps with missing data to determine if they were consistent with the overall population of data, or whether the mishaps with missing data indicated a trend in an inconsistent direction?

1. SUPPLEMENTAL RESPONSE

The sample size of data used for glide ratio is large enough to be representative of the total population of glide ratios within the entire data set, irrespective of whether the glide ratio is known. The good fit of the sample data to the theoretical distribution indicates that there is no significant bias from small sample sizes. Moreover, the tabulations that follow show that data with known parameters used for determining the crash frequency are consistent with the overall population of data, thus the omission of unknown information does not introduce a bias.

The last sentence of the first paragraph of the RAI 2.2.1.1.3-003 response (RAI Response) provided by the U.S. Department of Energy (DOE) on December 31, 2008, was a qualitative statement on the large number of data points used in the DOE aircraft crash analysis from the list of 282 military aircraft crash events found in Attachment III of *Frequency Analysis of Aircraft Hazards for License Application*, which is identified in SAR Section 1.6.5 and in this response as BSC 2007c.

Three separate sets of data are used from the list of 282 military aircraft crash events found in Attachment III of BSC 2007c. These data sets are: (1) known glide ratios for flights that are compatible with flight restrictions (also known as Type 1 Events), (2) known glide ratios from all events, and (3) known distances to crash from all events. The DOE used the complete data set for each calculation, that is, 58 data points for glide ratios from flights that are compatible with flight restrictions, 88 data points for glide ratios used in the sensitivity analysis, and 155 data points for distances to crash. These data point numbers were provided in the last paragraph of the RAI Response. Unknowns in the database found in Attachment III of BSC 2007c are interpreted as "no data."

A gamma distribution is the physically appropriate distribution for a situation in which there are two Poisson processes and the "waiting time" between the two Poisson events is relevant. A gamma distribution is an appropriate distribution in this analysis because the crash scenarios for which there is a glide ratio may be represented by two Poisson events (the initiating event and the actual impact on the ground after the initiating event). The two relevant random variables in this analysis are the time to the initiating event and the waiting time from the initiating event to ground impact. The waiting time from the initiating event to ground impact is relevant to the calculation of glide ratio. The sample population of 58 data points with known glide ratios is a

good fit to a gamma distribution with the shape parameter of two and scale parameter of approximately 1.5. The goodness of fit of the samples to the gamma distribution is indicated by a 0.98 value for the coefficient of determination (i.e., R^2) derived from a quantile–quantile correlation. This demonstrates a high probability that the total population of glide ratios within the entire data set used in the DOE analysis is gamma, and the 58 samples are a good representative sample of this population. This, in turn, provides good support that the data set represents the entire population of aircraft crashes with no statistical bias.

The good fit to a physically appropriate distribution strongly suggests that the sample of 58 data points used in the analysis represents the entire population, and there is no need for a statistical correction for bias.

Tables 1 and 2 examine the mishaps with missing data to determine if they were consistent with the overall population of data. The examination finds a consistent trend. Attachment III of BSC 2007c is used to create Tables 1 and 2 to show that the data with known parameters are consistent with the overall population of data, and the omission of unknowns introduces no bias in the estimated probabilities. There are six different categories of initiating events identified as engine failure in Table III-1 of BSC 2007c. These six categories are: (1) engine failure, (2) engine failure from pilot error, (3) engine failure due to fire, (4) engine failure due to fuel emergency, (5) engine failure due to loss of fuel, and (6) mechanical engine failure. For simplicity, the six different engine failure initiating event categories have been combined into one engine failure category for the purpose of the distribution exercises shown in Tables 1 and 2. Table 1 compares the data for glide ratios for Type 1 Events.

A comparison of the "Percent of Events" columns in Table 1 for each initiating event description in each major column (All Type 1 Events, Type 1 Events with Known Glide Ratios, and Type 1 Events without Known Glide Ratios) shows that the data with known glide ratios are consistent with the overall population of Type 1 Events. For example, engine failure accounts for 86.5% of the Type 1 Events and 89.7% of the Type 1 Events with known glide ratios, thus showing a consistent percentage of events. In contrast, if engine failures accounted for only 10% of the Type 1 Events with known glide ratios, one may conclude that a bias could be introduced by the omission of the engine failures with unknown glide ratios.

Table 2 compares the data for distance to crash for all events. As described on page 59 of BSC 2007c, landing and takeoff mishaps (except for Event 190 from Table III-1 of BSC 2007c) have not been included in the distance to crash so that the distribution function developed for the crash distances would not be biased by events that are not near the repository.

A comparison of the "Percent of Events" columns in Table 2 for the controlled flight into terrain event in each major column (All Events, Events with Known Distance, and Events without Known Distance) shows a variation in the percentages between the overall data, the data with known distances, and the data with unknown distances. Due to the nature of a controlled flight into terrain event where the plane essentially flies into the ground and the distance to crash is zero, a larger percentage of these events would have a known distance to crash, as indicated in Table 2. The percent of events with known distance to crash is consistent with the percent of events for the overall population of data for the remaining initiating event descriptions.

The crash database, exhibited by Tables 1 and 2, contain 58 glide ratio data points for Type 1 Events and 155 data points for distance to crash. All of these data points were used in the determination of probability of crash. It is not possible to quantitatively determine the effect of including those crashes that have no glide ratio or no distance to crash information on glide ratio of distance to crash (e.g. quantitatively estimate a bias). However, these tables qualitatively illustrate that there is no bias associated with aircraft crash initiating events. The population of Type 1 events with known glide ratios well represents the population of all Type 1 events. Similarly, the population with known distance to crash well represents the population of all events.

In summary, the good fit of the sample to a gamma distribution, which indicates that a statistical correction (i.e., bias) for small samples is not needed, coupled with the tables that indicate that each aircraft crash initiating event is reasonably represented by data of known glide ratios provide strong support that the DOE analysis is unbiased.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

Table 1. Glide Ratios for Type 1 Events

	All Type 1 Events		Type 1 Events with Known Glide Ratios			Type 1 Events without Known Glide Ratios		
Initiating Event Description	**Number of Events**	**Percent of Events**	**Number of Events**	**Fraction of All Type 1 Events (#/104)**	**Percent of Type 1 Events with Known Glide Ratios (#/58)×100**	**Number of Events**	**Fraction of All Type 1 Events (#/104)**	**Percent of Type 1 Events without Known Glide Ratios (#/46) ×100**
Engine Failure[a]	90	86.5%	52	0.50	89.7%	38	0.37	82.6%
Loss of control	6	5.8%	1	0.01	1.7%	5	0.05	10.9%
Aircraft fire	3	2.9%	2	0.02	3.4%	1	0.01	2.2%
Airframe failure	2	1.9%	1	0.01	1.7%	1	0.01	2.2%
Centerline fuel tank explosion	1	1.0%	1	0.01	1.7%	0	0.00	0.0%
Inadvertent ejection	1	1.0%	1	0.01	1.7%	0	0.00	0.0%
Unknown	1	1.0%	0	0.00	0.0%	1	0.01	2.2%
Total	104		58			46		

NOTE: [a]Engine Failures include all types of engine failure events.

Table 2. Distance to Crash for All Events

	All Events		Events with Known Distance			Events without Known Distance		
Initiating Event Description	**Number of Events**	**Percent of Events**	**Number of Events**	**Fraction of All Events (#/238)**	**Percent of Events with Known Distance (#/155)*100**	**Number of Events**	**Fraction of All Events (#/238)**	**Percent of Events without Known Distance (#/83)*100**
Engine Failure[a]	91	38.4%	55	0.23	35.5%	36	0.15	43.4%
Controlled flight into terrain	46	19.4%	44	0.18	28.4%	2	0.01	2.4%
Mid-air collision	41	17.3%	23	0.10	14.8%	18	0.08	21.7%
Loss of control during maneuvering	18	7.6%	7	0.03	4.5%	11	0.05	13.3%
Bird Impact	9	3.8%	7	0.03	4.5%	2	0.01	2.4%
Abandoned aircraft during maneuvering	8	3.4%	5	0.02	3.2%	3	0.01	3.6%
Loss of control	6	2.5%	2	0.01	1.3%	4	0.02	4.8%
Aircraft fire	3	1.3%	3	0.01	1.9%	0	0.00	0.0%
Airframe failure	2	0.8%	1	0.00	0.6%	1	0.00	1.2%
G-induced loss of consciousness	2	0.8%	2	0.01	1.3%	0	0.00	0.0%
Loss of control during testing	2	0.8%	1	0.00	0.6%	1	0.00	1.2%
Use of piddle pack	2	0.8%	1	0.00	0.6%	1	0.00	1.2%
Landing Mishap (Event 190)	1	0.4%	1	0.00	0.6%	0	0.00	0.0%
Centerline fuel tank explosion	1	0.4%	1	0.00	0.6%	0	0.00	0.0%
Controlled bailout	1	0.4%	0	0.00	0.0%	1	0.00	1.2%
Inadvertent ejection	1	0.4%	1	0.00	0.6%	0	0.00	0.0%
No crash	1	0.4%	0	0.00	0.0%	1	0.00	1.2%
Spatial disorientation	1	0.4%	1	0.00	0.6%	0	0.00	0.0%
Unknown	1	0.4%	0	0.00	0.0%	1	0.00	1.2%
Engine fire on runway	1	0.4%	0	0.00	0.0%	1	0.00	1.2%
Total	238		155			83		

NOTE: [a]Engine Failures include all types of engine failure events.

RAI Volume 2, Chapter 2.1.1.3, First Set, Number 5: Supplemental Question: Does the prohibition described apply to both non-combat and simulated-combat conditions? For example, are there restrictions in the flight-restricted airspace on a pilot catching up to his/her formation or for correcting his/her flight path?

1. SUPPLEMENTAL RESPONSE

The maneuvering prohibition applies to both simulated-combat and noncombat conditions. The prohibition is outlined in SAR Section 1.6.3.4.1 and in Section 7 of *Frequency Analysis of Aircraft Hazards for License Application*, identified in SAR Section 1.6.5 and this response as BSC 2007c, which state "maneuvering over the flight-restricted airspace is prohibited; flight is straight and level," and in SAR Section 5.8.3 and SAR Table 1.9-10 (Procedural Safety Control-10), which state "overflights are limited to straight and level flights (i.e., maneuvering is not permitted)." Under the proposed flight-restrictions outlined in these citations, it is prohibited for a pilot to catch up to his/her formation because catching up to a formation is a rejoin maneuver and maneuvering is prohibited.

As discussed in the clarification call, the flight restrictions outlined in these citations do not include a restriction on the direction that the plane could travel. Table III-1 of BSC 2007c and Table 1.1-1 of the RAI 2.2.1.1.3-005 response provided by the U.S. Department of Energy on December 31, 2008, show that mid-air collisions occurred during maneuvering, not straight and level flight. The frequency analysis of aircraft hazards is based on the data in Table III-1 of BSC 2007c. The absence of incidents of mid-air collision during straight and level flight in this database of 282 military aircraft mishaps from around the world over a 16.5 year period, provided in Table III-1 of BSC 2007c, does not mean that the probability is zero. The probability of a mid-air collision during straight and level flight, however, is shown to be far lower, due to the absence of the incident, than the probability of a mid-air collision during maneuvering. Thus, the proposed flight restrictions include a prohibition on maneuvering and not on the direction of travel.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

RAI Volume 2, Chapter 2.1.1.3, First Set, Number 7: Supplemental Question: In Enclosure 7, page 2, third paragraph, first sentence, DOE concludes "the 0.59 fraction, used in Section 4.3.2 of BSC 2007c to characterize the proportion of crashes that occur during overflights of the flight-restricted airspace that could pose a threat to the facilities, is a conservative estimate." However, isn't the reduction (for aircraft crashing beyond the target area) already taken into account in Equation 5 of the frequency analysis by the assumption of a uniform crash density, and the ratio of the target area, A, and the restricted surface area A_z? Clarify the apparent inconsistency between DOE's methodology and NUREG-0800. On page 3.5.1.6-3 of NUREG-0800, Rev. 2-July 1981, the target area crash frequency = CNA/w (where C = crashes/mi, N=no of flights the corridor per year, A=target cross section area, and w=width of the corridor). NUREG-0800 does not need any reduction factor for aircraft crashing beyond the target area. Furthermore, it appears that NUREG-0800 and DOE's methodology may predict significantly different crash frequencies.

1. SUPPLEMENTAL RESPONSE

1.1 INFORMATION REGARDING COMMENT ABOUT THE U.S. DEPARTMENT OF ENERGY METHOD AND NUREG-0800 PREDICTION OF DIFFERENT CRASH FREQUENCIES

The U.S. Department of Energy (DOE) aircraft crash methodology described in the *Frequency Analysis for Aircraft Hazards for License Application*, identified in SAR Section 1.6.5 and in this response as BSC 2007c, is more encompassing than NUREG-0800 and conservative when taken in its entirety. The DOE methodology takes into account the large geographic areas of interest at the Yucca Mountain site and also considers flight restrictions, neither of which is addressed in NUREG-0800. The risk-informed nature of 10 CFR Part 63 does not require an analysis to be conservative or bounding in the context of NUREG-0800. As described in BSC 2007c and discussed below as well as in the eleven RAI responses provided by the DOE on December 31, 2008, the submitted aircraft analysis provides an appropriate estimate of expected aircraft crash frequency at the Yucca Mountain site that supports excluding aircraft crash as an external hazard consistent with 10 CFR Part 63.

1.2 INFORMATION REGARDING APPARENT DIFFERENCES BETWEEN THE DOE METHOD AND NUREG-0800

Safety Analysis Report (SAR) Section 1.6.3.4.1 and the RAI 2.2.1.1.3-009 response provided by the DOE on December 31, 2008, present an overview of the aircraft impact analysis process used by the DOE. This process involves a two-stage evaluation: 1) identification of potential aircraft hazards, which is documented in *Identification of Aircraft Hazards* and identified in SAR Section 1.6.5 and this response as BSC 2007b, and 2) evaluation of those potential hazards through a quantitative analysis, which is documented in BSC 2007c. The potential aircraft hazards identified in the first stage of the process are divided into three distinct areas for evaluation in the second stage of the process:

- **Area 1**—The general aviation, military, and commercial flights in the airspace identified as the Beatty Corridor and addressed in Section 4.3.1 of BSC 2007c

- **Area 2**—The 1,000 permitted annual military aircraft overflights of the flight-restricted airspace addressed in Section 4.3.2 of BSC 2007c

- **Area 3**—The military flights in combat training exercises that take place outside the flight-restricted airspace addressed in Section 4.3.3 of BSC 2007c.

The first key difference between the DOE method and the NUREG-0800 method is concerning the airspace evaluated. The DOE method evaluates potential aircraft hazards in the three geographic areas identified above. These three areas are substantially larger than the airspace evaluated in the NUREG-0800 method, which applies to potential aircraft hazards in an area in very close proximity to the facilities being evaluated.

The DOE considers its two-stage process to be more appropriate than a NUREG-0800 aircraft analysis because NUREG-0800 focuses on aircraft activity in very close proximity to the area of concern, whereas the analysis described in SAR Section 1.6.3.4.1 considers the airspace in a 100-mile radius surrounding the repository. For example, Section 7.1.3 of BSC 2007b, establishes a criterion to screen out air activity in designated airways that pose negligible hazards to the facilities based on NUREG-0800. Section 3.5.1.6, Screening Criteria II.1(c) of NUREG-0800, states that a federal airway, holding pattern, or approach pattern at least two miles beyond the site presents an acceptably low risk. However, in Section 7.1.3 of BSC 2007b, the NUREG-0800 screening criterion of two miles was conservatively increased by a factor of 15, and, as such, air activity within 30 miles has been evaluated for impact probability in BSC 2007c. The air activity that the DOE could have eliminated from the evaluation based on NUREG-0800 Screening Criteria II.1(c) of two miles includes all flights in the Beatty Corridor, which is identified as Area 1, above, and all flights beyond the radius of the flight-restricted airspace, which is identified as Area 3, above. The only flight activity that would not have been eliminated when applying the NUREG-0800 approach is the portion of the flights that are permitted above the flight-restricted airspace and within two miles of the facilities.

The second key difference between the DOE method and the NUREG-0800 method is that the DOE method includes consideration of flight restrictions, while the NUREG-0800 method does not. Flight restrictions are a realistic expectation over the repository site due to its location.

Section 4.3.2 of BSC 2007c evaluates the military overflights of the flight-restricted airspace. The methodology for estimating crash frequency was developed to take into account the flight-restrictions surrounding the facilities and is based on conservative assumptions, including the following (paragraph citations in parentheses are citations to the RAI 2.2.1.1.3-007 response provided by the DOE on December 31, 2008):

- All aircraft transiting the airspace use the longest trip distance through the center of the airspace (first paragraph)
- Aircraft would glide past facilities, based on the 8.5 glide ratio of an F-16 with no ejection (second paragraph)

- Immediate ejection occurs following a mishap. This is conservative because after ejection, the glide ratio drops significantly (second paragraph)
- No credit is taken for pilot action, such as attempting to save the aircraft or avoid populated areas (second paragraph)
- All flights take place at 14,000 ft MSL (second paragraph). The higher the altitude, the lower the crash probability as shown in the sensitivity study on pages VI-3 and VI-4 of BSC 2007c and in the RAI 2.2.1.1.3-004 response provided by the DOE on December 31, 2008.

1.3 INFORMATION REGARDING REDUCTION FOR AIRCRAFT CRASHING BEYOND THE TARGET AREA

The NUREG-0800 equation given on page 3.5.1.6-3 does not account for flight restrictions, particularly, altitude restrictions. Equation 5 of BSC 2007c defines the crash frequency into relevant repository facilities as:

$$F = \frac{N\lambda p_c l_m}{A_z} A \qquad \text{(Eq. 5 of BSC 2007c)}$$

where

N	=	annual number of flights (number/yr)
λ	=	crash rate (mi^{-1})
p_c	=	fraction of overflights posing a risk to surface facilities
l_m	=	mean length of flight through the airspace (mi)
A	=	effective target area (mi^2)
A_z	=	circular area beneath airspace (mi^2)

The mean length of flight through the airspace extends from one edge of the perimeter of the airspace to the other edge of the perimeter of the airspace on a straight path; however, only flights on a portion of this path pose a hazard to facilities. The impact points on the ground are uniformly distributed within a circular area beneath the flight-restricted airspace (Assumption 3.2.1 of BSC 2007c). Therefore, if an aircraft has flown past the facility and then crashes, the impact point could still be within the circular area beneath the flight-restricted airspace but it would be beyond the facilities and, thus, not be a threat to the facilities. These particular flights that have flown past the facilities are still included in the ratio of variables l_m, and A_z, in that they have not yet been removed from the analysis. The application of p_c, the fraction of overflights that pose a risk to surface facilities, is the only variable that eliminates these flights from contributing to the crash frequency, as shown in detail in the next set of equations. Therefore, the reduction for aircraft crashing beyond the target is not already taken into account by the ratio of the target area, A, and the restricted surface area, A_z.

Continuing with the derivation of the crash frequency formula, for a convex area, the mean length, l_m, of a chord intersecting the area is given by π multiplied by the area divided by the perimeter. Thus, for a circle of radius R:

$$l_m = \frac{\pi A_z}{L_z} = \frac{\pi A_z}{2\pi R} \qquad \text{(Eq. 6 of BSC 2007c)}$$

where

A_z	=	circular area beneath airspace (mi^2)
L_z	=	perimeter (mi)
R	=	radius of circle (mi)

Combining Equations 5 and 6 gives the expected annual frequency of crashes that initiate over the flight-restricted airspace and strike the relevant surface facilities.

$$F = \frac{N\lambda p_c l_m}{A_z} A = \frac{N\lambda p_c \pi A_z}{2\pi R A_z} A = \frac{N\lambda p_c}{2R} A \qquad \text{(Eq. 7 of BSC 2007c)}$$

where

N	=	annual number of flights (number/yr)
λ	=	crash rate (mi^{-1})
p_c	=	fraction of overflights posing a risk to surface facilities
A	=	effective target area (mi^2)
R	=	radius of flight-restricted airspace (mi)

The reduction taken due to the aircraft already being past the facilities before the crash initiation event is accounted for in p_c. Therefore, this equation accounts for the altitude limitation imposed by the flight-restrictions.

In summary, while it is possible and even likely that NUREG-0800 and the DOE methodology will result in substantially different crash frequencies, the DOE believes that the specific bases of

the Yucca Mountain approach are both consistent with 10 CFR Part 63 and NUREG-1804 and more restrictive than those of NUREG-0800.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.

RAI Volume 2, Chapter 2.1.1.3, First Set, Number 9: Supplemental Question: In the RAI response, NRC noted that the applicant assumes in Section 3.2.18 of the analysis that for flights that are outside the flight-restricted airspace, the ejection as the result of a crash-initiating event that results in a crash occurs before the aircraft enters the flight-restricted airspace. In BSC 2007c, page 59, DOE develops, based on historical data, a cumulative distribution function of distances that fixed-wing military aircraft traveled after the pilot ejected. However, the total distance traveled (i.e., the distance traveled from mishap to pilot ejection plus the distance traveled from pilot ejection to landing) may significantly exceed the distances shown in the applicant's cumulative distribution function based only on the distance from pilot ejection to landing.

On pages 2-4 of Enclosure 9, DOE presents a detailed response to this RAI. Specifically,

- Page 3, second sentence, DOE acknowledges that there are "long distances associated with engine mishaps that allow continued flight without pilot ejection or delayed pilot ejection." But DOE reasons that these mishaps "are either not crashes because of a successful landing or are in the database used as the basis for this analysis and, therefore, taken into account."

- Page 3, last paragraph, second sentence. DOE further argues that "the location of mishap onset, that is, the initiating event that takes place prior to ejection is made irrelevant by the use of the use of uniform crash density." In particular, this approach accounts for the scenario where the mishap onset can occur anywhere, and circumstances subsequently bring the ailing aircraft in proximity to the flight-restricted airspace, as can occur if the pilot stays with the disabled aircraft for an extended period of time before ejection.

- Page 4, second paragraph, second and third sentences, DOE acknowledges mixed mishap/ejection scenario [mm/es] in that an engine mishap could occur outside the flight-restricted airspace, with the pilot remaining in the aircraft, attempting to resolve the failure, eventually crossing the flight-restricted airspace. DOE reasons that in these [mm/es], "the pilot finally ejects at low altitude."

It is not clear that DOE's response addresses the key points of the RAI. DOE is correct that engine mishaps are included in DOE's analysis. DOE is also correct that assuming a uniform crash density model, the crashes into the target area would include crashes with all variation of distances from mishap initiation to crash. But the question is which of these are to be excluded due to the effect of the flight-restricted airspace? (excluded from contributing to the probability, not excluded from the analysis) Those which should be excluded are those whose

distance from mishap initiation to crash is less than the restriction radius; because these events must have initiated inside the radius where no aircraft operate.

The sensitivity analysis on pp 12-13 of Attachment VI of BSC 2007c appears to only address violations of DOE's proposed limit on the number of overflights permitted for the flight-restricted airspace and not to address [mm/es].

To resolve this RAI, NRC staff needs clarification on:

- What does DOE mean by "low-altitude" in its assumption that pilot ejections in [mm/es] occur at low-altitude?
- How is DOE's assumption 3.2.18 (i.e., [mm/es] do not occur) reasonable, given that DOE acknowledges in enclosure 9, page 4, second paragraph, second and third sentences that [mm/es] can occur?
- How sensitive is the calculated target area crash frequency to [mm/es]?

1. SUPPLEMENTAL RESPONSE

1.1 DEFINITION OF THE TERM "LOW ALTITUDE"

In the second paragraph on page four of the RAI 2.2.1.1.3-009 response (RAI Response) provided by the U.S. Department of Energy (DOE) on December 31, 2008, the DOE discusses a hypothetical scenario concerning a crash for which the pilot ejection occurs inside the flight-restricted airspace. The hypothetical situation paragraph states "the pilot finally ejects at low altitude." The DOE does not have an assumption in the analysis concerning pilot ejections "at low altitude." The term "low altitude" was intended to convey that the ejection occurred below 14,000 ft MSL because events at or above 14,000 ft MSL are addressed elsewhere in the frequency analysis, specifically in Section 4.3.2 of *Frequency Analysis for Aircraft Hazards for License Application*, identified in SAR Section 1.6.5 and this response as BSC 2007c.

1.2 EVALUATION OF ASSUMPTION 3.2.18

Assumption 3.2.18 of BSC 2007c states that for flights that are outside of the flight-restricted airspace, the ejection as the result of a crash-initiating event occurs before the aircraft enters the flight-restricted airspace. As stated in Section 3.2.14 of BSC 2007c and on page 3, fifth paragraph of the DOE RAI Response, only overflights are permitted over the Nevada Test Site, which is the airspace in question.

The DOE presumes that due to the flight restrictions, there will be no flights inside the flight-restricted airspace, defined as below 14,000 ft MSL and within the 4.9 nautical miles radius from the North Portal. Therefore, crash-initiation events will occur outside of the flight-restricted airspace. The frequency analysis does not take credit for pilot action as stated in Section 3.2.15 of BSC 2007c. As stated in the first paragraph on the third page of the DOE RAI Response, the DOE assumes that the pilot does not intentionally direct the plane away from or does not

intentionally direct the plane towards the facility. Thus, because the flight's initial path would not cross into the flight-restricted airspace, the ailing plane's path would also not cross into the flight-restricted airspace prior to pilot ejection. In addition, as stated in Section 3.2.18 of BSC 2007c, because flights over the Nevada Test Site are limited to overflights, crashes due to maneuvering would occur at distances far from the repository. In fact, the database of crashes used in this analysis verifies that there have been no crashes within 30 miles of the Yucca Mountain site.

However, the use of a uniform crash frequency density eliminates the need to have knowledge of the flight path or the distance from crash-initiation event to the point of pilot ejection. Only the distance from pilot ejection to crash impact is relevant. As stated in Section 4.3.3 of BSC 2007c, the repository surface facilities are not concentrated at the North Portal but are spread out over a 1.0-mi radius. Therefore, the distance of concern that a plane travels after pilot ejection is 4.6 miles (1.0 miles less than the 5.6-mi radius of the flight-restricted airspace). Thus, crash initiating events that occur outside the flight-restricted airspace that have a distance from ejection to crash that are less than 4.6 miles would not contribute to the probability of crash impact to the facilities. Only the crashes that have a distance from pilot ejection to crash impact that are greater than 4.6 miles, regardless of the cause of the event, contribute to the crash impact probability.

1.3 SENSITIVITY OF RESULT TO MM/ES (MISHAP OCCURS OUTSIDE THE FLIGHT-RESTRICTED AIRSPACE AND EJECTION OCCURS INSIDE)

An important point made on page 4 of the DOE RAI Response is that crashes in which pilot ejection occurs inside the flight-restricted airspace have not occurred and are, therefore, not in the large database of military mishaps found in Attachment III of BSC 2007c used for the analysis. The above statement provides support for the DOE conclusion that such a situation is of much lower frequency of occurrence than the crashes documented in the database found in Attachment III of BSC 2007c. Inclusion of these crashes would have an insignificant contribution to the overall result. Moreover, the conclusion that such a hypothetical situation is not a significant contributor to the overall result is verified by the sensitivity study on page VI-13 of BSC 2007c and discussed on page 4 of the DOE RAI Response. This sensitivity study not only addresses "violations" of the flight-restricted airspace, but the situation, termed "mm/es" by the NRC, in which the mishap occurs outside the flight-restricted airspace and ejection occurs inside. The sensitivity study determines that the "upper bound" of the violations of the flight-restricted airspace shows the insignificance of the "mm/es" originating from outside the flight-restricted airspace.

In summary, the aircraft crash methodology documented in BSC 2007c is appropriate and conservative when taken in its entirety. As stated in the supplemental response to RAI 2.2.1.1.3-007, although the risk-informed nature of 10 CFR Part 63 does not require an analysis to be conservative or bounding in every detail, the overall aircraft analysis does provide a conservative estimate of expected aircraft crash probability that is well below the threshold for screening aircraft crash from consideration as an external hazard.

2. COMMITMENTS TO NRC

None.

3. DESCRIPTION OF PROPOSED LA CHANGE

None.