ENG.20070925.0012

BSC

Design Calculation or Analysis Cover Sheet

Complete only applicable items.

1. QA: QA

2. Page 1

3. System Waste Handling System	4. Document Identifier 000-00C-WHS0-00200-000-00F

5. Title

Frequency Analysis of Aircraft Hazards for License Application

6. Group

Preclosure Safety Analyses

7. Document Status Designation

☐ Preliminary ☒ Committed ☐ Confirmed ☐ Cancelled/Superseded

8. Notes/Comments

Chris Kimura performed a methodology review.

This revision supersedes Rev. 00E. Due to extensive reorganization of sections, no revisions bars have been used. The document has been checked as an extensive revision.

Attachments	Total Number of Pages
I. Flights Through the Beatty Corridor	4
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RECORD OF REVISIONS

9. No.	10. Reason For Revision	11. Total # of Pgs.	12. Last Pg. #	13. Originator (Print/Sign/Date)	14. Checker (Print/Sign/Date)	15. EGS (Print/Sign/Date)	16. Approved/Accepted (Print/Sign/Date)
00A	Initial issue	39	39	Guy Ragan	Peter Davis Nohemi Ramirez	N/A	Dennis Richardson 5/07/04
00B	Reflect changes in safety approach. Reflect changes in inputs. Supersede Rev. 00A	84	IV-8	Guy Ragan	Pierre Macheret John Wang	N/A	Dennis Richardson 2/14/05
00C	Change the size and shape of the flight-restricted airspace. Cite a revised reference and delete another reference because copyright clearance for a reference was denied. Make other minor technical and editorial changes. Supersede Rev. 00B.	84	IV-8	Guy Ragan	Pierre Macheret	N/A	Dennis Richardson 5/2/05
00D	Reflect changes in safety approach. Include additional discussion and justification of assumptions. Address CR-5664 and CR-5665.	84	IV-6	K.L. Ashley	Pierre Macheret	N/A	Mark Wisenburg 8/23/05
00E	Reflect changes in safety approach and rewriting for clarity. Reduce the flight-restricted airspace radius. Add additional aircraft crash data. Revise surface facility assumptions. Reformatting	136	VI-14	K.L. Ashley	Pierre Macheret	N/A	Mark Wisenburg 10/24/06
00F	Add additional aircraft crash data. Revise surface facility assumptions.	152	VI-16	K.L. Ashley K.L. Ashley 9/19/2007	Pierre Macheret 09/19/07 Chris Kimura Chris Kimura 9/24/07	M. Frank	Mark Wisenburg 9/24/2007

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ACRONYMS

AGL	above ground level
CDF	cumulative distribution function
CRCF	Canister Receipt and Closure Facility
DIRS	Document Input Reference System
DOE	U.S. Department of Energy
EC	Electronic Combat
FAA	U.S. Federal Aviation Administration
IHF	Initial Handling Facility
MOA	military operations area
MSL	mean sea level
NM	nautical mile
NRC	U.S. Nuclear Regulatory Commission
NTS	Nevada Test Site
NTTR	Nevada Test and Training Range
PDF	probability density function
RF	Receipt Facility
USAF	U.S. Air Force
WHF	Wet Handling Facility
YMR	Yucca Mountain Repository

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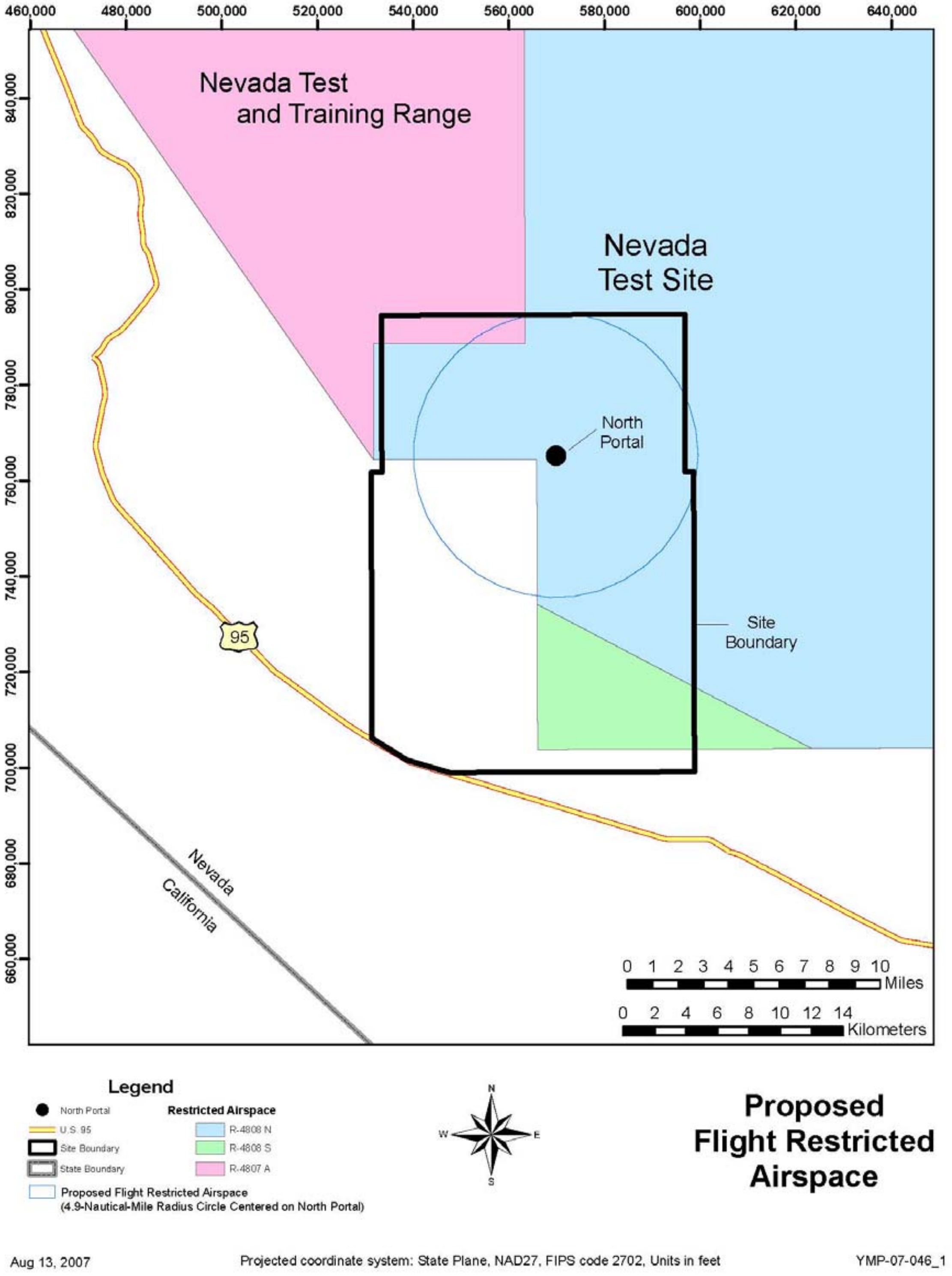
1. PURPOSE

The preclosure safety analysis for the monitored geologic repository at Yucca Mountain must consider the hazard that aircraft may pose to surface structures. Relevant surface structures are located beneath the restricted airspace of the Nevada Test Site (NTS) on the eastern slope of Yucca Mountain, near the North Portal (Figure 1). The North Portal is located several miles from the Nevada Test and Training Range (NTTR), which is used extensively by the U.S. Air Force (USAF) for training and test flights (Figure 1). The NTS airspace, which is controlled by the U.S. Department of Energy (DOE) for NTS activities, is not part of the NTTR. Agreements with the DOE allow USAF aircraft specific use of the airspace above the NTS (Reference 2.2.1 [DIRS 103472], Section 3.1.1 and Appendix A, Section 2.1; and Reference 2.2.2 [DIRS 157987], Sections 1.26 through 1.29). Commercial, military, and general aviation aircraft fly within several miles to the southwest of the repository site in the Beatty Corridor, which is a broad air corridor that runs approximately parallel to U.S. Highway 95 and the Nevada-California border (Figure 2). These aircraft and other aircraft operations are identified and described in *Identification of Aircraft Hazards* (Reference 2.2.3, Sections 6 and 8).

The purpose of this analysis is to estimate crash frequencies for aircraft hazards identified for detailed analysis in *Identification of Aircraft Hazards* (Reference 2.2.3, Section 8). Reference 2.2.3, Section 8, also identifies a potential hazard associated with electronic jamming, which will be addressed in this analysis. This analysis will address only the repository and not the transportation routes to the site. The analysis is intended to provide the basis for:

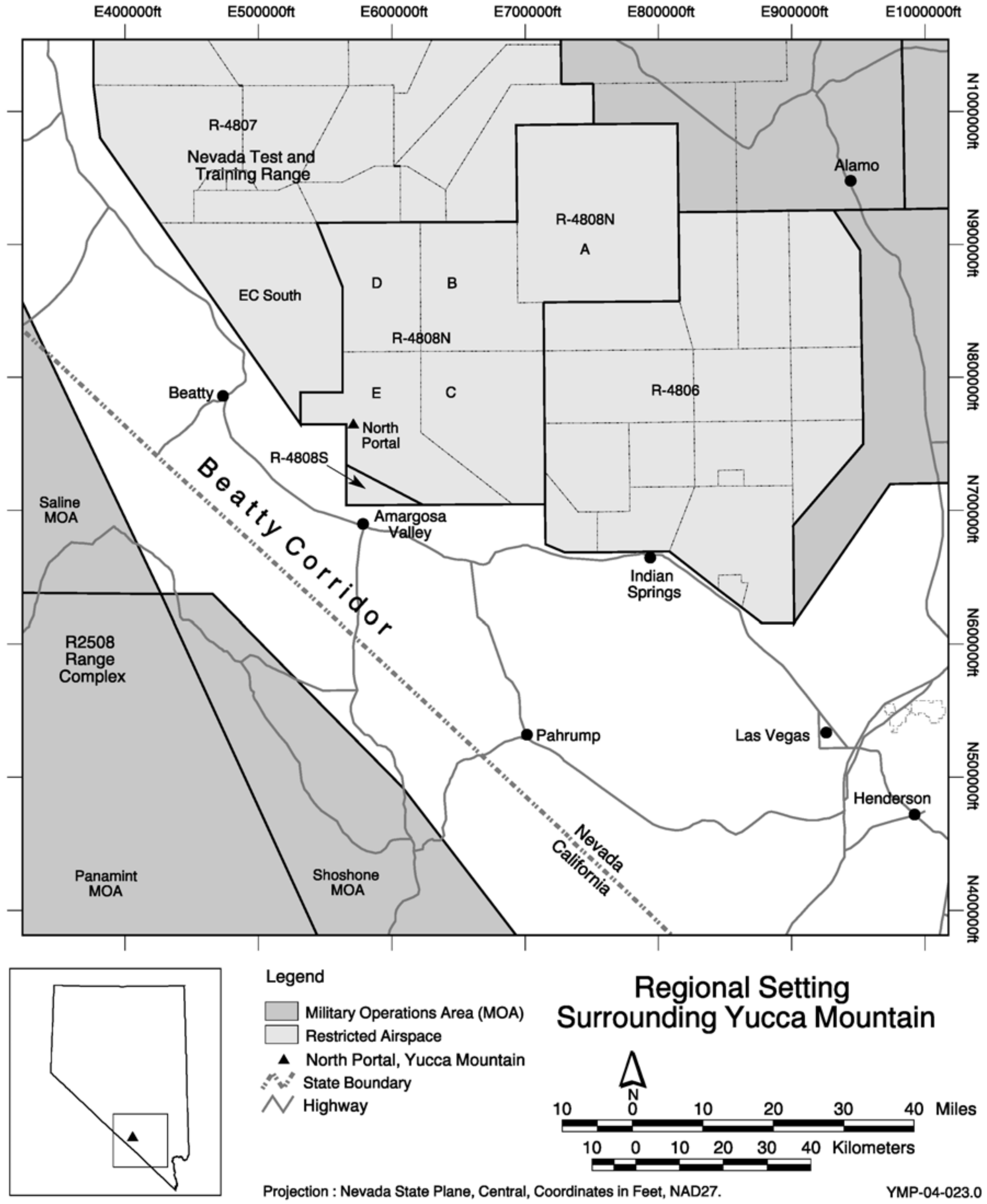
- Categorizing event sequences related to aircraft hazards
- Identifying design or operational requirements related to aircraft hazards.



Aug 13, 2007 Projected coordinate system: State Plane, NAD27, FIPS code 2702, Units in feet YMP-07-046_1

NOTE: The purpose of this figure is only for illustrating the location of the Flight-Restricted Airspace relative to the North Portal. No accuracy of information is intended or implied.

Figure 1. Features Near the Repository



NOTE: This figure is for illustrative purposes only.

Figure 2. The Beatty Corridor

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2.3 DESIGN CONSTRAINTS

None

2.4 DESIGN OUTPUTS

This calculation will be used as input for other calculations.

3. ASSUMPTIONS

3.1 ASSUMPTIONS REQUIRING VERIFICATION

No assumption in this analysis requires verification.

3.2 ASSUMPTIONS NOT REQUIRING VERIFICATION

3.2.1. Crash-Impact Points Uniformly Distributed Beneath the Flight-Restricted Airspace

Assumption: The distribution of crash-impact points for crashes that originate above the flight-restricted airspace (Section 4.3.2) is assumed uniform throughout the circular area beneath the airspace.

Rationale: Random variations in the distance traveled by aircraft, after initiation of a malfunction causing a crash, introduce randomness in the pattern of crashes on the ground. In addition, flight paths will be distributed throughout the area above the flight-restricted airspace (Assumption 3.2.4).

3.2.2. Flight Paths On the Beatty Corridor Approximately Straight and Parallel Near Yucca Mountain

Assumption: Flight paths are considered straight lines parallel to the edge of the flight corridor for the derivation in Section 4.3.1.

Rationale: The Beatty Corridor is defined in Assumption 3.2.8. The graphical displays of flight paths (Attachment I, Figure I-1) shows that, with respect to the relative sizes of the relevant surface structures (Sections 3.2.7 and 6.1.2) the assumption is reasonable in that the flights are approximately straight and parallel with respect to the boundary line between R-4808S and R-4808N (Figure 2). Any slight change in direction has no affect on the assumption and the analysis.

3.2.3. Flight Paths On the Beatty Corridor Uniformly Distributed Near Yucca Mountain

Assumption: Flight paths are uniformly distributed across the width of the Beatty Corridor for the derivation in Section 4.3.1.

Rationale: The Beatty Corridor is defined in Assumption 3.2.8. The radar tracks provided by the U.S. Federal Aviation Administration (FAA) (Attachment I, Figure I-1) show that flight paths are concentrated toward the center and away from the edges of the corridor. In this situation, the assumption is conservative because it exaggerates the flight density close to the facility. Although the flight density does not drop immediately to zero at the boundary of the Shoshone military operations area (MOA), defining the aviation corridor more narrowly with its southwestern edge at the Shoshone MOA exaggerates the crash rate density in the corridor and is therefore conservative.

3.2.4. Uniform Distribution of Overflights of the Flight-Restricted Airspace

Assumption: Overflights of the flight-restricted airspace are approximately uniformly distributed across the radius of the airspace.

Rationale: This assumption is consistent with recent historical observations as recorded in Attachment II.

3.2.5. Altitude of Flights Over the Flight-Restricted Airspace

Assumption: Overflights of flight-restricted airspace are assumed to conservatively be at 14,000 ft mean sea level (MSL), which is 10,000 ft above ground level (AGL).

Rationale: Due to the ceiling of the flight-restricted airspace, the altitude of aircraft is at least 14,000 ft MSL (Assumption 3.3.1). Elevations of the repository surface facilities are below 4,000 ft MSL (Reference 2.2.4). Therefore, the ceiling of the flight-restricted airspace is at least 10,000 ft above the repository surface facilities. In section 4.3.2 where this assumption is used, assuming the lowest allowable altitude for overflights results in the quickest descent to the ground in case of a crash, and thus is conservative. Reference 2.2.4 is used in this assumption for relative surface elevation and in Assumptions 3.2.6 and 3.2.7 for location and number of structures. Because this information is used in assumptions, the use of this reference is appropriate.

3.2.6. Maximum Dimension of the Site

Assumption: The radius of the smallest circle approximately centered on the North Portal and that encompasses the surface facilities where radioactive waste could be located is 1.0 mi.

Rationale: This is a modeling assumption used in Sections 4.3.2 and 4.3.3 to conservatively approximate the distance an aircraft would have to travel from the onset of the flight-restricted airspace to reach a surface facility. Reference 2.2.4 shows the layout of the site. The truck staging area is the southern most area where waste can be present. The plant grid coordinates for the North Portal are given in Reference 2.2.4 and can be estimated for the truck staging area. Reference 2.2.5 gives the plant grid coordinates for the northern most aging pad. Using these coordinates, the radius of the circle that encompasses all areas where waste is located is 0.9 miles. For conservatism, the radius is increased to one mile.

3.2.7. Relevant Surface Structures

Assumption: Relevant structures and areas of the surface facilities are given in Table 1. The included structures and areas are assumed to be in continuous use and at full capacity for waste transfer, staging, or aging throughout the emplacement period of 50 years (Assumption 3.3.4).

Rationale: Table 1 identifies the structures and areas used for spent nuclear fuel and high-level waste management. *DOE Standard, Accident Analysis for Aircraft Crash into*

Hazardous Facilities (Reference 2.2.6 [DIRS 101810], p. 19) states that a determination is made whether a facility contains sufficient inventory of hazardous radioactive material to pose a potential hazard. Using this criterion, the Low Level Waste Handling building has not been included in the relevant structures due to its very limited impact to potential offsite dose consequences. Section 6.1.4.5 of Reference 2.2.7 compares the source term from a fire event involving 100 low level waste drums with the source term from a seismic event. The source term from the seismic event is at least 10,000 times larger than the low-level waste fire event release source term. The resultant offsite public dose from the seismic event is 27 mrem (Reference 2.2.7, Table E-8). Thus, the resultant dose from the fire event involving 100 low level waste drums would be less than 0.0027 mrem. Even if an aircraft crash involved 100 times the low level waste inventory assumed in the analyzed low-level waste fire, the resultant dose at the site boundary would be less than 0.27 mrem. When this is compared to the performance objective of 15 mrem/yr for an offsite member of the public (Reference 2.2.8 [DIRS 180319], Paragraph 63.204), the Low Level Waste Handling building can be reasonably excluded from the list of relevant structures.

The surface facilities will be constructed in phases, thus some structures, such as the Wet Handling Facility, the Receipt Facility, the second and third Canister Receipt and Closure Facilities, and the second Aging Pad will not be operational during the initial part of the emplacement period (Reference 2.2.9, Section 2.2.1.10). The aging pads, even if fully available over the entire emplacement period, will take years to be filled and emptied. In Attachment V where this assumption is used, calculating the effective target area of the relevant structures by assuming that all structures and areas are at full capacity for the full surface operational period results in conservatively large effective target areas.

Table 1. Relevant Surface Structures

Building, Structure, or Area[a]	Quantity
Initial Handling Facility (IHF)	1
Canister Receipt and Closure Facility (CRCF)	3
Receipt Facility (RF)	1
Wet Handling Facility (WHF)	1
Aging Pad 17P	1
Aging Pad 17R	1
Rail Car Staging Area (not a building)	1
Truck Staging Area (not a building)	1
Loaded site transporters (not buildings)[b]	2

NOTES: [a] Numbers of structures, except aging pads (Reference 2.2.4).; Aging Pads (References 2.2.10 and 2.2.5).

[b] No estimate is available for the expected number of transporters in operation at any given time. Having two transporters in use at all times is considered to be conservative. Due to the size of the transporters as compared to the other areas and buildings, the overall effective target area is not sensitive to the precise number of the site transporters (See Section 6.1.2 for dimensions).

3.2.8. Definition of the Beatty Corridor

Assumption: The Beatty Corridor is defined to be a 26-mile wide band, with edges parallel to the Nevada-California border, passing between the edge of Shoshone MOA and passing within 5 mi of the North Portal at its closest. (Figure 2)

Rationale: The entire corridor between the R-2508 complex and the NTTR is used as a flight corridor (Figure 2) (Reference 2.2.11 [DIRS 158250]). Near Yucca Mountain, the width of the corridor is approximately 26 miles, measured as the closest distance between the Shoshone MOA to R-4808N (Reference 2.2.12 [DIRS 158638]). If the edge of the Beatty Corridor is defined to follow the border between R-4808S and R-4808N, and then angle slightly northward in a straight line to southernmost corner of EC South, then the closest distance to the North Portal at Yucca Mountain is about five miles (Figure 2) (Reference 2.2.12 [DIRS 158638], and Reference 2.2.13 [DIRS 149831]). The radar tracks for a typical day (Attachment I, Figure I-1) show that the northern half of R-4808S is infrequently used (Reference 2.2.14 [DIRS 177034]). Therefore the effective edge of the corridor is actually farther than 5 mi from the North Portal. A more realistic distance is about eight miles rather than five miles. This assumption is aimed at providing a simplifying modeling of the hazards posed to surface facilities by aircraft flying in the Beatty Corridor. This modeling is conservative because it assumes a distance between the edge of the Beatty Corridor and the North Portal shorter than in reality.

3.2.9. Assumed Frequency of Flights in the Beatty Corridor Under 10,000 ft

Assumption: The frequency of flights below 10,000 ft MSL in the Beatty Corridor is less than 10,000 per year. Flights below 10,000 ft MSL are assumed to be general aviation piston-engine aircraft.

Rationale: Radar coverage in the Beatty Corridor below 10,000 ft MSL is not reliable (Reference 2.2.15 [DIRS 160817]). Piston-engine aircraft are more likely than other aircraft to fly at low altitudes. Assumption 3.2.10 discusses the estimated flight frequency in the Beatty Corridor. The estimated frequency is five times the estimated 2005 annual count based on the average seven-day count. For the general aviation piston-engine flights, the estimated frequency was further augmented by an additional 10,000 flights per year to account for flights that occur below 10,000 ft MSL where the radar coverage is not reliable. The calculated crash frequency due to piston-engine general aviation aircraft, including the additional flights, is 1.36×10^{-9} y^{-1} (Section 6.5.1.3 and p. V-6), which is a small fraction of the frequency threshold 2×10^{-6} y^{-1} (Section 6.3). Therefore, the conclusions of this calculation are insensitive to the assumed frequency of flights below 10,000 ft MSL. Even so, the assumed frequency is likely to be conservative for the following reasons. The assumed flight frequency is equivalent to more than one flight every hour, 24 hours per day, 365 days per year. Flights below 10,000 ft MSL are less than 7,000 ft AGL, given a valley elevation of about 3,000 ft at the foot of Yucca Mountain (Reference 2.2.12 [DIRS 158638]) and are easily seen from the ground. Such flight activity would be noticed; yet, the area is not known for frequent low-altitude flights (Reference 2.2.3, Section 6.9).

3.2.10. Beatty Corridor Flight Frequency

Assumption: Estimated annual air-traffic counts in the Beatty Corridor (Table 2) are based on the average seven-day count from a 2005 FAA traffic count augmented by a factor of five and rounded up to the nearest 100 to accommodate traffic growth and uncertainty associated with data processing. The estimated annual counts (Table 2) are used in Attachment V to determine the annual crash frequency associated with flights through the Beatty Corridor.

Table 2. Estimates of Annual Traffic Counts for the Beatty Corridor

Aircraft Type	Average Seven-Day Count	Estimated 2005 Annual Count (52 weeks)	Estimated Annual Counts Used in Crash Frequency Calculation[a]
Small Military	55	2,860	14,300
Large Military	42	2,184	11,000
General Aviation Piston-Engine	64.5	3,354	26,800[b]
General Aviation Turboprop	342	17,784	89,000
General Aviation Turbojet	219.5	11,414	57,100
Air Taxi (14 CFR Part 135 [DIRS 168507])	214	11,128	55,700
Air Carrier (14 CFR Part 121 [DIRS 168506])	1,748.5	90,922	454,700
Total Annual Flights			708,600

NOTES: [a] Estimated annual counts are five times the estimated 2005 annual counts found in Table 3, rounded up to the nearest 100.

[b] The general aviation piston-engine count is five times the estimated 2005 annual counts, rounded up to the nearest 100, and increased by 10,000 per year (Assumption 3.2.9).

Rationale: Records of flights through the Beatty Corridor, in the form of tabular and graphical information, (Table 3), were tracked and provided by the FAA in 2005 (Reference 2.2.14 [DIRS 177034] and Reference 2.2.16 [DIRS 177035]). These data are further discussed in Attachment I. The tabular information consists of records of each flight tracked during two weeks in 2005, including aircraft information such as type, engine, weight class, as well as whether the flight was general aviation, air carrier (14 CFR Part 121, Reference 2.2.17 [DIRS 168506]), air taxi (14 CFR Part 135, Reference 2.2.18 [DIRS 168507]), or military, and the origin and destination of the flight. Attachment I explains how the FAA data were processed and displays an example of flights for one day, on a background of the airspace divisions of the NTTR and the R-2508 Range complex.

Table 3. Aircraft Counts On the Beatty Corridor From Two Weeks In 2005

Aircraft Type	Seven-Day Count Beginning Date		Average Seven-Day Count	Estimated 2005 Annual Count (52 weeks)
	6/1/2005	12/1/2005		
Small Military	38	72	55	2,860
Large Military	45	39	42	2,184
General Aviation Piston-Engine	83	46	64.5	3,354
General Aviation Turboprop	361	323	342	17,784
General Aviation Turbojet	197	242	219.5	11,414
Air taxi (14 CFR Part 135)	201	227	214	11,128
Air carrier (14 CFR Part 121)	1,769	1,728	1,748.5	90,922
Sum	2,694	2,677	2,685.5	139,646

SOURCES: Reference 2.2.14 [DIRS 177034] and Reference 2.2.16 [DIRS 177035].

To account for growth and for uncertainties associated with tracking, recording, analyzing and extrapolating the data, the estimated 2005 annual count from Table 3 was augmented by a factor of five (400% increase) and rounded up to the nearest 100. The data is reported in Table 2 as the estimated 2005 annual count used in the crash frequency calculation.

The FAA also provided one week of Beatty Corridor traffic data for every month in 2006 (Reference 2.2.19 [DIRS 181667]). To show that two weeks of data is sufficient for estimating annual traffic count, the 2006 FAA data was processed using the same method described above to estimate the Beatty Corridor annual count used in the analysis (five times the estimated annual count rounded to 100). Table 4 compares the 2006 weekly average and the estimated annual count, increased by a factor of 5, for two weeks of data, using the same months as provided in 2005, with one-week of data from every month. The total estimated annual count for the frequency analysis, using one week of data from every month, only increased 3.4%. However, note that if the annual counts used in the analysis (Table 2) were updated using the 2006 two weeks of data from June and December, the total counts would have decreased (708,600 from Table 2 versus 687,000 from Table 4). If the annual counts used in the analysis (Table 2) were updated using the 2006 twelve weeks of data, the total counts would have increased only 0.3% (708,600 from Table 2 versus 710,500 from Table 4). Using both sets of the 2006 data in the frequency calculation, the overall crash frequency would be 5.9×10^{-7} y^{-1} using two weeks of 2006 data and 5.9×10^{-7} y^{-1} using twelve weeks of 2006 data, which is the same as the analysis results using the 2005 data (Section 7). Thus, using two weeks of data results in approximately the same crash frequency. If this analysis is updated in the future, two weeks of data is sufficient.

Table 4. Aircraft Counts On the Beatty Corridor In 2006

Aircraft Type	Average Seven-Day Count Using Two Weeks	Estimated Annual Count For Frequency Analysis Using Two Weeks[a]	Average Seven-Day Count Using Twelve Weeks	Estimated Annual Count For Frequency Analysis Using Twelve Weeks[a]	Percent Difference Between Estimated Annual Counts
Small Military	50.5	13,200	51.1	13,300	0.8
Large Military	38.0	9,900	33.9	8,900	-10.1
General Aviation Piston-Engine	47.5	22,400[b]	67.2	27,500[b]	22.8
General Aviation Turboprop	276.0	71,800	285.1	74,200	3.3
General Aviation Turbojet*	218.0	56,700	240.6	62,600	10.4
Air taxi (14 CFR Part 135)	201.5	52,400	220.2	57,300	9.4
Air carrier (14 CFR Part 121)	1,771.5	460,600	1,794.8	466,700	1.3
Sum	2,603	687,000	2,692.8	710,500	3.4

SOURCES: Reference 2.2.19 [DIRS 181667]

NOTES: [a] Estimated annual counts are five times the average seven-day count based on either two weeks of data or twelve weeks of data, rounded up to the nearest 100.

[b] The general aviation piston-engine count is five times the estimated 2006 annual counts, rounded up to the nearest 100, and increased by 10,000 per year (Assumption 3.2.9).

As stated earlier, to account for growth and for uncertainties associated with processing the flight data, the estimated annual count is multiplied by five and rounded up to the nearest 100, which represents an increase of 400%. This increase also can be expressed as an increase of 2.5% every year compounded for 65 years. To show that this increase is sufficient to account for growth, the Beatty Corridor flight data for the years 2002, 2005 and 2006 are compared. Table 5 shows the flight counts for these years and the percent growth in the total flights from 2002. The percent growth from 2002 to 2005 is 3.9% while the percent growth from 2002 to 2006 is 2.1%. Therefore, increasing the estimated 2005 Beatty Corridor annual flight counts by 2.5% every year compounded for 65 years, which is equivalent to a 400% increase, reasonably represents the growth in the Beatty Corridor flights.

Table 5. Flight Counts On the Beatty Corridor for Various Years

	2002[a]	2005[b]	2006[c]
Average Seven-Day Count of all Aircraft Types	2,394.5	2,685.5	2,603.0
Annual Growth From 2002 to 2005		3.9%	
Annual Growth From 2002 to 2006			2.1%
Annual Growth From 2005 to 2006			-3.1%

SOURCES: [a] Reference 2.2.20 [DIRS 167725]

[b] Reference 2.2.14 [DIRS 177034] and Reference 2.2.16 [DIRS 177035].

[c] Reference 2.2.19 [DIRS 181667]

McCarran International Airport in Las Vegas, Nevada, has the largest operations per year of the airports in the vicinity of the repository (Reference 2.2.3, Table 6-4). Although the Beatty Corridor is only one of about twelve flight corridors into McCarran, the history of the landings at McCarran is evaluated to compare the flight history in the Beatty Corridor. Table 6 shows the number of landings per year at McCarran International Airport for the years 1996 through 2006, as well as the percent change from the previous year, the overall percent growth from 1996, and the overall percent growth from 2002.

Table 6. McCarran International Airport Landing Statistics

Year	Landings per Year	Change from Previous Year (%)	Annual Growth from 1996 (%)	Annual Growth from 2002 (%)
1996	164,477	-	-	-
1997	159,558	-3.0	-3.0	-
1998	164,715	3.2	0.1	-
1999	183,171	11.2	3.7	-
2000	196,583	7.3	4.6	-
2001	183,990	-6.4	2.3	-
2002	180,906	-1.7	1.6	-
2003	182,040	0.6	1.5	0.6
2004	205,327	12.8	2.8	6.5
2005	222,553	8.4	3.4	7.2
2006	228,690	2.8	3.4	6.0

Sources: Reference 2.2.21 ([DIRS 175667], p. 6) for years 1996 to 2001; Reference 2.2.22 ([DIRS 175666], p. 3) for 2002; Reference 2.2.23 ([DIRS 175665], p. 3) for 2003; Reference 2.2.24 ([DIRS 175664], p.3) for 2004; Reference 2.2.25 ([DIRS 181832], p. 3) for 2005; and Reference 2.2.26 ([DIRS 181801], p. 3) for 2006.

As seen in Table 6, the number of landings fluctuates from year to year, but McCarran airport has shown an overall growth in landings of 3.4% since 1996 and 6.0% since 2002. Although McCarran has shown a 6.0% growth in landings since 2002 (Table 6), during the same time frame of 2002 to 2006, the Beatty Corridor has only shown a 2.1% growth in the number of flights (Table 5).

The Beatty Corridor flight data provided by the FAA also gives the destination and origin of the flights. In 2002, 28% of the flights in the Beatty Corridor reported in Reference 2.2.20 [DIRS 167725] landed at McCarran International Airport, and in 2006, 32% of the Beatty Corridor flights landed at McCarran (Reference 2.2.19 [DIRS 181667]). This is a 14% increase, or a 3.4% growth rate, in the percentage of flights in the Beatty Corridor with a destination at McCarran. Table 7 shows the average number of flights per month in the Beatty Corridor with a McCarran destination and compares it to the actual landings at McCarran for that month. The helicopter landings have been excluded since they are not likely to originate from the Beatty Corridor. While the overall number of flights in the Beatty Corridor has show only a 2.1% growth since 2002 (Table 5), the percentage of those flights that go to McCarran has shown a 3.4% growth, as discussed earlier. In addition, as can be seen from Table 7, the percent of the McCarran landings that have originated in the Beatty Corridor has tracked consistently for the months compared. Thus, the flights in the Beatty Corridor that are used in this analysis reasonably represents future growth in the Beatty Corridor and the current and future growth at McCarran International Airport.

Table 7. McCarran Landing versus Flights in the Beatty Corridor

Month/Year	**McCarran Total Landings**[a]	**Helicopter Landings**[a]	**Difference**	**Beatty Corridor Flights with McCarran Destination**[b]	**Percent of McCarran Landings Originating in Beatty Corridor**
Aug/2002	15936	1445	14491	3138	22%
Nov/2002	14235	1348	12887	3224	25%
Jun/2005	18389	1544	16845	3491	21%
Dec/2005	18649	1410	17239	3711	22%
Jan/2006	18541	1439	17102	3680	22%
Feb/2006	17032	1367	15665	3476	22%
Mar/2006	19844	1810	18034	3729	21%
Apr/2006	19274	1911	17363	3720	21%
May/2006	19560	1752	17808	3809	21%
Jun/2006	19123	1565	17558	3634	21%
Jul/2006	19722	1732	17990	3494	19%
Aug/2006	20119	1823	18296	3892	21%
Sep/2006	18651	1220	17431	3484	20%
Oct/2006	19223	1188	18035	4100	23%
Nov/2006	18792	1358	17434	3797	22%
Dec/2006	18809	1028	17781	3747	21%

Sources: [a] Reference 2.2.22 ([DIRS 175666], p. 3) for 2002; References 2.2.25 ([DIRS 181832] p. 3) and 2.2.27 ([DIRS 181888] pp. 2 and 3) for 2005; and References 2.2.26 ([DIRS 181801] pp. 2 and 3) and Reference 2.2.28 ([DIRS 181889] pp. 2 and 3) for 2006.

[b] Reference 2.2.20 [DIRS 167725] for 2002; Reference 2.2.14 [DIRS 177034] and Reference 2.2.16 [DIRS 177035] for 2005; Reference 2.2.19 [DIRS 181667] for 2006.

The results of the analysis reported in Section 7 show that the conclusions of this calculation are insensitive to the flights in the Beatty Corridor in that the flights in the Beatty Corridor contribute approximately 5% of the total crash frequency.

3.2.11. Use of Fatal Accident Rate for 14 CFR Part 135 Crash Rates

Assumption: The fatal-accident rate, rather than the total accident rate, is used to estimate crash rates for commercial flight operations regulated by 14 CFR Part 135 (Reference 2.2.18 [DIRS 168507]).

Rationale: The total accident rate includes accidents that occur on the ground as well as other incidents, such as turbulence that cause injury to passengers or crew. The fatal accident rate is used in this analysis to discount minor accidents that are not relevant to this analysis. Any accident involving commercial flight that could affect the repository would originate on the Beatty Corridor at high altitude and would certainly involve fatalities. Use of the fatal-accident rate eliminates the minor accidents, but is conservative since some fatal aircraft accidents are not the result of crashes. For example, a person could walk into a spinning propeller or a fatality could occur during turbulence without resulting in a plane crash.

The calculated crash frequency of 8.05×10^{-9} y^{-1} (Section 6.5.1.6 and p. V-6), due to commercial flight operations regulated by 14 CFR Part 135 (Reference 2.2.18 [DIRS 168507]), is very low compared to the frequency threshold of 2×10^{-6} y^{-1} (Section 6.3). Therefore, the conclusions of this calculation are insensitive to the assumed accident rate for commercial flight operations regulated by 14 CFR Part 135.

3.2.12. Military Aircraft of Concern

Assumption: Small military aircraft of concern for flights over and outside the flight-restricted airspace are the F-15, F-16, F-22 and A-10.

Rationale: The F-16s, F-15s, and A-10s are the commonly used fighter and attack aircraft for exercises in the NTTR (Reference 2.2.3, Appendix B). The North Portal is located in R-4808W (Reference 2.2.1 [DIRS 103472], Figure 3.1-1), which is indicated as R-4808D and E in Figure 2. Of the 9,842 projected flights in R-4808W, over 87% are small military planes; Fighters and Attacks, which include Mirages and Tornadoes, for a total of 8,612, with 51% being F-16s, 28% being F-15s, 2% being A-10s, and about 7% making up the balance (Reference 2.2.1 [DIRS 103472], Table 6 of Appendix A.9). Large military planes account for less than 3% of the projected annual flights (Reference 2.2.1 [DIRS 103472], Table 6 of Appendix A.9); helicopters and other aircraft make up the balance. Therefore, F-15s, F-16s and A-10s are the small military aircraft of concern for the repository surface facilities. Because F-22s are projected to be the future attack/fighter plane of choice, it too is included as a small military aircraft of concern. This information was used for collecting historic crash data presented in Attachment III.

3.2.13. Military Aircraft Crash Rates

Assumption: The crash rate of 2.74×10^{-8} mi^{-1} for military aircraft overflights of the flight-restricted airspace is the updated F-16 accident rate in normal in-flight mode derived in Attachment IV. Crash rates used for military aircraft flying in the Beatty Corridor are the crash rate of 1.90×10^{-9} mi^{-1} for large military aircraft in normal operation (Section 6.2.2) and the updated crash rate of 2.74×10^{-8} mi^{-1} for the F-16, used for small military aircraft.

Rationale: The F-16 is projected to have almost twice the number of flights in R-4808W as the next most popular aircraft (Assumption 3.2.12). The estimated crash rate for F-16s in normal flight is greater than the corresponding crash rates of F-15s and A-10s (Reference 2.2.29 [DIRS 137367], Table 4.8). Table III-1 lists only two crashes for the F-22 in a 13-year period. Due to the limited crash data and operating history of the F-22 and due to the lower crash rates for F-15s and A-10s, it is reasonable to apply the crash rate for the F-16 to all small military aircraft.

The crash rate for the F-16 has been updated from crash data from 1989 to 1998 (2.736×10^{-8} mi^{-1}) using methodology that has been deemed acceptable by the US Nuclear Regulatory Commission in *Safety Evaluation Report Concerning the Private Fuel Storage Facility, Docket No. 72-22* (Reference 2.2.30 [DIRS 154930], Section 15.1.2.11). Attachment IV presents the derivation of the crash rates for F-15s and F-16s for the date range used in this analysis, 1990 to 2006, using the same methodology employed to derive the 2.736×10^{-8} mi^{-1} crash rate used in Reference 2.2.30. As seen in Attachment IV, the 10-year average crash rate increases slightly for the first three 10-year periods, decreases for three years and then increases slightly. To be conservative and to avoid the possibility of statistical aberrations that might occur from year to year, the 17-year average from 1990 to 2006 is used in this analysis. Thus, the updated crash rate for F-16 in normal flight mode of 2.74×10^{-8} mi^{-1}, which better represents the contemporary flight operations experience, is used in lieu of the value given in Table 14.

Military aircraft may use the Beatty Corridor for transit to and from NTTR airspace. The normal flight crash rate for large military aircraft of 1.90×10^{-9} mi^{-1} and the updated normal flight crash rate for the F-16 of 2.74×10^{-8} mi^{-1} are used for flights in the Beatty Corridor. It is appropriate to use the updated F-16 crash rate because it is based on flights in the area and because it better represents the contemporary flight operations experience. The normal-operations rate is used because the purpose of flight is transit not combat training.

The frequency of a large military aircraft crash originating in the Beatty Corridor is 1.57×10^{-9} y^{-1} (Section 6.5.1.2 and p. V-6), which is very low compared to the frequency threshold of 2×10^{-6} y^{-1} (Section 6.3). Therefore, the conclusions of this calculation are insensitive to the contribution from large military aircraft, and thus, the large military aircraft crash rate has not been updated.

The use of small aircraft crash rate for determining crash frequency for overflights of the flight-restricted airspace must be justified despite the fact that large aircraft may also be used for these overflights. The frequency of crashes into a surface facility is proportional to the crash rate and to the effective target area of the facility (see Equation 7, for example). The effective target area seen by small aircraft is about a factor of two less than that seen by large aircraft (Section 6.4 and Section V.1). However, the net effect of using the crash rate and effective target area for small aircraft is conservative because the crash rate for small aircraft is a factor of fourteen or more higher than that of large aircraft (2.74×10^{-8} mi^{-1} for small military aircraft versus 1.90×10^{-9} mi^{-1} for large military aircraft). In addition, large military aircraft account for less than 3% of the flights near the repository (Section 3.2.12).

3.2.14. Crash Frequency Density Outside the Flight-Restricted Airspace

Assumption: A uniform crash-frequency density of 7.5×10^{-5} crashes/y/mi^2 applies to military flight activities outside the flight-restricted airspace but in the NTS, the EC South area of R-4807, and the western portion of R-4806 as identified in Table 11. The uniform crash-frequency density does not apply to the southwest quadrant because those flights are accounted for in the Beatty Corridor (Assumption 3.2.10). Furthermore, it is assumed that crashes are uniformly distributed.

Rationale: The *Identification of Aircraft Hazards* report establishes a screening criterion by which federal, military and DOE designated airways more than 30 miles from the North Portal do not pose a hazard to the facility (Reference 2.2.3, Section 7.1.3). This criterion is based on NUREG-0800 (Reference 2.2.31 [DIRS 103124], Section 3.5.1.6) that states that federal airways, holding patterns or approach patterns at least two miles beyond the site presents an acceptably low risk. Thus, using the 30-mile criterion to establish a crash frequency density is conservative.

Table 8 identifies crashes that have occurred on the NTTR and Military Operations Areas (MOAs) from May 1990. However, none of the crashes have occurred in the NTS or NTTR within the 30-mile radius. Therefore, to estimate a crash frequency density within the 30-mile boundary, it is assumed that one crash has occurred. The area of concern is one half of the 30-mile circle since the other half is in the Beatty Corridor. The time frame is from May 1990 to December 2006, which is 16.5 years. Therefore, a conservative estimate of the military aircraft crash density in the vicinity of Yucca Mountain is:

$$(1 \text{ crash}) / (16.5 \text{ y}) / (0.5 \times \pi \times 30^2 \text{ mi}^2) = 4.3 \times 10^{-5} \text{ crashes / y / mi}^2.$$

The above crash density is now re-evaluated to further and conservatively account for military activity in a large regional setting. The NTS airspace is controlled by the DOE for NTS activities and is not part of the NTTR (Reference 2.2.1 [DIRS 103472], Section 3.1.1 and Appendix A, Section 2.1). Agreements with the DOE allow the USAF specific use of the airspace above the NTS. The specific use is published in the Weapons Range Management procedure (Reference 2.2.2 [DIRS 157987], Sections 1.26 through 1.29), which currently limits flights to overflight. However, to accommodate any future changes regarding the use of NTS airspace, it is assumed that military training activities in other portions of the NTTR and MOAs could be extended into NTS airspace (Reference 2.2.32 [DIRS 169894], pp. 5 and 6). Thus, to be conservative and to allow for future changes in airspace use, a crash-frequency density derived from crashes in the NTTR and MOAs, where aggressive flight and training exercises occur, is applied to flights within the 30-mile boundary in the NTS and NTTR. This is conservative as no aggressive maneuvering would be expected to occur in the vicinity of Yucca Mountain, which sits near the edge of the NTS and NTTR, less than 10 miles from the Beatty Corridor (Figure 2). The assumed density is derived from the number of crashes observed in the NTTR and MOAs over the 16.5-year period from May 1990 through December 2006, and the area of the NTTR and MOAs, excluding NTS.

The Nellis Air Force Range (also known as Nevada Test and Training Range), consisting of approximately three million acres of land, does not include the NTS (Reference 2.2.1 [DIRS 103472], p. ES-2). Additional airspace is included in the MOAs, for a total of approximately 15,000 mi^2 (Reference 2.2.33 [DIRS 177052], p. 2). This is approximately the restricted airspace area of the NTTR and the MOA, less the NTS. The crash frequency density for the expanded area is estimated to be:

$$(18 \text{ crashes}) / (16.5 \text{ y}) / (1.5 \times 10^4 \text{ mi}^2) = 7.3 \times 10^{-5} \text{ crashes / y / mi}^2.$$

A count of random events may be different for different realizations of the random process, that is, the calculated frequency density can change over time because crashes are random from year to year and the density will be different when the time span changes. As an example, if a 10-yr time span were used for determining the crash frequency density, the density varies from the lowest value of 6.0×10^{-5} crashes / y / mi^2 for the 10-yr period of 1995 to 2004 to the highest value of 8.0×10^{-5} crashes / y / mi^2 for the 10-yr period of 1991 to 2000 due to the number of crashes varying from year to year. If the most recent 10-yr period of 1997 to 2006 were used, the crash density would be 6.7×10^{-5} crashes / y / mi^2.

The calculated crash frequency density of 7.3×10^{-5} crashes / y / mi^2, which represents the crash frequency density for aggressive maneuvering and training activity, is rounded up to 7.5×10^{-5} crashes / y / mi^2 to account for future crashes beyond the historic trend. The crash frequency density of 7.5×10^{-5} crashes / y / mi^2, exceeds the most contemporary 10-yr period of 1997 to 2006, and it exceeds the calculated crash frequency density for the area within 30-mile of the repository. Thus, applying a crash frequency density based on aggressive maneuvering and training activity to the 30-mile area in the NTS and NTTR where this type of flight activity does not take place is conservative.

Table 8. Aircraft Crashes Within the Nevada Test and Training Range and Military Operations Areas

Date	Aircraft	Serial No.	Latitude	Longitude	Reference
28-Jan-91	F-16C	85-1423	3723	11449	Footnote 1 and Table III-1, #16
07-Oct-91	F-16CG	89-2059	3730	11612	Footnote 1 and Table III-1, #34
21-Jan-92	F-15C	81-0052	3714	11436	Footnote 1 and Table III-1, #42
10-Aug-92	F-15E	89-0479	3715	11430	Footnote 1 and Table III-1, #55
18-May-93	F-16C	87-0269	3659	11440	Footnotes 1, 2, and Table III-I, #73
10-Aug-93	F-16C	86-0250	3730	11616	Footnotes 1, 2, Table III-1, #80
08-Nov-93	F-16C	88-0448	3711	11526	Footnotes 1, 2, and Table III-I, #86
14-Feb-94	F-16C	87-0309	3652	11540	Footnotes 1, 2, and Table III-I, #96
16-Jun-99	F-15C	82-0008	3755	11601	Footnotes 1, 2, and Table III-I, #191
16-Jun-99	F-15D	79-0013	3755	11601	Footnotes 1, 2, 3, and Table III-I, #192
03-Aug-00	F-15C	86-0173	3751	11541	Footnotes 1, 2 and Table III-I, #208
08-Aug-00	F-16CG	88-0542	3658	11431	Footnotes 1, 2 and Table III-I, #209
04-Dec-02	A-10A	80-0225	3726	11624	Footnotes 1, 2 and Table III-I, #248
04-Dec-02	A-10A	79-0191	3726	11624	Footnotes 1, 2, 3, and Table III-I, #249
17-Mar-03	F-15C	80-0040	3704	11436	Footnotes 1, 2, and Table III-I, #250
18-Nov-03	A-10A	79-0143	3645	11527	Footnotes 1, 2, and Table III-I, #259
04-Jun-04	F-15C	79-0054	3659	11439	Footnote 1 and Table III-1, #265
25-Mar-05	F-15C	80-0052	3654	11438	Footnote 1 and Table III-1, #268

[1] See column 2 of Table III-1 for cited reference containing additional information.

[2] Reference 2.2.32 [DIRS169894], pp. 6 and 7

[3] Reference 2.2.32 [DIRS169894], pp. 6 and 7 gives only one crash on this date, however the incident was a midair collision with the loss of both planes.

There were two additional events identified by Reference 2.2.32 ([DIRS 169894], pp. 6 and 7) that were not included in Table 8. The item dated October 2002 involved an F-15C that experienced an engine malfunction, but the pilot shut down the engine and flew an uneventful single engine approach and landing (Reference 2.2.34 [DIRS 174431]). The incident in May 2003 involved an engine undergoing test cell runs (Reference 2.2.35 [DIRS 174430]). Although these two events involved a million dollar loss, neither incident involved a crash of an aircraft and, therefore, is not included in the list of aircraft crashes (Table 8). An additional event identified by Reference 2.2.32 ([DIRS 169894], pp. 6 and 7) involved an HH-60 helicopter, which is not included in this analysis due to restrictions on helicopter flights (Assumption 3.3.3).

3.2.15. Pilot Action

Assumption: No credit for pilot action is taken in this analysis.

Rationale: No credit is taken for pilot action for the time elapsed after the initiating event and before ejecting from the plane. Specifically, in Section 4.3.3, this translates into assuming that pilots do not intentionally direct their plane towards the repository or intentionally direct their plane away from the repository, which is reasonable. In Section 4.3.2, the assumption is conservatively applied by considering that the pilot ejects immediately after the initiating event that leads to a crash. This leads to the use of the glide ratios determined in Attachment III, which are determined from historical data from U.S. Air Force reports on aircraft crashes. The glide ratios are determined from the altitude the pilot ejected from the plane to the impact point. The glide ratios ranged from 0, where the pilot ejected just a few feet from the ground, to 11.2, with an average glide ratio of 2.6. As a comparison, when the pilot is attempting the recovery of an F-16 the glide ratio is about 8.5, derived from a glide ratio of 7 nautical miles for every 5,000 ft of altitude lost (Reference 2.2.36 [DIRS 177054], p. 5). Thus, if the F-16 glide ratio of 8.5 were used in Section 4.3.2 for determining the fraction of aircraft that have less than the glide ratio required to carry the aircraft past the facilities, that fraction would be zero, resulting in a zero crash frequency from overflights of the flight-restricted airspace. Thus, it is conservative to assume that there is no credit for pilot actions and the pilot ejects immediately after the cause of the in-flight emergency that leads to a crash.

3.2.16. Robustness of Structures and Components

Assumption: No credit is taken for the ability of transportation casks, aging casks, or the relevant surface facilities to withstand an impact by an aircraft.

Rationale: For conservatism, no credit is taken for the robustness of structures or casks to withstand an impact by an aircraft. Nevertheless, studies show no breach of a transportation cask, storage cask, or similar concrete structure, from an impact by a Boeing 747-400 or Boeing 767-400, reported in "Plane Tough Storage" (Reference 2.2.37 [DIRS 167732]) and "Deterring Terrorism: Aircraft Crash Impact Analyses Demonstrate Nuclear Power Plant's Structural Strength" (Reference 2.2.38 [DIRS 167733]).

3.2.17. Sorting of Military Aircraft Crashes

Assumption: Data on military aircraft crashes have been collected from May 1990 through December 2006 and are presented in Table III-1 of Attachment III. Each aircraft crash has been assigned an initiating-event type code that is used to evaluate the crash frequency from the allowable overflights of the flight-restricted airspace (Section 4.3.2). It is assumed that the following types of crash-initiating events are correctly applied to the crash data in Table III-1:

- Type 0 events are not applicable to overflight of the flight-restricted airspace.

- Type 1 events are applicable to overflight of the flight-restricted airspace.

Rationale: The aircraft crash data presented in Table III-1 of Attachment III is intended to be a comprehensive list of USAF crashes of aircraft of concern (Assumption 3.2.12), to the extent possible. The data is used to evaluate the crash frequency from the allowable overflights of the flight-restricted airspace. Since not all of the crashes are applicable to crashes that originate in a cruising type flight, the crashes have been sorted into two event types, as follows.

TYPE 0 EVENTS

The following initiating events from Table III-1 do not apply to overflight of the flight-restricted airspace for the reasons stated:

- Controlled flight into terrain. Not applicable because maneuvering is prohibited over the flight-restricted airspace. In addition, the altitude cap of the flight-restricted airspace is at least 10,000 ft above the repository surface facilities.
- Midair collision. Not applicable because maneuvering is prohibited over the flight-restricted airspace and midair collision is much more likely during simulated combat maneuvers.
- Bird impact. Not applicable because a bird impact is unlikely at 14,000 ft MSL. The USAF has collected information on reported bird strikes with aircraft. Statistics show that over 90% of the bird impacts have occurred at altitudes less that 2,500-ft and only 0.16% of the bird strikes have occurred at altitudes between 10,000 and 15,000 ft. (Reference 2.2.39 [DIRS 174423]). In addition, Table III-1 lists nine aircraft crashes caused by bird strikes. Three of the events occurred shortly after take off, while the remaining six events occurred between 300 and 2,200 ft AGL.
- Take-off mishap. Not applicable because of the location of airports.
- Landing mishap. Not applicable because of the location of airports.
- Abandoned aircraft during maneuvering. Not applicable over the flight-restricted airspace because maneuvering is prohibited.
- Loss of control during maneuvering. Not applicable over the flight-restricted airspace because maneuvering is prohibited.
- Loss of control during testing. Not applicable since testing is not consistent with transient, no maneuvering flight.
- Use of piddle pack. Not applicable since the use of a piddle pack is not considered straight and normal flight, which is required over the flight-restricted airspace (Events 10 and 59 from Table III-1).
- Engine failure from pilot error. Error occurred during defensive move during combat training, which is not applicable over the flight-restricted airspace because maneuvering is prohibited (Event 206 from Table III-1).
- Spatial disorientation. Spatial disorientation occurred during maneuvering, which is prohibited over the flight-restricted airspace. (Event 128 from Table III-1)
- No crash. The event did not involve the loss or damage of aircraft (Event 278 of Table III-1)

- Controlled bailout. The pilot intentionally ejected from the plane due to damage to the landing gear. (Event 279 of Table III-1)

TYPE 1 EVENTS

Type 1 events are applicable to overflights of the flight-restricted airspace. There are two subcategories of Type 1 events; Type 1A events where immediate ejection is unlikely, and Type 1B events where immediate ejection is considered likely. It is assumed that no action by the pilot intentionally takes the plane towards the facilities or away from the facilities (Assumption 3.2.15).

- Type 1A is a simple engine failure or airframe failure. Events 39 and 76 (Table III-1), which are airframe failure events, are categorized as Type 1A because the pilot was able to recover and return for an attempted landing in Event 39 and ejection occurred 5 minutes after the malfunction in Event 76, indicating that the pilot was able to be in control of the aircraft for a period of time.

- Type 1B is for events that may lead to immediate ejection, such as engine failure with complications (fire for example), inadvertent ejection, loss of control (except during maneuvering or acrobatics, which is Type 0), centerline tank explosion and unknown. Unknown was used for events with insufficient information for determining the cause of the initiating event. There is one event with an unknown cause and it has conservatively been classified as Type 1B.

These subcategories are strictly used for the sensitivity analysis of the glide capability of the plane presented in Attachment VI.

3.2.18. Ejection Location Outside the Flight-Restricted Airspace

Assumption: For flights that are outside of 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.

Rationale: Table 8 identifies crashes that have occurred on the NTTR and Military Operations Areas from May 1990. However, none of these crashes have occurred in the NTS or NTTR within a 30-mile radius of the North Portal. Cross-referencing Table 8 with Table III-1 shows that over 80% of the crashes in Table 8 are a direct result of aggressive maneuvering; specifically, controlled flight into terrain, abandoned aircraft during maneuvering, loss of control during maneuvering, and midair collision. Maneuvering is unlikely to occur near the repository because the repository is located on the edge of the NTTR and NTS and less than 10 miles from the Beatty Corridor (Figure 2). Aggressive maneuvering could be a hazard for the commercial and general aviation flights in the Beatty Corridor. In addition, as stated in Section 3.2.14, flights over the NTS are limited to overflights. Therefore, crashes due to maneuvering would occur at distances far from the repository. Note that the crash frequency density determined from the Table 8 crashes is conservatively applied to the area within a 30-mile radius of the North Portal (Assumption 3.2.14)

However, crashes could originate from aircraft transiting the area but not intending to fly over the flight-restricted airspace. For either case, no pilot action is assumed (Assumption 3.2.15), that is the pilot does not steer the aircraft intentionally away from the repository or intentionally towards the repository. Therefore, even a pilot that is attempting to glide an aircraft after an initiating event would simply translate the location of the ejection point, but the initiating event would have occurred too far away in the first place for the ejection to realistically occur inside the flight-restricted airspace. In fact, considering that ejection could occur right at the edge of the flight-restricted airspace is most likely conservative.

There is a possibility that an aircraft could be flying towards the flight-restricted airspace at an altitude lower than the altitude of the flight-restricted airspace, 14,000 ft above mean sea level (MSL) (Assumption 3.3.1), with the intention of veering around the airspace or increasing the altitude to go over the airspace and an initiating event occurs prior to the course change. Because this analysis does not take credit for pilot action (Assumption 3.2.15) and the pilot does not alter the course due the initiating event, the aircraft could fly into the flight-restricted airspace and ejection could occur within the airspace at an altitude lower than 14,000 ft MSL. These flights would be considered improbable since pilots would be unlikely to intentionally fly towards a flight-restricted airspace with the intention of altering course at the last minute. In any case, these flights are addressed in the sensitivity analysis found in Attachment VI.

3.3 ASSUMPTIONS NOT REQUIRING VERIFICATION THAT CALL FOR DESIGN OR OPERATIONAL REQUIREMENTS

3.3.1. Flight-Restricted Airspace Surrounds the North Portal

Assumption: A flight-restricted airspace for fixed-wing aircraft extending to 14,000 ft MSL surrounds the North Portal. The flight-restricted airspace is cylindrical in shape, with a radius of 4.9 nautical miles (NM) (5.6 mi) (Figure 1). The cylinder is centered on the North Portal, which is inside the smallest circle that encompasses the surface facilities (Assumption 3.2.6).

Rationale: A flight-restricted airspace is credited in this analysis to reduce the crash frequency due to flights through the NTTR and NTS airspace. The radius of the flight-restricted airspace is an important determinant of its effectiveness, as shown in Sections 4.3.2 and 4.3.3. The height of the flight-restricted airspace is set to 14,000 ft MSL so that aircraft that suffer a crash-initiating event while flying over the airspace would likely be able to glide most, if not all, of the way through the area. Separate restrictions are imposed on helicopters (Assumption 3.3.3).

3.3.2. Restrictions on Overflights of the Flight-Restricted Airspace

Assumption: The annual number of overflights of the flight-restricted airspace by fixed-wing aircraft is limited to 1,000 overflights per year. Tactical maneuvering is prohibited over the flight-restricted airspace; flights are straight and level. Carrying ordnance and electronic jamming activities over the flight-restricted airspace are prohibited.

Rationale: A limited number of straight-line overflights can be tolerated, as discussed in Section 4.3.2. The prohibition of tactical maneuvering allows the crash rate for normal flight to be used and ensures that flight paths are approximately straight as required in the derivation of the crash-frequency model (Section 4.3.2). The prohibition of ordnance reduces the threat from accidental release of ordnance during overflights or from intentional jettison of ordnance in case of in-flight emergencies. Electronic jamming activities are not consistent with transitory flight and as such aircraft overflying the flight-restricted airspace are prohibited from engaging in electronic jamming activities during overflights of the flight-restricted airspace.

3.3.3. Helicopter Flights Prohibited Within One-Half Mile of the Relevant Surface Facilities

Assumption: An operational requirement prohibits helicopter flights within one-half mile of the relevant surface facilities and areas listed in Table 1. A design requirement will require the helipad associated with the repository to be located at least one-half mile from the relevant surface facilities.

Rationale: The purpose of this assumption (design requirement) is to eliminate helicopter activity from consideration in the aircraft impact frequency.

On an hourly basis, general aviation helicopters with reciprocating-piston engines in flight mode crash at a rate of about 7.7×10^{-5} h^{-1} when crashes during takeoff and landing are omitted (Reference 2.2.29 [DIRS 137367], Table 3.34). Such a high crash rate implies that very little helicopter activity within crash range of the relevant surface facilities can be tolerated without exceeding the goal established above or 2×10^{-6} y^{-1} Category 2 event sequence frequency threshold (Section 6.3) when added to the overall results in Section 7. DOE-STD-3014-96, *DOE Standard, Accident Analysis for Aircraft Crash into Hazardous Facilities,* (Reference 2.2.6 [DIRS 101810], pp. 45 and 46), states that lateral variations in crash locations for a helicopter are conservatively assumed to be one-quarter mile on average from the centerline of its flight path. In addition, the skid distance for helicopters is zero (Reference 2.2.6 [DIRS 101810], Table B-18). Thus, helicopters within one-quarter mile from the centerline of their flight path are not within crash range and can be eliminated from consideration. Doubling this distance to one-half mile adds further conservatism.

Locating the helipad one-half mile from the relevant surface facilities also eliminates any potential impact to relevant surface structures (Table 1) due to landing or takeoff mishaps. Rotary wing aircraft are not considered to be capable of runway overruns and runoffs as their takeoff and landing runs are considered to be small, in the order of tens of feet rather than hundreds or thousands of feet for fixed wing aircraft (Reference 2.2.29 [DIRS 137367], Section 3.4). Locating the heliport one-half mile from the relevant surface structures eliminates from consideration helicopters in flight approaching the heliport and helicopter landings and takeoffs.

3.3.4. Duration of Emplacement Activities

Assumption: An operational requirement will limit the duration of emplacement activities to 50 years or less.

Rationale: Potential aircraft accidents only pose a hazard to radioactive waste prior to waste emplacement when the waste is located on the surface. Fifty years is a reasonable upper limit for useful life of surface facilities and allows ample time for waste emplacement and is consistent with design requirements (Reference 2.2.9, Sections 2.2.2.7 and 2.2.2.8).

4. METHODOLOGY

4.1 QUALITY ASSURANCE

This calculation was prepared in accordance with EG-PRO-3DP-G04B-00037, *Calculations and Analyses* (Reference 2.1.1) and LS-PRO-0201, *Preclosure Safety Analyses Process* (Reference 2.1.2). Therefore, the approved version is designated as QA:QA.

4.2 USE OF SOFTWARE

The commercially available Microsoft® Excel 2003, which is a component of Microsoft® Office 2003 Professional, and Mathsoft® Mathcad® Version 13.0 are used in this calculation to perform standard mathematical functions, which do not depend on the particular software program. The formulas used in this analysis are presented in sufficient detail in Section 4.3 and elsewhere at the point of use to allow the independent check to reproduce or verify the results using hand calculations, which was performed. Plots created using Excel were verified by visual inspection. Usage of Microsoft® Office 2003 Professional and Mathsoft® Mathcad® Version 13.0 in this calculation constitutes Level 2 software usage, as defined in IT-PRO-0011 (Reference 2.1.3, Attachment 12), and as such are listed in the current *Controlled Software Report*. Mathcad® is engineering software and is listed on the *Repository Project Management Automation Plan,* (Reference 2.1.4, Table 6-1). The operating environment used was Microsoft® Windows 2003 installed on a Dell OPTIPLEX GX620.

4.3 AIRCRAFT HAZARDS METHODOLOGY

Potential aircraft hazards requiring evaluation are identified in Reference 2.2.3 (Section 8) and listed in Section 6.1.1. These potential hazards are from three distinct sources: aircraft that travel in the Beatty Corridor (Assumption 3.2.8), military aircraft that traverse the flight-restricted airspace (Assumption 3.3.1), and military aircraft that fly outside of the flight-restricted airspace but in R-4808 (the NTS) and the EC South area of R-4807 and the western portion of R-4806 (parts of the NTTR) .

The methods derived in this section are used for estimating frequencies of aircraft crashes into surface facilities. These methods form the basis of the frequency calculations in Section 6 and Attachment V.

4.3.1. Crash Frequency Methods for Flights in the Beatty Corridor

This section presents the methodology for calculating the annual frequency of crashes into the relevant surface facilities when the initiating event leading to the crash occurs in the Beatty Corridor. The Beatty Corridor is defined to be a 26-mile wide band, with edges parallel to the Nevada-California border, passing between the edge of Shoshone MOA and passing within 5 mi of the North Portal at its closest (Assumption 3.2.8) (Figure 2). The Beatty Corridor contains federal airways, jet routes, and uncontrolled airspace (Reference 2.2.3, Section 8). In screening for potential aircraft hazards, NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants* (Reference 2.2.31 [DIRS 103124], Section 3.5.1.6

Criteria II.1(c)), states that a federal airway, holding pattern, or approach pattern at least 2 miles beyond the site presents an acceptably low risk. Therefore, using the NUREG-0800 Screening Criteria II.1(c), the flights in the Beatty Corridor could be eliminated from the hazards evaluation since they are at least five miles from the repository. However, for conservatism, the NUREG-0800 Screening Criteria II.1(c) was increased by a factor of 15 to 30 miles (Reference 2.2.3, Section 7.1.3) and the flights in the Beatty Corridor are evaluated for potential hazards.

4.3.1.1. NUREG-0800 Model for Airways

NUREG-0800 (Reference 2.2.31 [DIRS 103124], Section 3.5.1.6), states that for situations where federal airways or aviation corridors pass through the vicinity of the site, the probability per year of an aircraft crashing into the plant will depend on a number of factors such as the altitude, frequency and crash rate of the flights, and the width of the corridor. The following formula is given in NUREG-0800 as one way to calculate the frequency, *F*, of aircraft crashes into a facility when aviation corridors pass through the vicinity of the site, that is less than two miles away per NUREG-0800 Section 3.5.1.6 Criterion II.1(c):

$$
\begin{aligned}
F &\quad \frac{N\lambda}{w+2d}A \quad \text{for } d > 0; \\
F &\quad \frac{N\lambda}{w}A \quad \text{otherwise}\,,
\end{aligned}
\qquad \text{(Eq. 1)}
$$

where

$N =$ annual frequency of flights passing through flight area
$\lambda =$ crash frequency per mile
$w =$ width of airway
$d =$ distance from the edge of the airway to the facility
$A =$ effective target area

The formula may be regarded as the product of two factors: (1) the uniform areal crash density per year associated with a band that includes the flight corridor and extends out the distance to the facility on either side, and (2) the effective target area of the facility.

As shown in Section 4.3.1, the flights in the Beatty Corridor could have been screened from evaluation using the NUREG-0800 Screening Criteria (Reference 2.2.31 [DIRS 103124], Section 3.5.1.6) since the Beatty Corridor is more than two miles away from the site. Indeed, one feature of the NUREG-0800 (Reference 2.2.31 [DIRS 103124], Section 3.5.1.6) model that restricts the applicability of Equation 1 to the Yucca Mountain surface facilities is its treatment of edge effects. Because a uniform distribution is used, the crash-rate density assigned to the center of an airway is the same as that near the edge or beyond it as far away as the facility. The surface facilities for the Yucca Mountain repository will be more than five miles from the edge of an airway (Section 3.2.8), so edge effects are important. Thus, a more detailed analysis adjusting Equation 1 to account for edge effects is warranted.

4.3.1.2. An Exponential Model for the Beatty Corridor Airway

Solomon developed a model to estimate the probability that an aircraft passing near the Palo Verde nuclear power plant would impact the plant (Reference 2.2.54 [DIRS 167315], Appendix A.3) and published the model in "Analysis of Ground Hazards Due to Aircrafts and Missiles" (Reference 2.2.55 [DIRS 173314], p. 5). The assessment of aircraft hazards for the Palo Verde nuclear power plant was independently verified by the Nuclear Regulatory Commission (NRC) and found acceptable in NUREG-0857 (Reference 2.2.56 [DIRS 171469], Section 2.2.2). Solomon introduced the PDF $f(x)$ to describe the probability that a crash occurs at a distance x from an intended flight path. The size of the facility and its distance from the flight path are assumed to be such that $f(x)$ can be considered constant across the width of the facility in the x direction; that is, perpendicular to the intended flight path. The incremental distance, dx, which is necessary to convert the probability density into a probability, is approximated as Δx, the width of the facility in the x direction, and is absorbed into the definition of the effective target area, A. The flight path is assumed straight as it passes near the facility (Assumption 3.2.2). Solomon argued that $f(x)$ should be symmetrical on either side of the intended flight path, about $x = 0$, and that it should decay monotonically with distance from the flight path.

Reference 2.2.55 ([DIRS 173314], p.5) adopted the double exponential distribution with decay constant, γ, as follows:

$$f(x) \quad \frac{\gamma}{2} e^{-\gamma|x|} . \tag{Eq. 2}$$

To apply the double-exponential model to the Beatty Corridor, assume that flights are uniformly distributed across the width, w, of the airway (Assumption 3.2.3). The applicable uniform PDF is $1/w$. Because the analysis only concerns one side of the airway, it can be assumed, without loss of generality, that $x \geq 0$. The distance from the facility to the edge of the airway is denoted by d. For a site outside the airway, $d > 0$, the annual crash frequency for N annual flights on the airway with crash rate λ (mi^{-1}) into effective target area A (mi^2) is given by:

$$\begin{aligned} F \quad & N\lambda f(x)A \\ & N\lambda(\frac{\gamma}{2} e^{-\gamma x})A. \end{aligned} \tag{Eq. 3}$$

The crash frequency due to uniformly distributed flight paths across the width w of the airway is given by:

$$\begin{aligned} F \quad & \int_{d}^{d+w} \frac{N\lambda\gamma A}{2} e^{-\gamma x} \frac{1}{w} \mathrm{d}x \\ & \frac{N\lambda\gamma A}{2w}\left[-\frac{e^{-\gamma x}}{\gamma}\right]_{d}^{d+w} \\ & \frac{N\lambda A}{w}[\frac{e^{-\gamma d}(1-e^{-\gamma w})}{2}]. \end{aligned} \tag{Eq. 4}$$

Equation 4 is the same as the NUREG-0800 model (Reference 2.2.31 [DIRS 103124], Section 3.5.1.6) for a facility within the airway (Equation 1), except for the term in square brackets. Therefore, the edge adjustment, ρ, with respect to the NUREG-0800 model's value for a facility within the airway is $e^{-\gamma d}(1-e^{-\gamma w}) / 2$. For airways wide enough that $w >> 1/\gamma$, the term in parentheses is approximately equal to 1, so that the edge adjustment is approximately $e^{-\gamma d} / 2$. A special case emerges when the facility is located on the edge of a wide airway such that $d = 0$ and $w >> 1/\gamma$. The term in square brackets becomes approximately equal to 0.5. In that case, the edge adjustment with respect to the NUREG-0800 model is 0.5. This is not the case for the Yucca Mountain facilities since the North Portal is 5 miles from the edge of the Beatty Corridor (Assumption 3.2.8).

The Solomon model (Reference 2.2.55 [DIRS 173314], p. 5) requires estimates of the exponential decay constant γ. For the exponential distribution of crash locations, $1/\gamma$ is the mean distance to the crash from the intended flight path. Based on an examination of crash histories (Reference 2.2.54 [DIRS 167315], Appendix A.3), Solomon estimated the following exponential decay constants, depending on the type of aircraft:

- $\gamma = 1$ mi^{-1} for military aircraft
- $\gamma = 2$ mi^{-1} for general aviation other than aerial application
- $\gamma = 1.6$ mi^{-1} for air carriers.

Recall that the edge adjustment for the exponential model is approximately $e^{-\gamma d} / 2$. Table 9 and Figure 3 illustrates the exponential model with varying distances from the edge of the airway to the facility, d, and the decay constants for the aircraft types. As can be seen from Figure 3, high-performance military aircraft that fly at a wide range of altitudes are predicted to travel the farthest to the crash site from the intended flight path (Table 9 and Figure 3). General aviation that fly at lower altitudes travel the least distance from the intended flight path, while air carriers that fly at higher altitudes travel in between the two other types of aircraft. Also shown in Figure 3, the exponential model supports the NUREG 0800 Screening Criteria II.1(c) (Reference 2.2.31 [DIRS 103124], Section 3.5.1.6), which states that a federal airway, holding pattern, or approach pattern at least 2 miles beyond the site presents an acceptably low risk. This is evident because at 2 miles, the edge adjustment to NUREG-0800 model (Equation 1) ranges from 0.01 to 0.07, depending on the decay constant, and drops to essentially zero by 4 miles. Stated otherwise, the exponential model is compatible with NUREG-0800 for flight corridors farther than 2 miles from the site. Since the repository is over 5 miles from the Beatty Corridor, using the exponential model is acceptable.

Table 9. Example Edge Adjustments as a Function of Distance From the Airway

Distance *d* from Edge of Airway (mi)	**Exponential Model** **exp(−γ*d*) / 2**		
	γ=1	**γ=1.6**	**γ=2**
0	5.0E-01	5.0E-01	5.0E-01
1	1.8E-01	1.0E-01	6.8E-02
2	6.8E-02	2.0E-02	9.2E-03
3	2.5E-02	4.1E-03	1.2E-03
4	9.2E-03	8.3E-04	1.7E-04
5	3.4E-03	1.7E-04	2.3E-05
6	1.2E-03	3.4E-05	3.1E-06
7	4.6E-04	6.8E-06	4.2E-07
8	1.7E-04	1.4E-06	5.6E-08
9	6.2E-05	2.8E-07	7.6E-09
10	2.3E-05	5.6E-08	1.0E-09

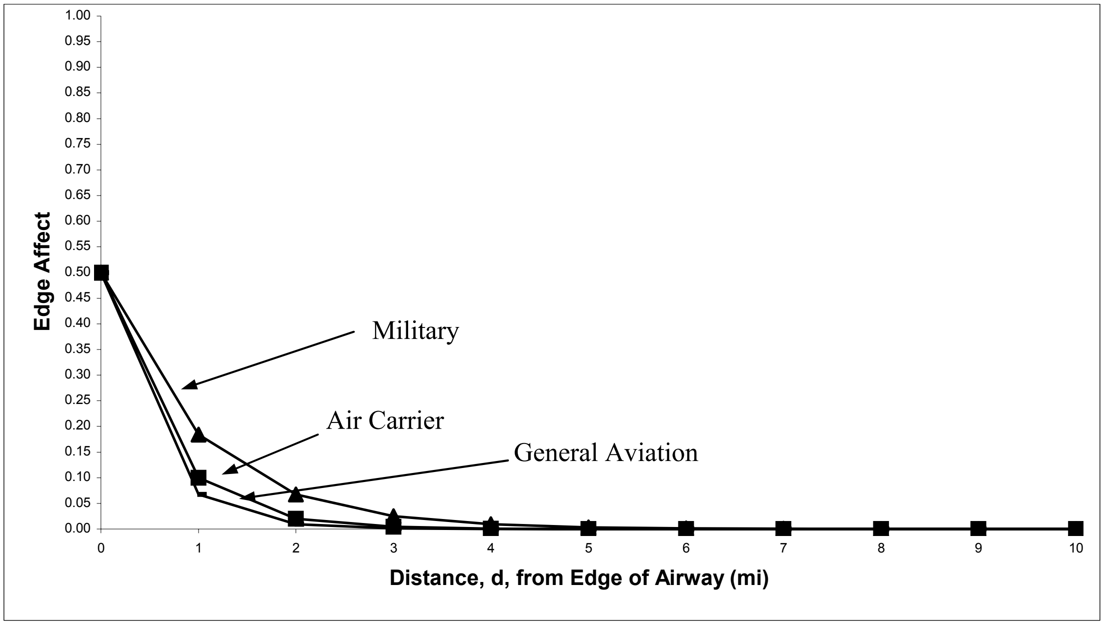

Figure 3. Illustration of Exponential Airway Models

4.3.2. Allowing for Overflights of the Flight-Restricted Airspace by Fixed-Wing Aircraft

This section presents the methodology for calculating the annual frequency of crashes into the relevant facilities when the initiating event leading to the crash occurs during an overflight of the flight-restricted airspace. To allow flexibility in the use of airspace near the repository, it is assumed that there is a specified annual frequency of overflights of the flight-restricted airspace by fixed-wing aircraft (Assumption 3.3.2). Aircraft are assumed to pass straight through the area above the flight-restricted airspace (Assumption 3.3.2), to be approximately uniformly distributed across the radius of the flight-restricted airspace (Assumption 3.2.4), and fly at the minimum allowable altitude (Assumption 3.2.5). Let N be the annual frequency of flights (y^{-1}) that pass over the flight-restricted airspace, and λ be the crash rate (mi^{-1}). The expected annual frequency of crashes initiated over the flight-restricted airspace is given by $N\lambda l_m$, where l_m is the mean length (mi) of flights over the flight-restricted airspace. Due to the altitude ceiling of the flight-restricted airspace, an aircraft flying over the restricted airspace that experience a crash-initiating event may have already flown past the facilities or may have sufficient glide ratio to carry it past the facilities. Thus, some fraction, p_c, of the flights that suffer crash-initiating events during overflight of the flight-restricted airspace pose a risk to repository surface facilities. It is assumed that the impact points on the ground are uniformly distributed within a circular area beneath the flight-restricted airspace, A_z (Assumption 3.2.1).

Given an effective target area, A, of the relevant surface facilities, the crash frequency into relevant repository facilities is:

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

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 (Reference 2.2.57 [DIRS 160334], p. 30). Thus, for a circle of radius R:

$$\begin{aligned} l_m &= \frac{\pi A_z}{L_z} \\ &= \frac{\pi(\pi R^2)}{2\pi R} \\ &= \frac{\pi R}{2}, \end{aligned} \qquad \text{(Eq. 6)}$$

where

A_z = surface area
L_z = perimeter

Combining Equations 5 and 6 gives the expected annual frequency of crashes that initiate over the flight-restricted airspace and strike relevant surface facilities (Table 1):

$$\begin{aligned} F \quad & \frac{N\lambda p_{\mathrm{c}} l_m}{A_{\mathrm{z}}} A \\ & \frac{N\lambda p_{\mathrm{c}} \pi R}{2\pi R^2} A \\ & \frac{N\lambda p_{\mathrm{c}}}{2R} A. \end{aligned} \qquad \text{(Eq. 7)}$$

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)

As shown in Section 4.3.1.1, NUREG-0800 (Reference 2.2.31 [DIRS 103124], Section 3.5.1.6) provides a formula as one way for calculating the frequency, F, of aircraft crashes into a facility when aviation corridors pass through the vicinity of the site (Equation 1).

For the flight-restricted airspace, the width of the airspace, w, is twice the radius of the flight-restricted airspace, $2R$, thus Equation 7 and Equation 1 are identical except for the factor, p_c, which is used to account for the altitude of the aircraft flying over the flight-restricted airspace.

The fraction, p_{c}, of the flights that suffer crash-initiating events during overflight of the flight-restricted airspace that pose a risk to repository surface facilities is calculated as follows.

Aircraft flying over the facilities have an initial altitude of 14,000 ft MSL or above (Assumption 3.3.1). Elevations of the repository surface facilities are below 4,000 ft MSL (Reference 2.2.4). Therefore, the ceiling of the flight-restricted airspace is at least 10,000 ft above the repository surface facilities. Conservatively, the aircraft over flying the facilities are assumed to be at 10,000 ft AGL (Assumption 3.2.5).

Data on military aircraft crashes have been collected from May 1990 through December 2006 and are presented in Table III-1 of Attachment III. Each aircraft crash has been assigned an initiating-event type code that is used for determining which events are applicable to flights over the facilities (Assumption 3.2.17). The following types of crash-initiating events are considered:

- Type 0 events are not applicable to overflight of the flight-restricted airspace.
- Type 1 events are applicable to overflight of the flight-restricted airspace.

TYPE 1 EVENTS

There are two subcategories of Type 1 events; Type 1A events where immediate ejection is unlikely, and Type 1B events where immediate ejection is considered likely. These subcategories are only used for the sensitivity analysis presented in Attachment VI. In fact, conservatively, it is assumed that the pilot ejects immediately after the engine failure or the crash-initiating event (Assumption 3.2.15).

To determine the fraction of Type 1 events that pose a hazard to the surface facilities, consider an aircraft crossing directly above the center of the flight-restricted airspace. This is the longest trip across the restricted airspace and therefore carries the greatest likelihood of a crash during overflight of the area. An aircraft that has already flown beyond surface facilities prior to the crash-initiating event can be eliminated from further consideration. The radius of the smallest circle approximately centered on the North Portal that encompasses the relevant surface facilities is 1.0 mi (Assumption 3.2.6). Therefore, an aircraft that has already passed 6.6 mi [(4.9NM × 1.1508 mi/NM) + 1.0 mi)] from the edge of the flight-restricted airspace will have traveled beyond all relevant surface facilities.

Assuming that flights over the flight-restricted airspace are uniformly distributed (Assumption 3.2.4), the fraction of aircraft that have not flown beyond the repository surface facilities when engine failure, or other crash initiating event occurs can be estimated by the ratio of the radius of the flight-restricted airspace plus the radius of the smallest circle that encompasses the relevant surface facilities to the diameter of the flight-restricted airspace.

$$\frac{6.6mi}{\left(4.9NM \times 1.1508 \, {}^{mi}\!/_{NM}\right) * 2} \quad 0.59$$

If an aircraft experiences a crash-initiating event, anywhere from the edge of the flight-restricted airspace up to while over the facilities, the aircraft glide ratio could carry it beyond the surface facilities. Likewise, if an aircraft experiences a crash-initiating event anywhere from the edge of the flight-restricted airspace up to the near edge of the smallest circle that encompasses the relevant surface facilities, the aircraft may not have sufficient glide ratio to reach the surface facilities. Note that those aircraft that experience a crash-initiating event while outside the radius of the flight-restricted airspace are accounted for in Section 4.3.3.

To determine the fraction of aircraft that pose a threat to the facilities requires determining the fraction of aircraft that have a glide ratio large enough for the aircraft to reach the 1.0 mi inner circle, but less than the glide ratio required to carry the aircraft past the facilities or beyond the 1.0 mi circle. The glide ratio is determined by the distance from the aircraft to the near edge and far edge of the circle that encompasses the surface facilities divided by the altitude of the flights (Assumption 3.2.5).

As shown above, only the flights within the first 6.6 miles that have not flown past the facilities are of interest. By dividing the 6.6 miles into 10 discrete sections, glide ratios necessary to carry the plane to the edge of the inner circle and past the facilities can be determined for each of the sections. From Figure 4, it can be seen that flights in sections 1, 2 and 3 are already over the area that encompasses the facilities. Therefore, for section 1 of Figure 4, the plane would have to travel 0.66 miles to clear the facilities. The glide ratio would be:

$$\frac{0.66 mi \times 5280 \, {}^{ft}\!/\!_{mi}}{10000 \, ft} \quad 0.35\,.$$

For section 4 of Figure 4, the plane would have to travel 0.64 miles to reach the facilities and 2.64 miles to clear the facilities. The glide ratio for the ten sections of Figure 4 varies from 0.34 to 3.48, as shown in Table 10. For comparison, if no ejection occurs, the glide ratio for an F-16 is about 8.5, derived from a glide ratio of 7 nautical miles for every 5,000 ft of altitude lost (Reference 2.2.36 [DIRS 177054], p. 5). Thus, if the F-16 glide ratio of 8.5 were used for determining the fraction of aircraft that have less than the glide ratio required to carry the aircraft past the facilities, that fraction would be zero, resulting in a zero crash frequency from overflights of the flight-restricted airspace. Thus it is conservative to assume that the pilot ejects immediately after the initiating event (Assumption 3.2.15) and accordingly to use the historic data in Attachment III, which analyze glide ratios after ejection. Therefore, the methodology derived herein for determining the frequency of aircraft crash from overflights of the flight-restricted airspace is conservative.

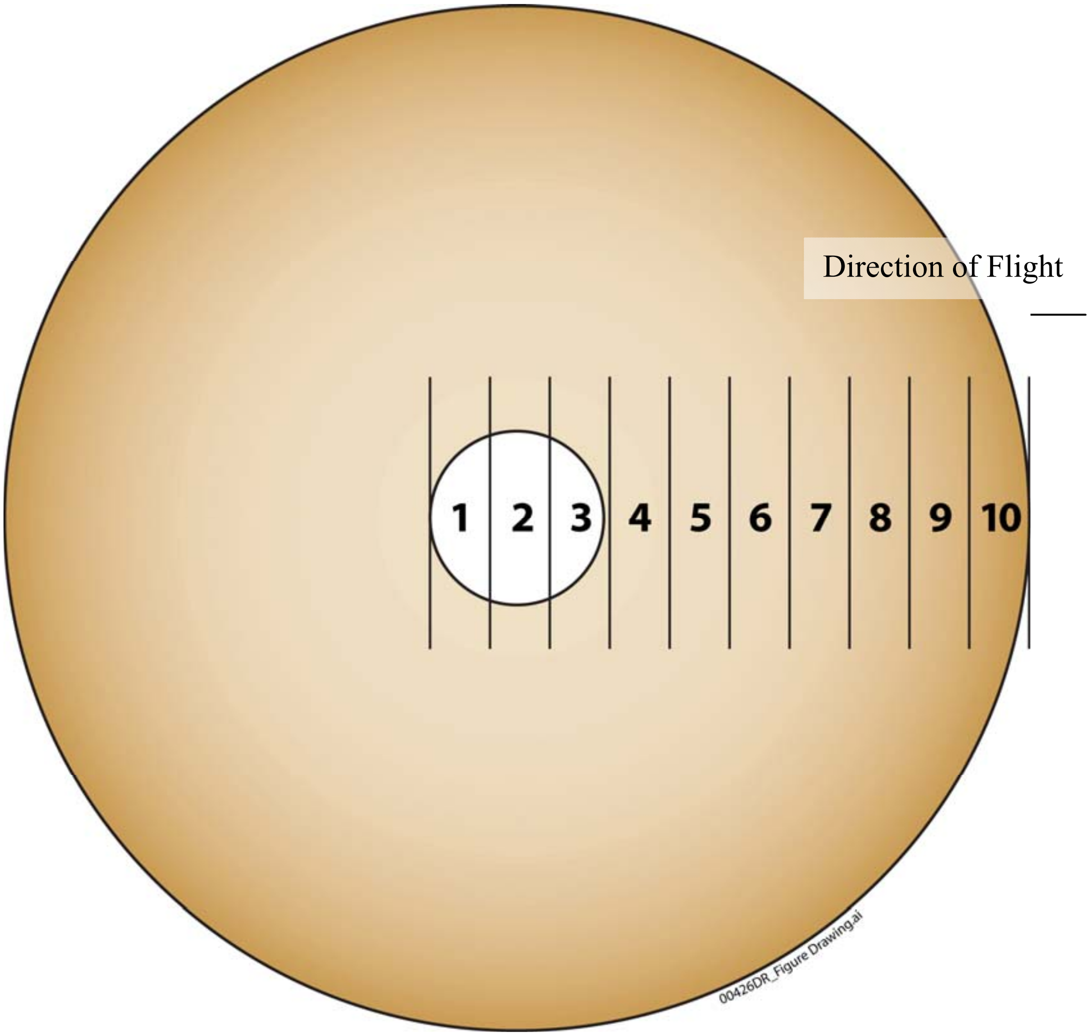

Figure 4. Illustration of Flight-Restricted Airspace Divided into Ten Sections

Using the glide ratios for the Type 1 crashes in Table III-1, the fraction of the aircraft in each section that have sufficient glide ratios to carry them to the facilities but do not have sufficient glide ratios to carry them past the facilities can be determined by counting the number of aircraft that have glide ratios in the range of the facilities for each of the ten sections as depicted in Figure 4. From Table III-1, fifty-eight Type 1 events have known glide ratios. Dividing the number of flights from each section that have the required glide ratios by 58 gives the fraction of observable flights from each section that have the correct range of glide ratios. Combining this fraction with the fraction of the aircraft that would be in each section, 0.1, and the fraction of the aircraft that have not flown past the facilities, 0.59, derived above, gives the fraction from each section that could endanger the facilities. Adding up the fraction of aircraft that could endanger the facilities from each of the sections gives the total fraction of Type 1 Events that could endanger the facilities. Table 10 shows the calculation of the total fraction using the military crash data in Table III-1.

Table 10. Calculation of Type 1 Events Endangering Facilities

Section	Far Distance (mi)	Near Distance (mi)	Far Glide Ratio	Near Glide Ratio	Number of Flights from each Section within Glide Ratio Range	Fraction (Number of flights/58)
1	0.66	-	0.35	-	3	0.05
2	1.32	-	0.70	-	7	0.12
3	1.98	-	1.05	-	7	0.12
4	2.64	0.64	1.39	0.34	7	0.12
5	3.30	1.30	1.74	0.69	8	0.14
6	3.96	1.96	2.09	1.03	15	0.26
7	4.62	2.62	2.44	1.38	14	0.24
8	5.28	3.28	2.79	1.73	16	0.28
9	5.94	3.94	3.14	2.08	14	0.24
10	6.60	4.60	3.48	2.43	12	0.21
Sum of Fractions						1.78

$$p_c \quad 1.78 \times 0.1 \times 0.59$$

$$p_c \quad 0.105$$

Thus, 10.5% of the flights that suffer crash-initiating events during overflight of the flight-restricted airspace could pose a risk to repository surface facilities.

4.3.3. Flights Beyond the Radius of the Flight-Restricted Airspace

This section presents the methodology for calculating the annual frequency of crashes into the relevant surface facilities when the initiating event leading to the crash occurs outside the flight-restricted airspace but in the NTS, the EC South area of R-4807, and the western portion of R-4806 as defined in Table 11.

The flight-restricted airspace that is assumed to surround the surface facilities (Assumption 3.3.1) will reduce the frequency of crashes into any of the facilities from flights that occur outside the flight-restricted airspace. Following the crash-initiating event, ejection occurs outside the flight-restricted airspace (Assumption 3.2.18). As stated in the rationale for Assumption 3.2.18, the unlikely scenario where a plane enters the flight-restricted airspace before the pilot ejects is investigated in Attachment VI in the sensitivity analysis.

To derive an expression that accounts for a flight-restricted airspace, first consider a small area, δA, on the ground under a flight area. Suppose the flight area extends horizontally in all directions to an unlimited distance. Further, suppose that the locations of ejection events and the directions of travel after ejection are uniformly distributed throughout the flight area, which is consistent with the assumption that the pilot does not intentionally direct the plane away from or towards the facility (Assumption 3.2.15). For accidents in which ejection does not occur, the distance between ejection and crash is defined as zero. Let $f(r)$ denote the probability density function (PDF) of the distance, r, that an aircraft travels after the pilot ejects and let Φ_0 denote the annual number of crashes initiated per unit flight area. The uniform PDF for direction of travel is $1/(2\pi)$.

With the passage of time, crashes into δA are expected. The crashes that strike the area, δA, are randomly selected, have traveled distances distributed according to $f(r)$, and have traveled in random directions according to the uniform PDF equal to $1/(2\pi)$. The precise locations of the initiation points of the crash trajectories and the directions of travel are not relevant, but the endpoints of the crash trajectories are located within δA. Because the ejection locations and directions of travel are uniformly distributed over an infinite flight area, the crash frequency density on the ground is equal to the crash-initiation frequency density. With no restrictions on distance or direction of travel, the expected number of crashes into δA at time, T, is given by:

$$\begin{aligned} M_0 \quad & \Phi_0\, \delta A\, T \int_{r\ 0}^{\infty} \int_{\theta\ 0}^{2\pi} \frac{1}{2\pi} f(r)\, \mathrm{d}\theta\, \mathrm{d}r \\ & \Phi_0\, \delta A\, T\,. \end{aligned} \qquad \text{(Eq. 8)}$$

where

M_0	=	expected number of crashes into δA over time T
Φ_0	=	annual number of crashes initiated per unit flight area
δA	=	small area on the ground under a flight area
T	=	time

The double integral merely indicates that, with no restrictions on distance or direction of travel, all possible crash trajectories may be realized.

Now consider a flight-restricted airspace with a radius, R, surrounding δA, where the largest dimension of δA is much less than R, and such that the uniform crash initiation density applies only to the area beyond R (Assumption 3.2.18). Other conditions remain the same. Again, with the passage of time, crashes into δA are expected. In this case, however, crashes with trajectories shorter than R are filtered out by the presence of the flight-restricted airspace. The expected number of crashes, M_c, into δA at the center of the flight-restricted airspace at time T is given by:

$$\begin{aligned} M_{\mathrm{c}} \quad & \Phi_0\, \delta A\, T \int_R^{\infty} \int_0^{2\pi} \frac{1}{2\pi} f(r)\, \mathrm{d}\theta\, \mathrm{d}r \\ & = \Phi_0\, \delta A\, T\, [1 - F(R)]\,. \end{aligned} \tag{Eq. 9}$$

where

M_c = expected number of crashes into δA within flight-restricted airspace of radius R
Φ_0 = annual number of crashes initiated per unit flight area
δA = small area on the ground under a flight area
T = time
$[1-F(R)]$ = complementary cumulative distribution function evaluated at the edge of the flight-restricted airspace

Thus, the flight-restricted airspace reduces the expected number of crashes according to the ratio:

$$\begin{aligned} \frac{M_{\mathrm{c}}}{M_0} \quad & \frac{\Phi_0\, \delta A\, T\, [1 - F(R)]}{\Phi_0\, \delta A\, T} \\ & [1 - F(R)]. \end{aligned} \tag{Eq. 10}$$

So far, the flight area has been considered infinite in every direction from δA. However, the repository site is actually near the edge of the restricted NTTR and NTS airspace. Now assume that the ejection locations and directions of travel corresponding to Φ_0 are uniformly distributed outside the flight-restricted airspace out to an infinite distance; except in the southwest quadrant from the center of the flight-restricted airspace, which is almost entirely in the Beatty Corridor (Assumption 3.2.14) and is considered in Section 4.3.1. Excluding the southwest quadrant filters out crashes with angles from π to $3\pi/2$. This results in an edge adjustment of approximately 0.75, three quarters of the way around the repository.

Considering the edge adjustment and the effectiveness of the flight-restricted airspace for the restricted airspace, the annual crash frequency per unit area at the center of the flight-restricted airspace, Φ_c, is given by:

$$\begin{aligned} \Phi_{\mathrm{c}} \quad & \frac{\text{Number of crashes expected in area } \delta A \text{ during time } T}{\text{Area and time under consideration}} \\ & \frac{\Phi_0\, \delta A\, T \int_R^{\infty} \int_0^{3\pi/2} \frac{1}{2\pi} f(r)\, \mathrm{d}\theta\, \mathrm{d}r}{\delta A\, T} \\ & 0.75\, \Phi_0 [1 - F(R)]\,. \end{aligned} \tag{Eq. 11}$$

In this case, the double integral determines the filtering effect of the flight restrictions represented by the flight-restricted airspace and the omission of a quadrant.

To estimate the complementary cumulative distribution function evaluated at the edge of the flight-restricted airspace or [1 - $F(R)$], Attachment III presents historical data on distances that fixed-wing military aircraft traveled after the pilot ejected. If the pilot did not eject before impact, then the distance traveled after ejection was taken to be zero. If the event involved a failed landing or takeoff, the distance was given as not applicable so that the distribution function would not be biased by events that are not likely to occur near the repository. The cumulative distribution function (CDF), that is, the probability that the crashing aircraft traveled a distance less than r, can be estimated from the data. The sample CDF as a function of the variable r, $F_n(r)$, is defined as the number of observations less than or equal to r divided by the total number of observations, n (Reference 2.2.58 [DIRS 122506], p. 264). The sample CDF (Figure 5) is an unbiased estimator of the true CDF, $F(r)$ (Reference 2.2.58 [DIRS 122506], p. 507).

Because the repository surface facilities (Table 1) are not concentrated at the North Portal, but are spread out over a 1.0-mi radius (Assumption 3.2.6), credit is only taken for a flight-restricted airspace of a 1.0 mi smaller radius. Thus, using Assumption 3.3.1, the flight-restricted airspace radius credited is 4.6 mi (1.0 mi less than the 5.6-mi radius of the flight-restricted airspace). For the 155 applicable observations, for which a distance estimate is possible, 151 of the distances are less than the reduced radius of the flight-restricted airspace, 4.6 mi. Thus, $F_n(4.6 \text{ mi}) = 151 / 155 = 0.974$. The estimated probability of exceeding 4.6 mi is $[1 - F_n(4.6 \text{ mi})] = 1 - 151/155 = 0.026$.

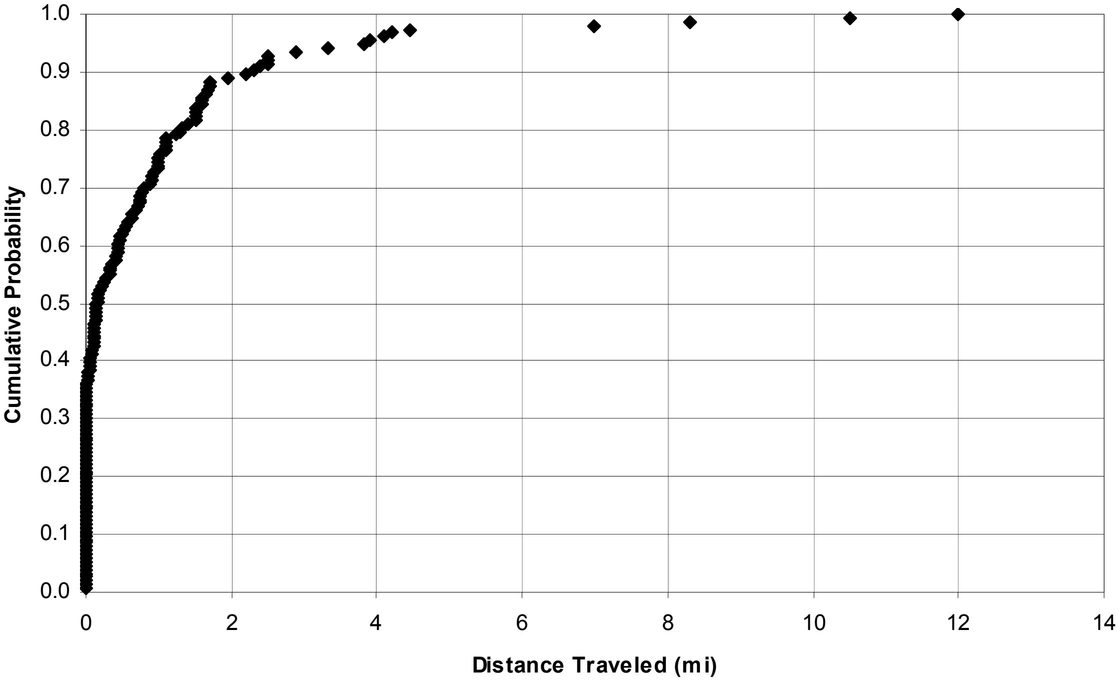

Figure 5. Sample Cumulative Distribution Function of Crash Distances

5. LIST OF ATTACHMENTS

		Number of Pages
Attachment I.	Flights Through the Beatty Corridor	4
Attachment II.	Flight Distribution in the Nevada Test and Training Range and Nevada Test Site Airspace	4
Attachment III.	Information on a Sample of Military Aircraft Crashes	40
Attachment IV.	Derivation of Small Military Aircraft Crash Rate	6
Attachment V.	Effective Target Areas and Beatty Corridor Crash Frequency	6
Attachment VI.	Sensitivity Calculations	16

6. BODY OF CALCULATION

6.1 INPUTS FROM INTERNAL SOURCES

6.1.1. Hazards Considered

Hazards considered in this analysis are from Reference 2.2.3 (Section 8), which provides more detail about the airspace near the repository. Dropped ordnance is also considered a potential hazard because ordnance may be carried over EC South and NTS airspace; however, ordnance is not armed until over USAF land on the R-4807 or R-4806 bombing range (Reference 2.2.32 [DIRS 169894], pp. 3 through 6). Ordnance is prohibited on flights over the flight-restricted airspace (Assumption 3.3.2). Figure 1 and Figure 2 depict airspace in the vicinity of the repository. Table 11 maps the identified hazards from Reference 2.2.3 (Section 8), to sections in this analysis. In addition, as a defense-in-depth measure, Reference 2.2.3 (Section 8) recommends that electronic jamming activities not occur while aircraft fly over the facilities and that radio frequency spectrum used at the Yucca Mountain site is coordinated through the appropriate Spectrum Management Office. Electronic jamming activities are prohibited over the flight-restricted airspace (Assumption 3.3.2) and coordination with the Spectrum Management Office has been identified as a recommendation in Section 7, therefore, electronic jamming does not represent a significant risk to the Yucca Mountain Repository.

Table 11. Aircraft Hazards Considered

Type of Airspace/Airport[a]	Aircraft[a]	Cross Reference to Sections in this Analysis
DOE Designated Airspace		
R-4808	Small attack/fighter military aircraft, including dropped ordnance from outside the flight-restricted airspace	3.3.2, 4.3.2, 4.3.3, 6.5.2, 6.5.3, and 6.7
Military Designated Airspace		
Electronic Combat (EC) South area of R-4807 and western portion of R-4806	Small attack/fighter military aircraft	4.3.3 and 6.5.3
Civilian and DOE Airports		
DOE Area Pad 29	Helicopters	3.3.3 and 6.6
Field Operations Office Helipad	Helicopters	3.3.3 and 6.6
Federal Airways and Jet Routes (Beatty Corridor; includes R-4808S)[b]		
Jet Route J-86	Military, commercial and general aviation aircraft	4.3.1 and 6.5.1
Jet Route J-92	Military, commercial and general aviation aircraft	4.3.1 and 6.5.1
Federal Airway V-105	Military and civilian aircraft	4.3.1 and 6.5.1
Federal Airway V-135	Military and civilian aircraft	4.3.1 and 6.5.1
Uncontrolled Airspace (Beatty Corridor)		
Class G airspace	Small piston-engine aircraft, helicopters, and gliders	4.3.1 and 6.5.1

NOTES: [a] Reference 2.2.3, Section 8

[b] These federal airways and jet routes are depicted in Reference 2.2.3 (Figure 6-2).

6.1.2. Facilities and Dimensions

Table 12 lists the relevant surface structures and dimensions. Building dimensions encompass areas where waste forms can be present such as the interior of structures and the entrance and exit vestibules for waste forms. Office areas and personnel entrance vestibules are not included because waste will not be present in such areas. The structure sizes are based on references cited in the footnotes of Table 12. *Basis of Design for the TAD Canister-Based Repository Design Concept* (Reference 2.2.9, Section 9.9.2.2.1) states that the rail car storage area has the capacity to stage 25 rail cars loaded with transportation casks. The dimensions of the standard gage rail car are 90-ft long, 16-ft wide and 17-ft high (Reference 2.2.9, Section 9.9.2.2.3). Reference 2.2.4 shows that the rail car area has six rail lines. The rail lines are for ingress, egress and staging. Thus, to allow for ingress and egress, four rail lines are used for staging. To allow space between rail cars, the length of the car is increased to 100 ft and the width is increased to 20 ft. This results in the dimensions for the rail car staging area of 700 ft by 80 ft. This is increased to 800 ft by 80 ft to accommodate five additional railcars.

Table 12. Characteristics of Relevant Surface Structures

Building, Structure, or Area[a]	Quantity	Length (ft)	Width (ft)	Height (ft)
Initial Handling Facility (IHF)	1	300	167	105
Canister Receipt and Closure Facility (CRCF)	3	419	318	100
Receipt Facility (RF)	1	318	282	100
Wet Handling Facility (WHF)	1	385	299	100
Aging Pad 17P	1	1,152	1,030	22
Aging Pad 17R	1	1,511	750	22
Rail Car Staging Area (not a building)[b]	1	800	80	17
Truck Staging Area (not a building)[b]	1	300	150	17
Loaded site transporters (not buildings)[c]	2	23	18	23

NOTES: [a] Numbers of structures (Assumption 3.2.7); Dimensions: IHF (References 2.2.40 and 2.2.41); CRCF (References 2.2.42 and 2.2.43); RF (References 2.2.44 and 2.2.45); WHF (References 2.2.46 and 2.2.47); Aging Pads (References 2.2.5, 2.2.10, and 2.2.48); Truck Staging Area (Reference 2.2.4); Site Transporter (Reference 2.2.49) (Width for site transporter rounded to whole number).

[b] Rail car height (Reference 2.2.9, Section 9.9.2.2.3). The height of the transportation cask on a truck is assumed to be less than the height on rail, but is conservatively assigned the same height of 17 ft.

[c] No estimate is available of the expected number of transporters in operation at any given time. Having two transporters in use at all times is considered to be conservative. Due to the size of the transporters as compared to the other areas and building, the overall effective target area is not sensitive to the precise number of the site transporters.

6.2 INPUTS FROM EXTERNAL SOURCES

6.2.1. Aircraft Characteristics for Calculating Effective Target Areas

The effective target area of an object on the ground is the equivalent area on the ground of the object, considering that the aircraft:

- May have a significant wingspan compared to the dimensions of the object
- May skid some distance on the ground before striking the object
- Approaches the object at some angle ϕ from horizontal.

The effective target area of an object on the ground depends on characteristics of the aircraft potentially involved in a crash. Aircraft characteristics used in this calculation (Table 13) are from Reference 2.2.6 [DIRS 101810], Tables B-16, B-17, and B-18.

Table 13. Aircraft Characteristics Used for Effective Target Area Calculations

Aircraft Type	Representative Wingspan [a] G (ft)	Mean Skid Distance [b] S (ft)	ϕ [c] (degrees)	Cot(ϕ) [d] (unitless)
General Aviation				
Piston engine	50	60	7.0	8.2
Turboprop	73	60	7.0	8.2
Turbojet	50	60	7.0	8.2
Commercial Aviation				
Air carrier (14 CFR Part 121)[e]	98	1440	5.6	10.2
Air taxi (14 CFR Part 135)[e]	59	1440	5.6	10.2
Military Aviation				
Large aircraft	223	780	7.7	7.4
Fighter, attack, and trainer aircraft	78	246	6.8	8.4

NOTES: [a] Reference 2.2.6 [DIRS 101810], Table B-16.

[b] Reference 2.2.6 [DIRS 101810], Table B-18. Takeoff values are used for in-flight crashes of military aircraft in accordance with the recommendations of Reference 2.2.6 [DIRS 101810], p. B-28.

[c] Impact angle is calculated here as $\tan^{-1}(1 / \cot \phi)$.

[d] Mean of the cotangent of the impact angle ($\cos \phi$ / $\sin \phi$) from Reference 2.2.6 [DIRS 101810], Table B-17. Takeoff values for military aircraft are used for in-flight crashes in accordance with the recommendations of Reference 2.2.6 [DIRS 101810], p. B-28.

[e] The “air carrier” type includes major airlines that may be scheduled or unscheduled and cargo carriers that fly large aircraft. Reference 2.2.6 [DIRS 101810], generally refers to flights regulated by 14 CFR Part 121 (Reference 2.2.17 [DIRS 168506]) as air carriers and those regulated under 14 CFR Part 135 (Reference 2.2.18 [DIRS 168507]) as air taxis. This corresponds to usage by the Federal Aviation Administration of the air-carrier and air taxi types in data that was provided by Reference 2.2.50 [DIRS 168482]. The definition of air taxis used in Reference 2.2.6 [DIRS 101810], p. 10, includes aircraft under 30 seats or a maximum payload capacity of less than 3,401 kg (7,500 lb) that are operating in accordance with 14 CFR Part 135 (Reference 2.2.18 [DIRS 168507]). In March 1997, after Reference 2.2.6 [DIRS 101810] was published, the definitions of 14 CFR Part 121 (Reference 2.2.17 [DIRS 168506]) and 14 CFR Part 135 (Reference 2.2.18 [DIRS 168507]) operations changed (Reference 2.2.51 [DIRS 168398], pp. 1 and 2). Under the new rules most carriers known as commuters now operate under 14 CFR Part 121 (Reference 2.2.17 [DIRS 168506]). Unscheduled and14 CFR Part 135 (Reference 2.2.18 [DIRS 168507]) aircraft are a diverse group that includes small aircraft and large corporate jets (Reference 2.2.51 [DIRS 168398], p. 2).

6.2.2. Crash Rates for Aircraft

Statistics for crash rates of fixed-wing aircraft (Table 14 and Table 15) are extracted from *Data Development Technical Support Document for the Aircraft Crash Risk Analysis Methodology (ACRAM) Standard* (Reference 2.2.29 [DIRS 137367]). Attachment IV updates these statistics to derive the crash rates for small military fixed-wing aircraft that are used in this analysis.

Table 14. Crash Rates for Military Aircraft

Military Aircraft Type	Crash Rate (mi^{-1})	Used In
F-16s (normal flight)	3.86×10^{-08}	Attachment IV
F-16s (special operations)	1.12×10^{-07}	Attachment IV
F-15s (normal flight)	6.25×10^{-09}	Attachment IV
F-15s (special operations)	8.45×10^{-08}	Attachment IV
Large (normal flight)	1.90×10^{-09}	Attachment V

SOURCE: Reference 2.2.29 [DIRS 137367], Table 4.8

Table 15. Crash Rates for General Aviation Aircraft

General Aviation Aircraft Type	Cruise or Normal-Flight Crash Rate (mi^{-1})	Used In
Single engine, piston	2.233×10^{-07}[a]	Attachment V
Turboprop	3.557×10^{-08}[b]	Attachment V
Turbojet	3.067×10^{-09}[c]	Attachment V

SOURCE: [a] Reference 2.2.29 [DIRS 137367], Table 3.29
[b] Reference 2.2.29 [DIRS 137367], Table 3.31
[c] Reference 2.2.29 [DIRS 137367], Table 3.32

An estimate of crash rates per mile for unscheduled 14 CFR Part 135 (Reference 2.2.18 [DIRS 168507]) operations is made by using the average hourly fatal accident rate for scheduled and unscheduled 14 CFR Part 135 operations for the years 1998 through 2006 (Table 16 and Table 17) and the average speed for scheduled 14 CFR Part 135 flights (Table 17) over the same period. The fatal accident rate is used rather than the total accident rate (Assumption 3.2.11).

The crash rate per mile, which is the hourly accident rate divided by the speed, is provided in Table 18. The speed for scheduled 14 CFR Part 135 (Reference 2.2.18 [DIRS 168507]) flights is used as the speed for both the scheduled and unscheduled 14 CFR Part 135 flights because the same type of aircraft fly both the scheduled and unscheduled 14 CFR Part 135 flights.

Table 16. Statistics for Unscheduled 14 CFR Part 135 Operations 1998 through 2006

Year	Number of Fatal Accidents	Hours Flown
1998	17	3,802,000
1999	12	3,204,000
2000	22	3,930,000
2001	18	2,997,000
2002	18	2,911,000
2003	18	2,927,000
2004	23	3,238,000
2005	11	3,815,000
2006	10	3,600,000
Total	149	30,424,000

NOTES: Reference 2.2.52 [DIRS 181787], Table 9. Data before 1998 is omitted due to the change in the scope of 14 CFR Part 121 (Reference 2.2.17 [DIRS 168506]) and 14 CFR Part 135 (Reference 2.2.18 [DIRS 168507]) that occurred in March 1997 (Reference 2.2.51 [DIRS 168398], pp. 1 and 2).

Table 17. Statistics for Scheduled 14 CFR Part 135 Flights 1998 through 2006

Year	Number of Fatal Accidents	Hours Flown	Miles Flown	Average Speed (mi/h)
1998	0	353,670	50,773,000	-
1999	5	342,731	52,403,000	-
2000	1	369,535	44,943,000	-
2001	2	300,432	43,099,000	-
2002	0	273,559	41,633,000	-
2003	1	319,206	47,404,000	-
2004	0	302,218	46,809,000	-
2005	0	295,034	45,721,000	-
2006	1	280,000	44,900,000	-
Total or average	10	2,836,385	417,685,000	147

NOTES: Reference 2.2.52 [DIRS 181787], Table 8. Data before 1998 is omitted due to the change in the scope of 14 CFR Part 121 (Reference 2.2.17 [DIRS 168506]) and 14 CFR Part 135 (Reference 2.2.18 [DIRS 168507]) that occurred in March 1997 (Reference 2.2.51 [DIRS 168398], pp. 1 and 2).

Table 18. Crash Rates for Commercial Aviation

Commercial Aviation Aircraft Type	Cruise or Normal-Flight Crash Rate (mi^{-1})	Used In
Air carrier (14 CFR Part 121 [DIRS 168506])	3.094×10^{-10} [a]	Attachment V
Air taxi (14 CFR Part 135 [DIRS 168507])	3.25×10^{-08} [b]	Attachment V

NOTES: [a] Reference 2.2.29 [DIRS 137367], Table 2.15

[b] The crash rate for 14 CFR Part 135 (Reference 2.2.18 [DIRS 168507]) aircraft is estimated as: (149 crashes + 10 crashes)/ ((30,424,000 h + 2,836,385 h) x 147 m/h). The number of crashes, hours and speed are from Table 16 and Table 17.

6.2.3. Historical Data on Military Aircraft Crashes

Attachment III compiles historical USAF aircraft crash data for military aircraft of concern (Assumption 3.2.12) from May 1990 to December 2006. The crash events were compiled and summarized by evaluating information from three types of USAF reports: safety reports, accident investigation reports, and the executive summaries from the accident investigation reports (Table III-1). The safety reports were the primary source for the data in Table III-1.

The Safety Reports are compiled and maintained at the Air Force Safety Center located at Kirtland Air Force Base in Albuquerque, New Mexico. Visits to the Air Force Safety Center were undertaken in August and September 2004, June 2005, and June 2006. Safety reports or accident investigation reports for USAF military aircraft of concern (Assumption 3.2.12), F-16, F-15, F-22 and A-10, mishaps that resulted in a crash or pilot ejection that occurred worldwide from May 1990 to December 2005 were reviewed. The latest reports available from the Air Force Safety Center during the June 2006 visit were from December 2005. Some reports were unavailable from the Safety Center library when the crash data were reviewed. Primary data extracted from the reports were the distance that a disabled aircraft traveled after pilot ejection, the altitude of ejection, and the cause of the crash. Information about crashes when the pilot did not eject was also obtained.

The executive summary reports and the accident investigation reports were used to supplement the safety reports. The executive summary reports for years 2000 to 2006 are publicly available on the USAF Accident Investigation Board web site at http://usaf.aib.law.af.mil/. Some accident investigation reports for F-16s are publicly available on the Nuclear Regulatory Commission (NRC) Agency Documents Access and Management System (ADAMS) search web site at http://www.nrc.gov/reading-rm/adams/web-based.html. Sources for the information in Table III-1 are referenced in Section 2 and are deemed appropriate sources for USAF aircraft mishap information since they are USAF reports.

6.3 FREQUENCY-SCREENING THRESHOLD

Event sequences that are expected to occur one or more times before permanent closure of the geologic repository operations area are defined as Category 1 event sequences in 10 CFR 63.2 (Reference 2.2.8 [DIRS 180319]). Other event sequences that have at least one chance in 10,000 of occurring before permanent closure are referred to in 10 CFR 63.2 as Category 2 event sequences (Reference 2.2.8 [DIRS 180319]). Less likely event sequences are considered Beyond Category 2. Stating the screening threshold in terms of frequency requires knowledge of the duration of the potentially affected activities. Because aircraft do not pose a hazard to subsurface activities, the relevant time period is the duration of emplacement operations. The duration of emplacement operations will not exceed 50 years (Assumption 3.3.4). A 50-year emplacement period gives a threshold frequency of:

$$(1/10{,}000)\ /\ 50\ \text{y} = 2 \times 10^{-6}\ \text{y}^{-1}.$$

6.4 EFFECTIVE TARGET AREAS OF THE SURFACE FACILITIES

The effective target area, *A,* depends on characteristics of the aircraft (Section 6.2.1), the size of the object on the ground, and the characteristics of the site. A formula for effective target area is derived by approximating an object on the ground as a bounding rectangular prism of length *L*, width *W*, and height *H*, as discussed in *ACRAM Modeling Technical Support Document* (Reference 2.2.53 [DIRS 158248], Section 4.4). The formula depends on the wingspan, *G*, of the aircraft, the skid distance, *S*, which may depend on characteristics of the site as well as those of the aircraft, and the approach angle, ϕ, to the ground, which may depend on site, aircraft, and flight characteristics. The fly-in area is the effective target area of the structure, considering an airborne approach at an angle, and ignoring the possibility of hitting the ground and skidding into the structure:

$$A_{\text{fly-in}} \quad L\,W\,(1+\frac{2G}{D})+(G+D\ )H\ \cot\phi\,, \qquad \text{(Eq. 12)}$$

where

$A_{fly\text{-}in}$ = effective fly-in target area
L = length
W = width
G = wingspan
D = diagonal, $D \equiv \sqrt{(L^2 + W^2)}$
H = height
ϕ = approach angle to the ground

The skid area, which is the effective target area that considers the possibility that the aircraft will hit the ground and skid into the structure and ignores the possibility of an airborne approach, is:

$$A_{\text{skid}} \quad (D+G)S\,. \qquad \text{(Eq. 13)}$$

where

A_{skid} = effective skid target area
D = diagonal
G = wingspan
S = skid distance

The total effective target area is $A_{\text{fly-in}} + A_{\text{skid}}$. The impact angle and the skid distance depend on characteristics of the aircraft, although they may be limited by characteristics of the site, such as topography and landscaping. Skid distances may also be limited by close proximity to other structures. Reference 2.2.6 ([DIRS 101810], Section B.4) states that the effective area should be determined using the locations in a facility that contains hazardous material to reduce the unnecessary conservatism if the facility's dimensions are used blindly. For conservatism, the calculation of the effective target area does not take credit for topography, landscaping effects or the presence of nearby structures and the full dimensions of the facility, excluding office areas and personnel entrance vestibules, are used in determining the effective target area.

Attachment V presents the calculation of the effective area using Equations 12 and 13, the building dimensions in Table 12, and the aircraft characteristics in Table 13. The total effective area of the relevant surface structures for each aircraft type is given in Table 19.

Table 19. Effective Area

Aircraft	**Effective Area (mi^2)**
Small military aircraft	0.33
Large military aircraft	0.58
Piston-engine general aviation	0.26
Turboprop general aviation	0.27
Turbojet general aviation	0.26
Commercial air taxi (14 CFR Part 135 [DIRS 168057])	0.69
Commercial air carrier (14 CFR Part 121 [DIRS 168506])	0.73

6.5 CRASH FREQUENCIES FOR FIXED-WING AIRCRAFT

6.5.1. Flights In the Beatty Corridor

The exponential airway model (Equation 4) is used to estimate crash frequencies from air traffic passing through the Beatty Corridor. The Beatty Corridor is a 26-mi wide band, whose edges run parallel to the Nevada-California border, that passes between the edge of Shoshone MOA and within 5 mi of the North Portal at its closest (Assumption 3.2.8). Attachment V, Section V.2, presents the calculation of the crash frequency from flights in the Beatty Corridor.

6.5.1.1. Small Military Aircraft In the Beatty Corridor

Using the updated F-16 crash rate of 2.74×10^{-8} mi^{-1} (Section 3.2.13), the effective area for small military aircraft (Table 19), the assumed number of flights (Table 2), and γ equal to 1 mi^{-1} for military aircraft, the resultant crash frequency is 1.68×10^{-8} y^{-1}. This is a small fraction of the Category 2 event sequence acceptance threshold of 2×10^{-6} y^{-1}. Therefore, small military aircraft traveling in the Beatty Corridor will not pose a significant risk to the relevant surface facilities (Table 1).

6.5.1.2. Large Military Aircraft In the Beatty Corridor

Using the large military aircraft crash rate of 1.90×10^{-9} mi^{-1} (Table 14), the effective area for large military aircraft (Table 19), the assumed number of flights (Table 2), and γ equal to 1 mi^{-1} for military aircraft, the resultant crash frequency is 1.57×10^{-9} y^{-1}. This is a small fraction of the Category 2 event sequence acceptance threshold of 2×10^{-6} y^{-1}. Therefore, large military aircraft traveling in the Beatty Corridor will not pose a significant risk to the relevant surface facilities (Table 1).

6.5.1.3. Piston Engine General Aviation In the Beatty Corridor

Using the piston engine general aviation crash rate of 2.233×10^{-7} mi^{-1} (Table 15), the effective area for this aircraft type (Table 19), the assumed number of flights (Table 2), and γ equal to 2 mi^{-1} for general aviation, the resultant crash frequency is 1.36×10^{-9} y^{-1}. This is a small fraction of the Category 2 event sequence acceptance threshold of 2×10^{-6} y^{-1}. Therefore, piston engine general aviation traveling in the Beatty Corridor will not pose a significant risk to the relevant surface facilities (Table 1).

6.5.1.4. Turboprop General Aviation In the Beatty Corridor

Using the turboprop general aviation crash rate of 3.557×10^{-8} mi^{-1} (Table 15), the effective area for this aircraft type (Table 19), the assumed number of flights (Table 2), and γ equal to 2 mi^{-1} for general aviation, the resultant crash frequency is 7.48×10^{-10} y^{-1}. This is a negligible fraction of the Category 2 event sequence acceptance threshold of 2×10^{-6} y^{-1}. Therefore, turboprop general aviation traveling in the Beatty Corridor will not pose a significant risk to the relevant surface facilities (Table 1).

6.5.1.5. Turbojet General Aviation In the Beatty Corridor

Using the turbojet general aviation crash rate of 3.067×10^{-9} mi^{-1} (Table 15), the effective area for this aircraft type (Table 19), the assumed number of flights (Table 2), and γ equal to 2 mi^{-1} for general aviation, the resultant crash frequency is 3.98×10^{-11} y^{-1}. This is a negligible fraction of the Category 2 event sequence acceptance threshold of 2×10^{-6} y^{-1}. Therefore, turbojet general aviation traveling in the Beatty Corridor will not pose a significant risk to the relevant surface facilities (Table 1).

6.5.1.6. Commercial Air Taxi In the Beatty Corridor

Using the commercial air taxi (14 CFR Part 135 [DIRS 168507]) crash rate of $3.25 \times 10^{-8}\ mi^{-1}$ (Table 18), the effective area for this aircraft type (Table 19), the assumed number of flights (Table 2), and γ equal to $1.6\ mi^{-1}$ for air carriers, the resultant crash frequency is $8.05 \times 10^{-9}\ y^{-1}$. This is a small fraction of the Category 2 event sequence acceptance threshold of 2×10^{-6} y. Therefore, commercial air taxi will not pose a significant risk to the relevant surface facilities (Table 1).

6.5.1.7. Commercial Air Carrier

Using the commercial air carrier (14 CFR Part 121 [DIRS 168506]) crash rate of $3.094{\times}10^{-10}\ mi^{-1}$ (Table 18), the effective area for this aircraft type (Table 19), the assumed number of flights (Table 2), and γ equal to $1.6\ mi^{-1}$ for air carriers, the resultant crash frequency is $6.64 \times 10^{-10}\ y^{-1}$. This is a negligible fraction of the Category 2 event sequence acceptance threshold of $2 \times 10^{-6}\ y^{-1}$. Therefore, commercial air carriers will not pose a significant risk to the relevant surface facilities (Table 1).

6.5.1.8. Total Frequency From Aircraft In the Beatty Corridor

The estimated crash frequency due to flights in the Beatty Corridor is the sum of the crash frequencies of the aircraft that travel in the Beatty Corridor. The total crash frequency is approximately $2.9 \times 10^{-8}\ y^{-1}$ (Attachment V), which is a small fraction of the Category 2 event sequence acceptance threshold of $2 \times 10^{-6}\ y^{-1}$. Therefore, aircraft traveling in the Beatty Corridor do not pose a significant risk to the relevant surface facilities of the repository (Table 1).

6.5.2. Overflights of the Flight-Restricted Airspace

Equation 7 is used to estimate the crash frequency for flights over the flight-restricted airspace.

$$\begin{aligned} F_{o} \quad & \frac{N\lambda p_{c}}{2R}A \\ & \frac{(1{,}000\ y^{-1})(2.74\times10^{-8}\ mi^{-1})\ (0.105)}{2\ (5.6\ mi)}(0.33\ mi^{2}) \\ & 8.5\times10^{-8}\ y^{-1}\ . \end{aligned}$$

where

R = flight-restricted airspace of radius 5.6 mi (Section 3.3.1)
λ = crash rate of $2.74 \times 10^{-8}\ mi^{-1}$ (Section 3.2.13)
p_c = 10.5% of events found to pose a hazard to surface facilities (Section 4.3.2)
A = effective target area of $0.33\ mi^2$ for small military aircraft (Table 19)
N = 1,000 overflights per year (Assumption 3.3.2)

In this case, the full 5.6-mi radius is used because the overflights are counted across the entire flight-restricted airspace.

The crash frequency of $8.5 \times 10^{-8}\ \mathrm{y}^{-1}$ is a small fraction of the Category 2 event sequence acceptance threshold of $2 \times 10^{-6}\ \mathrm{y}^{-1}$. Therefore, overflights of the flight-restricted airspace do not pose a significant risk to the relevant surface facilities of the repository (Table 1).

6.5.3. Crash Frequency due to Flights Outside the Radius of the Flight-Restricted Airspace

To accommodate any future changes regarding the use of NTS airspace, it is assumed that military training activities in other portions of the NTTR and MOAs could be extended into NTS airspace (Reference 2.2.32 [DIRS 169894], pp. 5 and 6). Therefore, the annual number of crashes initiated per unit flight area, $\Phi_0 = 7.5 \times 10^{-5}$ crashes / y / mi^2 in the NTTR and MOA, calculated without NTS airspace, is applied to the 30-mile area in the NTS and NTTR even though this type of flight activity does not take place within 30-miles of the repository (Assumption 3.2.14). Thus, applying a crash frequency density based on aggressive maneuvering and training activity to this area is conservative.

Applying Equation 11, the crash frequency density at the center of the flight-restricted airspace is

$$\begin{aligned}\Phi_c \quad & 0.75\,\Phi_0[1 - F_n(4.6\ \mathrm{mi})] \\ & 0.75\,(7.5 \times 10^{-5}\ \mathrm{crashes / y / mi^2})(0.026) \\ & 1.46 \times 10^{-6}\ \mathrm{crashes / y / mi^2}.\end{aligned}$$

where

Φ_0 = 7.5×10^{-5} crashes/y/mi^2 (Section 3.2.14)

$[1 - F_n(4.6\ \mathrm{mi})]$ = 0.026 (Section 4.3.3)

The effective target area of the surface facilities as seen by small military aircraft (Table 19) is 0.33 mi^2. Thus, the estimated crash frequency due to flights outside the radius of the flight-restricted airspace is:

$$(1.46 \times 10^{-6}\ \mathrm{crashes / y / mi^2})(0.33\ \mathrm{mi^2}) = 4.8 \times 10^{-7}\ \mathrm{crashes / y}.$$

The crash frequency of $4.8 \times 10^{-7}\ \mathrm{y}^{-1}$ is well below the Category 2 event sequence acceptance threshold of $2 \times 10^{-6}\ \mathrm{y}^{-1}$. Therefore, flights outside the flight-restricted airspace do not pose a significant risk to the relevant surface facilities of the repository (Table 1).

6.5.4. Total Crash Frequency Due to Fixed Wing Aircraft

Summing the three contributors to the crash frequency:

- $2.9 \times 10^{-8}\ \mathrm{y}^{-1}$ from the Beatty Corridor (Section 6.5.1.8) (5% of the total frequency)

- 8.5×10^{-8} y^{-1} from overflights of the flight-restricted airspace (Section 6.5.2) (14% of the total frequency), and
- 4.8×10^{-7} y^{-1} from flights outside the flight-restricted airspace (Section 6.5.3) (81% of the total frequency).

The total crash frequency is approximately 5.9×10^{-7} y^{-1}, which gives over a 200% margin to the Category 2 event sequence frequency-screening threshold of 2×10^{-6} y^{-1}.

6.6 HELICOPTER CRASHES

To avoid the possibility of radiological release due to a helicopter crash into a repository surface facility (Table 1), helicopter flights are prohibited within one-half mile horizontally from the relevant surface facilities (Assumption 3.3.3). To facilitate the prohibition, the helipad associated with the repository is assumed to be located at least one-half mile from the relevant surface facilities (Assumption 3.3.3).

6.7 DROPPED OR JETTISONED ORDNANCE

Military aircraft fly over the flight-restricted airspace, outside the flight-restricted airspace and in the Beatty corridor. For overflight of the flight-restricted airspace, ordnance is prohibited (Assumption 3.3.2); therefore, the hazard of accidentally dropping or intentionally jettisoning ordnance from aircraft that fly over the flight-restricted airspace is considered negligible or non-existent.

It is estimated that 5% of the military aircraft carry ordnance, although ordnance is not armed until over R-4807 and R-4806 bombing ranges (Reference 2.2.32 [DIRS 169894], p. 3). In addition, there are no reports of aircraft delivering ordnance that have impacted outside the NTTR, or of any flight-related mishaps involving ordnance delivered outside the NTTR and inside the NTS during the period of 1993 through 2003. All ordnance impacts were within the designated surface hazard area (Reference 2.2.32 [DIRS 169894], p. 1).

The frequency of a crash into a surface facility from aircraft outside the flight-restricted airspace is estimated as 4.8×10^{-7} y^{-1}in Section 6.5.3. The frequency of a crash from small military aircraft in the Beatty Corridor is 1.7×10^{-8} y^{-1} (Section 6.5.1.1) and from large military aircraft in the Beatty Corridor is 1.6×10^{-9} y^{-1} (Section 6.5.1.2). If 5% of the aircraft carry ordnance and the ordnance is jettisoned during the in-flight emergency and it is assumed that all jettisoned ordnance impact the facilities, the frequency of an ordnance impact would be 2.5×10^{-8} y^{-1} [$0.05 \times (4.8 \times 10^{-7}\ y^{-1} + 1.7 \times 10^{-8}\ y^{-1} + 1.6 \times 10^{-9}\ y^{-1})$], which is well below the screening threshold of 2×10^{-6} y^{-1}. Moreover, as previously stated, there have been no reports of aircraft delivering ordnance outside the designated surface hazard area. Therefore, the hazard of dropped or jettisoned ordnance is considered extremely low when compared to the acceptance threshold of 2×10^{-6} y^{-1} and ordnance does not pose a significant risk to the Yucca Mountain facilities.

6.8 UNCERTAINTIES

To cope with uncertainties, the analysis takes a conservative approach. Conservative assumptions are discussed in context elsewhere in the analysis as applicable, and several are summarized as follows:

- No credit is taken for pilot action (Assumption 3.2.15).

- The repository is near the edge of the airspace available for training activities. Aggressive maneuvering and simulated combat, which may lead to ejection, do not take place within the 30-mile radius of the repository, but at locations deeper into the NTTR (Figure 1 and Figure 2). Trace plots of aircraft activity during Red Flag exercises at the NTTR in August 2003 and April 2004 show that flight activity is concentrated far from the repository (Reference 2.2.32 [DIRS 169894], Attachments 7 and 8). Yet the crash density used for the flights within the 30-mile radius is based on crashes that occurred within the NTTR and MOAs (Section 3.2.14).

- Flights over the flight-restricted airspace are assumed to be at the lowest allowable elevation: 14,000 ft MSL, which results in the quickest descent to the ground in case of a crash (Assumption 3.2.5).

- No credit is taken for phased construction of surface facilities, or for the time needed to load and unload the aging pads (Assumption 3.2.7). Thus the effective area used in the analysis is conservatively large.

- No credit is taken for increased approach angles, and decreased skid and shadow areas, that result from topography, landscaping and the proximity of nearby surface facilities (Section 6.4). Thus, the effective area used in the analysis is conservatively large.

- No credit is taken for the ability of transportation casks, aging casks, or buildings to withstand an impact by an aircraft (Assumption 3.2.16).

- The F-16 crash rate, which is the highest military crash rate, is used for all small military aircraft (Assumptions 3.2.12 and 3.2.13).

- The assumed distance to the edge of the Beatty Corridor is conservatively small (Assumption 3.2.8).

6.9 SENSITIVITY CALCULATIONS

Sensitivity calculations are given in Attachment VI.

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7. RESULTS AND CONCLUSIONS

The three contributors to the crash frequency are:

- 2.9×10^{-8} y^{-1} from the Beatty Corridor (Section 6.5.1.8) (5% of the total frequency)
- 8.5×10^{-8} y^{-1} from overflights of the flight-restricted airspace (Section 6.5.2) (14% of the total frequency), and
- 4.8×10^{-7} y^{-1} from flights outside the flight-restricted airspace (Section 6.5.3) (81% of the total frequency).

The total crash frequency is approximately 5.9×10^{-7} y^{-1}. Assuming that the probability of a radiological release upon impact of a crash is 1 (Assumption 3.2.16), the frequency of a radiological release is 5.9×10^{-7} y^{-1} which is well below, with over a 200% margin ($[(2 \times 10^{-6} - 5.9 \times 10^{-7})/ 5.9 \times 10^{-7})] \times 100$), the frequency screening threshold of 2×10^{-6} y^{-1}. Therefore, an aircraft crash is categorized as a Beyond Category 2 event sequence. Converting the frequency to a probability by multiplying by the 50-year surface operations period, the probability of an aircraft crash is 2.95×10^{-5}. Category 2 event sequences are defined in 10 CFR 63.2 (Reference 2.2.8) as those events that have at least one chance in 10,000 of occurring (1×10^{-4}). Therefore, aircraft hazards do not pose a significant risk to the relevant surface facilities (Table 1).

Credit for a flight-restricted airspace and operational constraints are taken, as follows:

- Flights by fixed-wing aircraft in NTS or NTTR airspace within 4.9 NM (5.6 statute mi) of the North Portal and below 14,000 ft MSL are prohibited.
- 1,000 overflights of the flight-restricted airspace per year are permitted above 14,000 ft MSL for fixed-wing aircraft.
- Maneuvering over the flight-restricted airspace is prohibited; flight is straight and level.
- Carrying ordnance over the flight-restricted airspace is prohibited.
- Aircraft overflying the flight-restricted airspace are prohibited from engaging in electronic jamming activity while over the flight-restricted airspace.
- Helicopter flights within 0.5 mi of the relevant surface facilities (Table 1) are prohibited. Helicopter flights are not restricted by the flight-restricted airspace for fixed-wing aircraft. The helipad associated with the repository shall be located at least one-half mile from the relevant surface facilities.
- The duration of emplacement activities is limited to 50 years.

As defense-in-depth, it is recommended that radio frequency spectrum used at the Yucca Mountain project be coordinated with the appropriate Spectrum Management Office, which coordinates radio frequency spectrum with affected agencies.

ATTACHMENT I.

FLIGHTS THROUGH THE BEATTY CORRIDOR

Flights through the Beatty Corridor are counted based on tabular information supplied by the Federal Aviation Administration.

Figure I-1 shows radar tracks for aircraft flying through the public airspace to the southwest of the repository site for a typical day. The figure shows that flights are concentrated between the two restricted airspace complexes in what is designated here as the Beatty Corridor. The image indicates the locations of the R-2508 Range complex, R-4808N and R-4808S on the NTTR, and the approximate locations of the North Portal, Las Vegas, and the Beatty VORTAC (very high frequency omnidirectional range and tactical air navigation station) (Reference 2.2.12 [DIRS 158638]). R-4808N covers most of the NTS, although the southwest corner of the NTS is beneath the triangular R-4808S. The flights that passed through the Beatty Corridor are shown as gray traces. Flights that did not pass through the Beatty Corridor are not shown. Note that while some flights cross R-4808S, it is not heavily used, especially near the border with R-4808N.

For this analysis, it is useful to separately count air carriers (14 CFR Part 121 Reference 2.2.17 [DIRS 168506]); air taxis (14 CFR Part 135 Reference 2.2.18 [DIRS 168507]); general aviation turbojets, turboprops, and reciprocating-piston aircraft; and small and large military aircraft. After a few minor enhancements and error corrections, as described below, the counts are performed as follows. Flights regulated by 14 CFR Part 121 (labeled AC for air carrier) and flights regulated by 14 CFR Part 135 (labeled AT for air taxi) are directly counted in the tabular information provided by the FAA. General aviation aircraft (labeled GA for general aviation) are identified and further classified by engine type: J = jet, T = turboprop, and P = reciprocating-piston, making counting straightforward. Military aircraft are identified and further classified by weight class. Military aircraft in the H weight class (>255,000 lb) are counted as large military, and military aircraft in other categories are counted as small military. The results of the counts produced according to the scheme outlined above are provided in Section 3.2.10.

The flight-count information for 6/1/05 through 6/7/05 (Reference 2.2.14 [DIRS 177034]) and 12/1/05 through 12/7/05 (Reference 2.2.16 [DIRS 177035]) have, in a few instances, missing information that is addressed as follows. The "unknown" GA aircraft are classified as the same engine type as the other GA aircraft in the altitude range. For example, an "unknown" GA would be classified as a "P" for reciprocating piston when the other GA aircraft at that altitude are "P". The regional jets are classified as "T" for turboprop since the definitions state that the regional jet performs like a turboprop. Unclassified military aircraft are classified as small military aircraft due to their higher crash rate. Results of the data counting are contained in Table 3 in Section 3.2.10.

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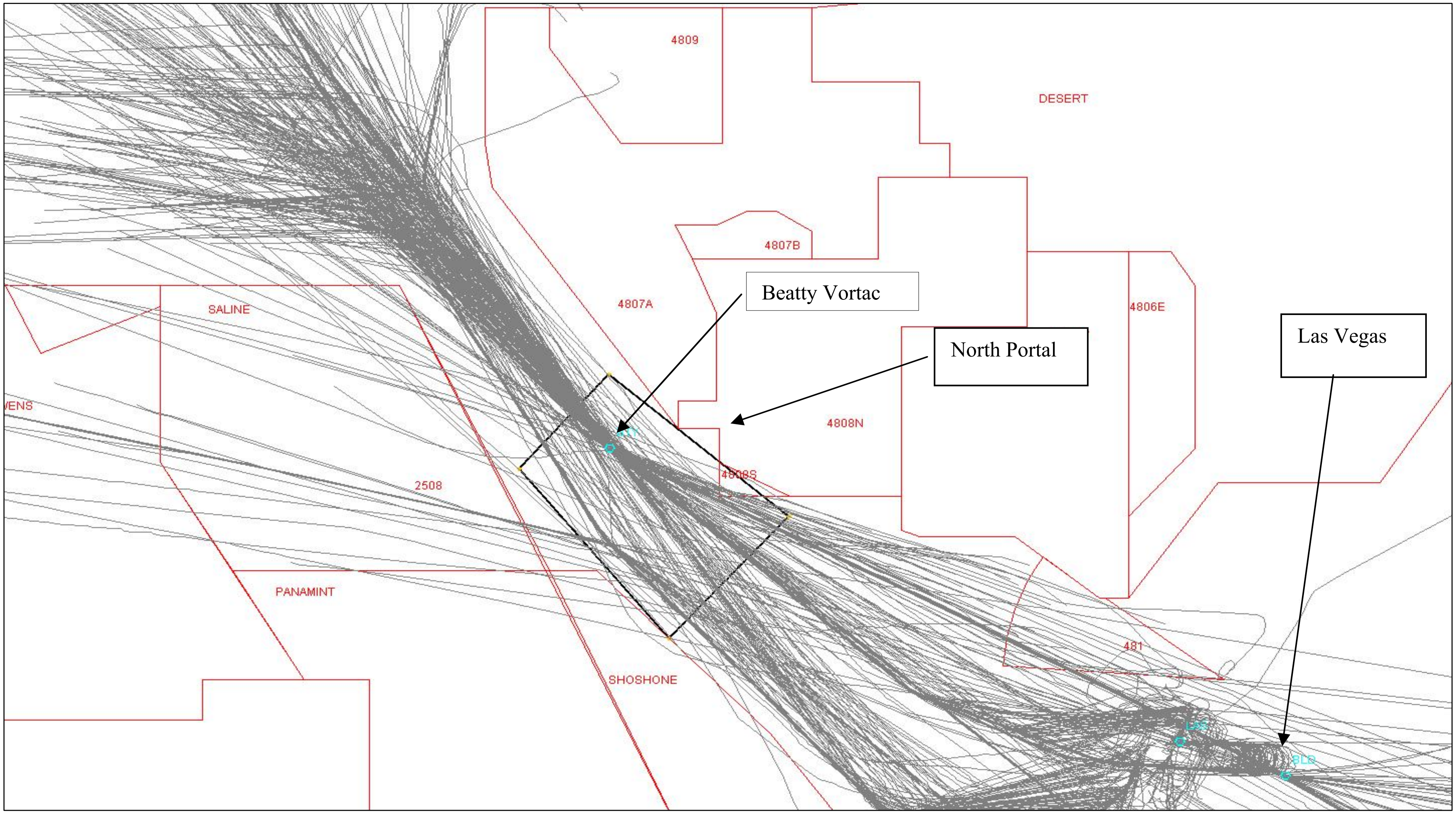

SOURCE: Reference 2.2.14 [DIRS 177034]

Figure I-1. Flights Through the Beatty Corridor On 7 June 2005

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ATTACHMENT II.

FLIGHT DISTRIBUTION IN THE NEVADA TEST AND TRAINING RANGE AND NEVADA TEST SITE AIRSPACE

The conceptual model for estimating crash frequencies for overflights of the flight-restricted airspace assumes that overflights of the restricted airspace are approximately straight and are distributed uniformly over the airspace (Assumption 3.2.4). The concept of uniform distribution of flights within a flight area requires clarification. The concept of uniformly distributed points on a geometric plane is more often encountered, and more readily understood. For example, suppose a hailstorm is said to have distributed hailstones uniformly throughout the front lawn. This is taken to mean that if the lawn is divided into smaller zones, the ratio of the number of hailstones counted in each zone to the area of the zone will be approximately equal for all zones. The shapes of the zones are irrelevant. The sizes are also irrelevant, except that the statistical precision of the calculated density degrades, as the size gets smaller. Now consider an example of lines in a geometric plane: suppose the claim is made that the tracks left by slugs crossing a large leaf are uniformly distributed across the leaf. Attempting to apply the same method for lines as for points runs into mathematical difficulties. To illustrate, suppose the outline of the central vein on the surface of the leaf is used as a zone. The area of the zone is a very small fraction of the leaf's surface due to the narrow width of the vein, but there may be many crossings—perhaps a substantial fraction of the number that cross the entire leaf. The result is a large number of crossings per unit area. In fact, the number of crossings per unit area can be made arbitrarily large by further narrowing the zone. Clearly, a different measure of traffic density is needed.

The literature of integral geometry shows that the conditional probability that a random line that intersects a convex area also intersects a smaller convex area within the larger area is given by the ratio of the perimeters of the two areas (Reference 2.2.57 [DIRS 160334], p. 30). Taking for granted the fact that the larger area has been intersected, the result indicates that the probability of crossing an arbitrarily selected convex area within the larger area is proportional to the perimeter of the smaller area. Thus, a useful measure of traffic density across a convex flight area is the number of crossings divided by the perimeter of the flight area. As an intuitive illustration of this claim, imagine marbles rolling randomly, one at a time, on a table where a coffee mug is resting. The probability of a given marble hitting the mug is proportional to the diameter of the mug, not its footprint area. The diameter of the mug, in turn, is proportional to the perimeter of the mug. Finally, note that the crash frequency estimated by Equation 7 (Section 4.3.2) is proportional to the number of crossings divided by the perimeter of the flight area.

Incursions into concentric circles centered on the North Portal, a 5.8-by-7-mi area termed the Yucca Mountain Repository [YMR] Box roughly centered on the North Portal, and an incursion area that approximates the NTS, were counted on a monthly basis (Reference 2.2.59 [DIRS 166809]). The circles used for the counts are 1, 2, 3, 5, 7, and 10 mi in radius (Reference 2.2.60 [DIRS 161341]) and are designated here as YMR-1, YMR-2, and so on. Coordinates of the YMR incursion area are: northwest corner at 36° 54.00' north latitude and 116° 28.00' west longitude, southeast corner at 36° 48.00' north latitude and 116° 22.00' west longitude

(Reference 2.2.59 [DIRS 166809]). The resulting YMR rectangle is about 7 mi long north and south, 5.8 mi wide east and west, and roughly centered on the North Portal (Reference 2.2.12 [DIRS 158638]); this gives a perimeter length of about 25.6 mi. The NTS incursion area is composed of three separate areas: a triangle and two rectangles (Reference 2.2.61 [DIRS 160821]), which together form a single polygon that approximately coincides with the NTS (excluding R-4808S). The three areas are defined as follows:

- First rectangle. Northwest corner: 37° 16.00’ north latitude, 116° 27.00’ west longitude; southeast corner: 36° 46.25’ north latitude, 115° 56.00’ west longitude.

- Second rectangle. Northwest corner: 36° 46.25’ north latitude, 116° 14.75’ west longitude; southeast corner: 36° 41.00’ north latitude, 115° 56.00’ west longitude.

- Triangle. First corner: 36° 46.25’ north latitude, 116° 27.00’ west longitude; second corner: 36° 41.00’ north latitude, 116° 14.75’ west longitude; third corner: 36° 46.25’ north latitude, 116° 14.75’ west longitude.

The perimeter of the NTS incursion area is about 133 mi (Reference 2.2.12 [DIRS 158638]).

An examination of the ratios of the total incursion counts to the perimeters of the corresponding flight areas for a recent 18-month period (Table II-1) indicates that flights are approximately uniformly distributed within about 7 mi of the North Portal and within the YMR Box. Air traffic is denser for the NTS as a whole and for the larger concentric circle. Thus, traffic density is nearly uniform within about 7 mi of the North Portal, but increases beyond 7 mi from the North Portal. The count for the YMR Box is representative of air traffic within about 7 mi of the North Portal.

Table II-1. Aircraft Incursion Counts By Month and Flight Area

Flight Area Designator	**NTS**	**YMR Box**	**YMR-1**	**YMR-2**	**YMR-3**	**YMR-5**	**YMR-7**	**YMR-10**
Radius of Concentric Circle (mi)	**-**	**-**	**1**	**2**	**3**	**5**	**7**	**10**
Perimeter of Flight Area (mi)	**133**	**25.6**	**6.3**	**12.6**	**18.8**	**31.4**	**44.0**	**62.8**
Month in 2003								
January	1437	118	7	12	21	53	87	216
February	1205	98	13	45	58	128	224	491
March	1679	207	34	91	139	289	434	757
April	2347	222	47	92	130	301	432	930
May	2418	304	98	196	246	421	634	1999
June	2184	110	30	68	87	184	334	718
July	1499	121	31	57	84	186	290	693
August	2505	185	46	99	143	295	452	846
September	1308	130	36	71	96	187	274	586
October	2904	326	69	129	226	455	664	1097
November	2460	266	48	103	167	392	592	977
December	1735	120	32	56	95	162	228	496
Month in 2004								
January	1525	170	25	76	130	227	311	545
February	1332	183	63	96	142	254	340	533
March	3006	410	55	223	298	660	896	1314
April	1930	274	38	99	169	384	531	927
May	3231	600	80	211	393	828	1317	2191
June	1978	276	62	254	154	280	464	884
Average monthly	2038	229	45	110	154	316	472	900
Average annual	24455	2747	543	1319	1852	3791	5669	10800
Average annual / Perimeter (mi^{-1})	184	107	86	105	98	121	129	172

NOTE: The flight areas are the NTS, the 5.8-by-7-mi YMR Box, and concentric circles surrounding the North Portal.

SOURCES: Reference 2.2.59 [DIRS 166809], Reference 2.2.62 [DIRS 171184]; Reference 2.2.63 [DIRS 171185]; Reference 2.2.64 [DIRS 171303].

NTS = Nevada Test Site; YMR = Yucca Mountain Repository.

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ATTACHMENT III.

INFORMATION ON A SAMPLE OF MILITARY AIRCRAFT CRASHES

To support the frequency analysis of aircraft hazards, U.S. Air Force (USAF) aircraft crash data for the aircraft of concern (Section 3.2.12) were compiled and summarized by evaluating information from aircraft crash investigation reports (Table III-1). There are three types of reports used to compile the data on the crashes: Safety Reports, Accident Investigation Reports, and Executive Summary Reports. The Safety Reports are compiled and maintained at the Air Force Safety Center located at Kirtland Air Force Base in Albuquerque, New Mexico. The Executive Summary reports for years 2000 to 2006 are publicly available on the USAF Accident Investigation Board web site at http://usaf.aib.law.af.mil/. The Accident Investigation Reports for F-16s were collected from publicly available reports on the Nuclear Regulatory Commission (NRC) Agency Documents Access and Management System (ADAMS) search web site at http://www.nrc.gov/reading-rm/adams/web-based.html. Visits to the Air Force Safety Center were undertaken in August and September 2004, June 2005, and June 2006. Safety reports that were reviewed were mishaps that resulted in the loss of an aircraft of concern (Section 3.2.12), F-16, F-15, F-22 and A-10, which occurred worldwide from May 1990 to December 2005. The latest reports available from the Air Force Safety Center during the June 2006 visit were from December 2005. Some safety reports were unavailable when the crash data was compiled. Primary data extracted from the reports included the distance that a disabled aircraft traveled after pilot ejection, the altitude of ejection, and the cause of the crash. Information was also obtained from the reports about crashes when the pilot did not eject.

A direct indication of the distance traveled by the aircraft to the crash point after ejection was not provided in most reports. The actual location of the aircraft at the time of ejection was not routinely provided. In such cases, the ground impact location of the ejection seat or the canopy, which is released from the aircraft just prior to ejection, was generally used as an estimate of the ejection point. This procedure introduces uncertainties because the canopy or ejection seat could have been transported by wind. Nonetheless, this potential is negligible in most cases because ejection altitudes were found to be small, which would tend to minimize the drop time and lateral movement of the canopy or seat. Further, this error is expected to be random in that it could either increase or decrease the actual distance from ejection to crash location so that use of the entire data set could tend to obscure this error.

In most cases, the ejection-to-crash distance estimates had to be calculated or inferred, dependent upon information included in the reports. The following methods were used:

- Scaling from crash maps, or, if not possible, locating the crash and the canopy, ejection seat, or the pilot on scaled maps based on map locations included in the crash reports.
- Use of the Haversine formula (Reference 2.2.65 [DIRS 172067], p. 159) when longitude and latitude coordinates of the canopy or ejection seat and the crash location were provided in the reports. As explained in Reference 2.2.65 ([DIRS 172067], p. 159), this method is appropriate for calculations involving small angular differences. The calculations of distance require the mean radius of the Earth, taken as 6,371 km (Reference 2.2.66 [DIRS 128733], p. F-193).

- Use of angle of descent and elevation of ejection.

In some cases, the altitude or distance traveled after ejection differed between the Safety Report and the Accident Investigation Report. When conflicting information existed, the source of the information, that is statements from pilots versus data, was taken into account when determining which source to use. When information concerning the locations of both the canopy and ejection seat was available, the ejection-to-crash distance was calculated as the average of the distances from the crash site to the canopy and ejection seat.

The data obtained are provided in Table III-1, arranged chronologically. The table gives:

- The source document for the event. Reference 2.2.67 ([DIRS 174605]) is an electronic copy of excerpts organized in electronic files named by year. The citations for Reference 2.2.67 ([DIRS 174605]) are by file name, which is the year, followed by the page number.
- Description of the initiating event, such as engine failure or midair collision
- Type of aircraft involved
- Serial number of the aircraft
- Date of the event
- Ejection altitude
- Distance traveled from actual or inferred ejection point to the crash site
- Method used to estimate the ejection to crash distance
- Comments that provide additional relevant information
- Glide ratio
- Initiating event type, as defined in Assumption 3.2.17.

Crash reports provided from May 1990 to December 2006 are included in Table III-1, even if an ejection-to-crash distance estimate could not be made because of lack of information or if no ejection occurred. Table III-2 provides a summary of information from Table III-1.

Table III-1. Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
1	Reference 2.2.68 ([DIRS 172743] pp. 174 and 175)	Controlled flight into terrain	F-16A	81-0798	25-May-90	0	0	NA	No ejection.	NA	0
2	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 73 and 74)	Controlled flight into terrain	A-10A	79-0125	20-Jun-90	0	0	NA	No ejection	NA	0
3	Reference 2.2.68 ([DIRS 172743] p. 172); Reference 2.2.69 ([DIRS 175319] p. 2)	Engine failure, mechanical	F-16D	84-1321	07-Aug-90	1000 AGL	Unknown	NA	Ejection was successful.	Unknown	1A
4	Reference 2.2.67 ([DIRS 174605], file 1990, pp. 3 to 7); Reference 2.2.68 ([DIRS 172743] p. 173)	Engine failure, fire	F-16C	83-1151	03-Sep-90	500 AGL	0.24	Map	Ejection was successful. Altitude was taken as the altitude just prior to the zoom. The distance to the crash was taken as the mean of the distance from the crash site to the seat and canopy.	2.53	1B
5	Reference 2.2.67 ([DIRS 174605], file 1990, pp. 8 and 9)	Controlled flight into terrain	F-16C	89-2027	19-Sep-90	0	0	NA	No ejection. Night operations.	NA	0
6	Reference 2.2.68 ([DIRS 172743] pp. 170 and 171)	Engine failure, mechanical	F-16D	85-1510	20-Sep-90	1665 AGL	1.51	Lat, Long	Distance to crash is based on canopy and seat distance from crash site. Coordinates are given in degrees, minutes, and seconds.	4.79	1A
7	Reference 2.2.67 ([DIRS 174605], file 1990, pp. 10 and 11)	Controlled flight into terrain	F-15E	87-0203	30-Sep-90	0	0	NA	No ejection.	NA	0
8	Reference 2.2.68 ([DIRS 172743] pp. 99 and 100); Reference 2.2.70 ([DIRS 175320] p. 2)	Engine failure, mechanical	F-16C	86-0354	23-Oct-90	1500 AGL	1.5	Text	Ejection was successful.	5.28	1A
9	Reference 2.2.67 ([DIRS 174605], file 1990, pp. 12 and 13)	Loss of Control during maneuvering	F-15C	79-0067	24-Oct-90	Unknown	Unknown	NA	Ejection was successful. Mishap occurred during maneuvering. Crashed at sea.	Unknown	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
10	Reference 2.2.67 ([DIRS 174605], file 1990, pp. 14 to 19); Reference 2.2.71 ([DIRS 175321] p. 5)	Use of piddle pack	F-16C	88-0461	01-Dec-90	Unknown	0.06	Map	Loss of control of aircraft during pilot "piddle pack" use. Distance is average of canopy, seat, and pilot distance to crater.	Unknown	0
11	Reference 2.2.68 ([DIRS 172743] p. 169)	Engine failure, mechanical	F-16A	79-0400	13-Jan-91	20,000 MSL	Unknown	NA	Ejection was successful.	Unknown	1A
12	Reference 2.2.68 ([DIRS 172743] pp. 167 and 168)	Centerline fuel tank explosion	F-16A	83-1089	15-Jan-91	3,500 AGL	4.2	Map	Distance from ejection to aircraft impact; map distances transposed to Reference 2.2.72 ([DIRS 172083] p. 23) and scaled.	6.3	1B
13	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 1 to 3)	Mid-air collision	F-16A	78-0009	24-Jan-91	0	0	NA	No ejection.	NA	0
14	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 1 to 3)	Mid-air collision	F-16A	80-0536	24-Jan-91	Unknown	Unknown	NA	Ejection was successful.	Unknown	0
15	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 4 to 17); Reference 2.2.73 ([DIRS 175383] p. 3)	Engine failure, mechanical	F-16A	81-0717	26-Jan-91	2,000 AGL	0.62	Map	Ejection, aircraft over coastline so MSL was taken as AGL. Distance calculated as mean of distances from point of impact to canopy and seat.	1.64	1A
16	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 18 to 24)	Engine failure, mechanical, followed by immediate complete loss of control	F-16C	85-1423	28-Jan-91	13,800 MSL/8,900 AGL	1	Map	Successful ejection. Hand sketch gives ejection seat located 3641 ft from impact. Map plots impact point, ejection seat as well as ejection point. Ejection point was further than seat location. The distance of 1 mi was estimated from map using grids and the information in the sketch.	0.6	1B
17	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 25 and 26)	Controlled flight into terrain	F-16C	84-1379	15-Feb-91	0	0	NA	No ejection.	NA	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
18	Reference 2.2.68 ([DIRS 172743] pp. 104 to 106)	Engine failure, mechanical	F-16C	86-0329	20-Feb-91	300 AGL	0.1	Map	Distance to crash based on indicated distance from canopy to initial impact point, and scaled distance from ejection seat to initial impact point. Ejection distance taken as mean of two distances.	1.8	1A
19	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 27 to 34)	Aircraft fire	F-16C	88-0453	13-Mar-91	Unknown	0.34	Map	Successful ejection. Distance from approximate center of crash site to average of canopy and seat.	Unknown	1B
20	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 35 to 41); Reference 2.2.74 ([DIRS 175323] p. 3)	Loss of control during maneuvering	F-16A	82-1003	15-Mar-91	4525 AGL	0.22	Map	Air-to-air fighter maneuvering. Loss of control during defensive role. Distance from canopy.	0.26	0
21	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 42 to 55)	Landing mishap	F-15C	78-0526	27-Mar-91	NA	NA	NA	Impacted ridgeline 2.6 NM from runway on landing approach. Although pilot ejected, altitude and distance to crash is not applicable per Section 3.2.17.	NA	0
22	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 56 and 57)	Controlled flight into terrain	F-16A	81-0758	02-Apr-91	0	0	NA	Impact with water during maneuvering. No ejection.	NA	0
23	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 58 to 60); Reference 2.2.68 ([DIRS 172743] p. 164)	Loss of control	F-16C	89-2061	04-Apr-91	Unknown	Unknown	NA	Aircraft went into steep nose-low spiral. Ejection was successful.	Unknown	1B
24	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 61 and 62)	Take-off mishap	F-16A	79-0391	11-Apr-91	NA	NA	NA	Aborted takeoff, successful ejection from ground.	NA	0
25	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 63 to 67); Reference 2.2.75 ([DIRS 175324] pp. 2 and 3)	Bird Impact	F-16A	82-0920	18-Apr-91	2800 AGL	0.62	Text	Low-level flight, collision with bird at 300 ft AGL.	1.2	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
26	Reference 2.2.68 ([DIRS 172743] pp. 107 to 109); Reference 2.2.76 ([DIRS 175325] p. 12)	Engine failure, mechanical	F-16C	87-0302	07-May-91	506 AGL	0.17	Map	Distance to crash based on distance from canopy and ejection seat to crash site given on map in crash report (900 ft). Event occurred at takeoff.	1.77	1A
27	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 71 and 72); Reference 2.2.68 ([DIRS 172743] pp. 160 and 161)	Engine failure, mechanical	F-16B	81-0814	08-Jun-91	900 AGL	0.5	Map	Distance to crash calculated as mean of distances from canopy and seat to impact crater, indicated on diagram adjoined to report.	2.9	1A
28	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 75 to 82)	Engine failure, fire	A-10A	80-0260	16-Jul-91	300 AGL	0.09	Map	Low Altitude Training - Distance taken from ejection seat to impact crater. Ejection taken as altitude of event.	1.6	1B
29	Reference 2.2.68 ([DIRS 172743] pp. 112 and 113); Reference 2.2.77 ([DIRS 175360] p. 2)	Engine failure, fire	F-16C	86-0045	17-Jul-91	2500 MSL (AGL)	Unknown	NA	Aircraft crashed in sea.	Unknown	1B
30	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 83 and 84)	Controlled flight into terrain	F-16DG	88-0168	30-Jul-91	0	0	NA	No ejection.	NA	0
31	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 85 to 91)	Loss of control during maneuvering	F-15E	87-0172	16-Sep-91	8000 AGL	0.10	Map	Successful ejection. Distance taken as mean distance from crash site to canopy and seats.	0.07	0
32	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 92 to 94)	Mid-air collision	A-10A	80-0209	23-Sep-91	0	0	NA	No ejection.	NA	0
33	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 92 to 94)	Mid-air collision	A-10A	79-0203	23-Sep-91	0	0	NA	No ejection.	NA	0
34	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 95 and 96)	Controlled flight into terrain	F-16CG	89-2059	07-Oct-91	0	0	NA	No ejection.	NA	0
35	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 97 and 98)	Controlled flight into terrain	F-16B	79-0419	14-Nov-91	0	0	NA	No ejection.	NA	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
36	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 99 and 100); Reference 2.2.78 ([DIRS 175327] pp. 1 and 2)	Engine failure, mechanical	F-16A	80-0484	27-Nov-91	900 to 1000 AGL	1	Text	Low-level flight. Glide ratio calculated with mean ejection altitude of 950 ft AGL.	5.56	1A
37	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 101 to 106)	Engine failure, fire	F-16C	89-2089	16-Dec-91	11,000 MSL	4.47	Lat, Long	Close to coast so MSL is taken as AGL. Site at 34°11’36.8”N, 79° 18’45.7”, canopy at 34°15’23”N, 79° 17’20”, seat at 34°15’13.8”N, 79°17’18.5”. Distance as average of seat and canopy.	2.14	1B
38	Reference 2.2.67 ([DIRS 174605], file 1991, pp. 107 and 108)	Unknown	F-16B	82-1040	19-Dec-91	Unknown	Unknown	NA	Aircraft not located.	Unknown	1B
39	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 1 to 5); Reference 2.2.68 ([DIRS 172743] pp. 54 to 56)	Airframe failure	F-16C	84-1267	13-Jan-92	300 AGL	0.24	Map	Pilot was able to land but engine did not shut down. Pilot elected to take off again and subsequently successfully ejected after climb-out. Distance taken as average of seat and canopy	4.3	1A
40	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 6 to 9); Reference 2.2.79 ([DIRS 175328] p. 7)	Controlled flight into terrain	F-16CG	88-0470	14-Jan-92	900 AGL	0.1	Map	Pilot saw terrain and ejected. Distance taken as average of seat and canopy.	0.59	0
41	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 10 to 13)	Mid-air collision	F-15A	75-0071	15-Jan-92	6500 AGL	3.90	Lat, Long	Other plane returned to base. Initiating event altitude assumed for ejection. Distance taken from parachute landing site.	3.17	0
42	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 14 to 19)	Abandoned aircraft during maneuvering	F-15C	81-0052	21-Jan-92	Unknown	Unknown	NA	Mishap during acrobatics. Insufficient information in report for altitude and distance. Successful ejection.	Unknown	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
43	Reference 2.2.80 ([DIRS 175329] pp. 3 to 13)	Mid-air collision	F-16C	85-1496	23-Jan-92	15,000 MSL	Unknown	NA	Other plane returned to base. Ejection altitude is 15,000 MSL, over water, therefore; altitude is also AGL; no distance to crash is known.	Unknown	0
44	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 20 to 30)	Mid-air collision	F-16A	81-0704	03-Mar-92	21,000 MSL	Unknown	NA	Ejection altitude assumed to be the altitude of mid-air collision.	Unknown	0
45	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 20 to 30)	Mid-air collision	F-16A	81-0706	03-Mar-92	0	0	NA	Pilot did not eject.	NA	0
46	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 31 to 38)	Landing mishap	A-10A	76-0526	11-Apr-92	NA	NA	NA	Although pilot ejected, altitude and distance to crash is not applicable per Section 3.2.17.	NA	0
47	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 39 and 40)	Take-off mishap	F-16CG	89-2110	24-Apr-92	NA	NA	NA	Loss of power at take-off. No apparent ejection.	NA	0
48	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 41 and 42)	Landing mishap	F-22A	87-0701	25-Apr-92	NA	NA	NA	Premeditated aborted landing for testing the F-22 during a crash. No ejection.	NA	0
49	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 43 and 44)	Landing mishap	F-16ADF	80-0610	05-May-92	NA	NA	NA	Crashed on landing. Ejection occurred at landing.	NA	0
50	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 45 to 50)	Abandoned aircraft during maneuvering	F-16A	83-1071	21-May-92	Unknown	0.09	Map	Event took place during a low altitude intercept. Successful ejection. Distance of mean from canopy and seat.	Unknown	0
51	Reference 2.2.68 ([DIRS 172743] pp. 28 to 30)	Engine failure, mechanical	F-16C	90-0749	31-May-92	<3000 AGL	Unknown	NA	Scaling from map was not performed because scale is given under a text form (as “1 500”). Because map may have been resized when formatted into the compilation report, this form of scaling cannot be trusted for estimating distances.	Unknown	1A

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
52	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 51 and 52)	Controlled flight into terrain	F-16DG	88-0160	02-Jun-92	0	0	NA	No ejection.	NA	0
53	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 53 to 56)	Loss of control	F-15C	85-0116	13-Jul-92	Unknown	Unknown	NA	Impact with water. Successful ejection over water.	Unknown	1B
54	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 57 and 58)	Controlled flight into terrain	F-16A	82-0943	31-Jul-92	0	0	NA	No ejection.	NA	0
55	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 59 to 66)	Loss of control during maneuvering	F-15E	89-0479	10-Aug-92	41 AGL	0	Text	During maneuvering exercise, saw terrain and ejected; unsuccessful ejection	0	0
56	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 67 to 69)	Loss of control during testing	A-10A	78-0695	28-Aug-92	11,800 AGL	Unknown	NA	During a functional flight check, mishap occurred at 15,000 ft during engine cross bleed start. Shutdown one engine for restart but would not restart. Sketch was not detailed enough to determine distance.	Unknown	0
57	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 70 to 73); Reference 2.2.68 ([DIRS 172743] pp. 31 and 32); Reference 2.2.81 ([DIRS 175330] p.3)	Engine failure, mechanical	F-16ADF	81-0697	31-Aug-92	2,000 MSL	Unknown	NA	Ejection was successful. Scale on sketch not reliable.	Unknown	1A
58	Reference 2.2.68 ([DIRS 172743] pp. 33 to 38); Reference 2.2.82 ([DIRS 175384] p. 7)	Engine failure, mechanical	F-16C	83-1139	01-Sep-92	2,000 AGL	1.4	Map	Distance to crash is measured from parachute (near canopy and seat) to center of main crash site as provided on map.	3.70	1A
59	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 93 to 98); Reference 2.2.83 ([DIRS 175331] pp. 7 to 11)	Use of piddle pack	F-16C	85-1451	08-Sep-92	2,000 AGL	Unknown	NA	Seat belt interference during “piddle pack” use. Insufficient information to determine distance to crash.	Unknown	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
60	Reference 2.2.68 ([DIRS 172743] pp. 39 to 41; Reference 2.2.84 ([DIRS 175385] p. 2)	Bird Impact	F-16A	80-0566	18-Sep-92	750 AGL	0.9	Map	Used mean of altitudes from two sources. Distance scaled on map from ejection point to crash site. Bird strike shortly after liftoff.	6.3	0
61	Reference 2.2.68 ([DIRS 172743] pp. 44 to 47); Reference 2.2.85 ([DIRS 175333] p. 2)	Engine failure, mechanical	F-16C	85-1485	22-Oct-92	310 AGL	Unknown	NA	Crash site survey information is provided but text is illegible. Ejection was successful.	Unknown	1A
62	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 101 and 102); Reference 2.2.86 ([DIRS 175334] p. 3)	Landing mishap	F-16CG	90-0761	27-Oct-92	NA	NA	NA	Unsuccessful landing. Although pilot ejected, altitude and distance to crash is not applicable per Section 3.2.17.	NA	0
63	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 103 and 104)	Engine failure, mechanical	F-16A	82-0985	30-Oct-92	1,500 AGL	0.8	Text	Engine failure during take-off. Successful ejection. Distance from pilot to crash site.	2.8	1A
64	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 105 to 108)	Loss of control	A-10A	79-0184	12-Nov-92	Unknown	Unknown	NA	Engine failures with multiple malfunctions. Successful ejection.	Unknown	1B
65	Reference 2.2.68 ([DIRS 172743] pp. 62 to 64)	Controlled flight into terrain	A-10A	81-0993	06-Dec-92	0	0	NA	No ejection.	NA	0
66	Reference 2.2.67 ([DIRS 174605], file 1992, pp. 109 to 115); Reference 2.2.68 ([DIRS 172743] pp. 244, and 258 to 260); Reference 2.2.87 ([DIRS 175335] pp. 3, 4, and 8)	Bird Impact	F-16A	83-1078	17-Dec-92	3200 AGL	0.17	Map	Distance to crash is based on distance between seat and approximate center of crash site (ventral fin). Ground level taken as 300 ft MSL. Bird strike was at 1000 ft AGL.	0.28	0
67	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 1 and 2)	Controlled flight into terrain	F-16DG	90-0784	18-Feb-93	0	0	Text	Ejection was initiated, but interrupted by ground impact.	NA	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
68	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 3 to 6); Reference 2.2.68 ([DIRS 172743] pp. 72 to 76)	Aircraft fire	F-16A	83-1102	19-Feb-93	1800 AGL	0.2	Map	Distance calculated as distance from center of crash debris (engine) to mean distance to ejection seat and canopy; scaled on map.	0.59	1B
69	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 7 and 8); Reference 2.2.68 ([DIRS 172743] pp. 145 and 146)	Engine failure, mechanical	F-16CG	88-0523	23-Feb-93	1210 AGL	Unknown	NA	Several air-start attempts. Ejection was successful.	Unknown	1A
70	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 9 to 11)	Loss of control during maneuvering	F-15C	79-0027	15-Mar-93	8000 AGL	Unknown	NA	Ejected, but crashed at sea.	Unknown	0
71	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 12 to 17); Reference 2.2.68 ([DIRS 172743] pp. 153 and 154); Reference 2.2.88 ([DIRS 175336] p. 4)	Engine failure, mechanical	F-16A	79-0379	21-Apr-93	50 AGL	Unknown	NA	Illegible map. Ejection was successful. Engine failure following takeoff. Crash on attempted landing.	Unknown	1A
72	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 18 and 19)	Landing mishap	F-16C	85-1492	28-Apr-93	NA	NA	NA	Impact with trees on a ridgeline during approach for landing. Safely ejected. Although pilot ejected, altitude and distance to crash is not applicable per Section 3.2.17.	NA	0
73	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 20 to 23); Reference 2.2.68 ([DIRS 172743] pp. 110 and 111); Reference 2.2.89 ([DIRS 175337] p. 3)	Abandoned aircraft during maneuvering	F-16C	87-0269	18-May-93	7,700 AGL	8.3	Map	G-induced loss of consciousness. Distance to crash measured from canopy to crash site; map distances transposed to Nevada state map Reference 2.2.90 ([DIRS 156950]) and scaled. Given uncertainties, value calculated is taken as the average of distance range found (8.0 mi to 8.6 mi).	5.7	0
74	Reference 2.2.67 ([DIRS 174605], file 1993 pp. 24 and 25)	Controlled flight into terrain	F-16C	89-2069	18-May-93	0	0	NA	No ejection.	NA	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
75	Reference 2.2.67 ([DIRS 174605], file 1993 pp. 26 and 27); Reference 2.2.91 ([DIRS 175338] p. 5)	Loss of control during maneuvering	F-16C	90-0832	24-May-93	620 AGL	0	Text	Unsuccessful ejection.	0	0
76	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 28 to 34)	Airframe failure	F-15A	77-0117	12-Jun-93	Unknown	Unknown	NA	Ejection approximately 5 minutes after malfunction. Mode II ejection which is < 15,000 ft. Insufficient information for determining altitude and distance.	Unknown	1A
77	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 35 to 37)	Mid-air collision	F-16B	82-1042	23-Jun-93	Unknown	Unknown	NA	Mid-air collision, one plane landed successfully.	Unknown	0
78	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 38 to 40)	Take-off mishap	F-16C	87-0335	27-Jul-93	NA	NA	NA	No ejection. Collision with other plane while one plane landing and one plane in takeoff.	NA	0
79	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 38 to 40)	Landing mishap	F-16C	86-0275	27-Jul-93	NA	NA	NA	Successful ejection near ground. Collision with other plane while one plane landing and one plane in takeoff. Although pilot ejected, altitude and distance to crash is not applicable per Section 3.2.17.	NA	0
80	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 41 and 42)	Controlled flight into terrain	F-16C	86-0250	10-Aug-93	0	0	NA	No ejection.	NA	0
81	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 43 to 48); Reference 2.2.68 ([DIRS 172743] pp. 151 and 152)	Engine failure, mechanical	F-16C	86-0343	11-Aug-93	1700 AGL	Unknown	NA	Ejection was successful. Plane crashed in water.	Unknown	1A
82	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 49 and 50)	Engine failure, mechanical	F-16A	82-0990	27-Aug-93	0	Unknown	NA	Pilot ejected upon landing.	NA	1A

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
83	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 51 to 53); Reference 2.2.68 ([DIRS 172743] pp. 148 to 150)	Engine failure, fire	F-16A	81-0779	11-Sep-93	22,000 MSL	0.17	Map	Distance to crash calculated as mean of distances from canopy and ejection seat to crash site (distances indicated on map). Elevation of Union, MO approximately 500 ft MSL.	0.04	1B
84	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 54 to 64); Reference 2.2.92 ([DIRS 175339] p. 6)	Mid-air collision	F-16C	86-0253	27-Sep-93	4,600 AGL	0.1	Map	Other plane safely returned to base. Distance to crash is mean of canopy and seat location to impact site. Ground level taken from map.	0.12	0
85	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 65 to 66); Reference 2.2.93 ([DIRS 175340] p. 5)	Engine failure, fuel emergency	F-16CJ	91-0350	08-Oct-93	Unknown	Unknown	NA	Engine flame-out due to running out of fuel. Crashed on landing.	Unknown	1B
86	Reference 2.2.68 ([DIRS 172743] p. 77 and 78)	Controlled flight into terrain	F-16C	88-0448	08-Nov-93	0	0	NA	No ejection.	NA	0
87	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 67 to 73); Reference 2.2.94 ([DIRS 175342] p. 3)	Engine failure, mechanical	F-16C	86-0325	09-Nov-93	610 AGL	Unknown	NA	Initiating event altitude was at 10,000 ft MSL/ 1000 ft AGL	Unknown	1A
88	Reference 2.2.67 ([DIRS 174605], file 1993, pp. 74 and 75)	Controlled flight into terrain	F-16A	81-0770	29-Nov-93	0	0	NA	No ejection.	NA	0
89	Reference 2.2.67 ([DIRS 174605], file 1993 pp. 76 to 78)	Mid-air collision	F-16A	82-0927	17-Dec-93	0	0	NA	No ejection.	NA	0
90	Reference 2.2.67 ([DIRS 174605], file 1993 pp. 76 to 78)	Mid-air collision	F-15A	75-0054	17-Dec-93	Unknown	Unknown	NA	Insufficient information. Successful ejection.	Unknown	0
91	Reference 2.2.67 ([DIRS 174605], file 1994, pp. 1 and 2)	Engine failure, mechanical	A-10A	78-0669	24-Jan-94	Unknown	Unknown	NA	Attempted single engine approach and landing. Engine stalled. Pilot ejected. Insufficient information for distance to crash from ejection.	Unknown	1A

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
92	Reference 2.2.95 ([DIRS 175343] pp. 1 and 2)	Take-off mishap	F-16C	87-0270	26-Jan-94	NA	NA	NA	Problems occurred during takeoff. Successful ejection.	NA	0
93	Reference 2.2.95 ([DIRS 175343] pp. 1 and 2)	Take-off mishap	F-16D	87-0389	26-Jan-94	NA	NA	NA	Problems occurred during takeoff. No ejection.	NA	0
94	Reference 2.2.68 ([DIRS 172743] pp. 84 and 85)	Engine failure, mechanical	F-16CJ	90-0823	02-Feb-94	2000 AGL	Unknown	NA	Ejection was successful.	Unknown	1A
95	Reference 2.2.68 ([DIRS 172743] pp. 86 to 88); Reference 2.2.96 ([DIRS 175344] p. 5)	Engine failure, mechanical	F-16CG	90-0764	07-Feb-94	2200 AGL	0.78	Map	Distance to crash provided on map from ejection seat to crashed aircraft.	1.9	1A
96	Reference 2.2.68 ([DIRS 172743] p. 10)	Controlled flight into terrain	F-16C	87-0309	14-Feb-94	0	0	NA	No ejection.	NA	0
97	Reference 2.2.97 ([DIRS 175345] p. 1)	Engine failure, mechanical	F-16CG	89-2134	16-Feb-94	0	NA	NA	Ejected on the ground at the end of the runway.	NA	1A
98	Reference 2.2.67 ([DIRS 174605], file 1994, pp. 3 and 4)	Controlled flight into terrain	F-16A	80-0486	28-Feb-94	0	0	NA	No ejection.	NA	0
99	Reference 2.2.67 ([DIRS 174605], file 1994, pp. 5 to 7)	Mid-air collision	F-16D	88-0171	23-Mar-94	0	0	Text	Mid-air collision during runway approach. Ejection was on or near the ground. Other plane landed.	NA	0
100	Reference 2.2.67 ([DIRS 174605], file 1994, pp. 8 and 9)	Landing mishap	F-16C	88-0411	30-Mar-94	NA	NA	NA	Crashed on landing. Ejected on or near the ground.	NA	0
101	Reference 2.2.67 ([DIRS 174605], file 1994, pp. 10 to 13)	Take-off mishap	F-15C	78-0497	04-Apr-94	NA	NA	NA	Crashed at take-off. Although pilot ejected, altitude and distance to crash is not applicable per Section 3.2.17.	NA	0
102	Reference 2.2.67 ([DIRS 174605], file 1994, pp. 14 to 17)	Loss of control during maneuvering	F-15C	79-0058	05-May-94	11,000 MSL (AGL)	Unknown	NA	Maneuvering training. Aircraft impacted water after pilot ejected.	Unknown	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
103	Reference 2.2.67 ([DIRS 174605], file 1994, pp. 18 to 22)	Mid-air collision	F-16C	87-0274	06-May-94	15,000 MSL	Unknown	NA	Insufficient information for distance to crash. Plane crashed in water. Ejection altitude taken as altitude of mid-air collision. Event occurred over water so altitude is AGL.	Unknown	0
104	Reference 2.2.67 ([DIRS 174605], file 1994, pp. 18 to 22)	Mid-air collision	F-15C	78-0530	06-May-94	0	0	NA	Insufficient information. Plane crashed in water. Pilot did not eject.	NA	0
105	Reference 2.2.67 ([DIRS 174605], file 1994, pp. 23 to 26)	Mid-air collision	A-10A	80-0227	18-May-94	1200 AGL	Unknown	NA	Mid-air collision. Insufficient information of map. Ejection altitude taken as altitude of mid-air collision.	Unknown	0
106	Reference 2.2.67 ([DIRS 174605], file 1994, pp. 23 to 26)	Mid-air collision	A-10A	81-0940	18-May-94	1200 AGL	Unknown	NA	Mid-air collision. Insufficient information of map. Ejection altitude taken as altitude of mid-air collision.	Unknown	0
107	Reference 2.2.67 ([DIRS 174605], file 1994, pp. 27 and 28)	Take-off mishap	A-10A	80-0249	08-Jun-94	NA	NA	NA	Crashed at take-off; no ejection.	NA	0
108	Reference 2.2.67 ([DIRS 174605], file 1994, pp. 29 to 31)	Take-off mishap	F-16A	82-0934	12-Jun-94	NA	NA	NA	Aborted takeoff. Although pilot ejected, altitude and distance to crash is not applicable per Section 3.2.17.	NA	0
109	Reference 2.2.67 ([DIRS 174605], file 1994, pp. 32 to 65); Reference 2.2.68 ([DIRS 172743] pp. 245 to 249); Reference 2.2.98 ([DIRS 175346] p. 2)	Bird impact	F-16B	83-1173	01-Jul-94	1500 AGL	0.75	Map	Engine failure due to bird ingestion. Distance to crash calculated as mean of distances from canopy and seat to crash site; scaled from map. Engine failure was caused by bird ingestion shortly after lift off.	2.64	0
110	Reference 2.2.67 ([DIRS 174605], file 1994, pp. 66 and 67)	Controlled flight into terrain	A-10A	79-0214	17-Sep-94	0	0	NA	Controlled flight into ground. No ejection.	NA	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
111	Reference 2.2.68 ([DIRS 172743] pp. 147, 234 and 235); Reference 2.2.99 ([DIRS 175348] pp. 3 to 8)	Engine failure, mechanical	F-16CG	88-0488	20-Sep-94	3300 AGL	7	Text	Ejection was successful.	11.2	1A
112	Reference 2.2.100 ([DIRS 175349] pp. 1 and 2)	Landing mishap	F-16CG	89-2058	18-Oct-94	NA	NA	NA	Gear-up landing due to hydraulic failure. No ejection.	NA	0
113	Reference 2.2.68 ([DIRS 172743] pp. 89 to 91); Reference 2.2.101 ([DIRS 175350] pp. 4 to 6)	Engine failure, mechanical	F-16CJ	90-0814	25-Oct-94	1380 AGL	1.5	Text	Distance to crash obtained from text.	5.74	1A
114	Reference 2.2.67 ([DIRS 174605], file 1995, pp. 1 to 8); Reference 2.2.68 ([DIRS 172743] pp. 70 and 71); Reference 2.2.102 ([DIRS 175351] pp. 4 and 5)	Engine failure, mechanical	F-16D	90-0849	13-Jan-95	4440 AGL	Unknown	NA	Ejection 9 minutes after takeoff. Ejection altitude (5640 ft MSL) from Reference 2.2.67, ground level (1200 ft MSL) from Reference 2.2.102 ([DIRS 175351] pp. 4 and 5).	Unknown	1A
115	Reference 2.2.67 ([DIRS 174605], file 1995, pp. 9 and 10)	Controlled flight into terrain	F-16CG	89-2036	26-Jan-95	0	0	NA	Impact with water. No ejection.	NA	0
116	Reference 2.2.68 ([DIRS 172743] pp. 52 and 53); Reference 2.2.103 ([DIRS 175352] pp. 1 and 2)	Engine failure, mechanical	F-16CG	89-2000	05-Feb-95	3000 AGL	2.5	Text	Ejection was successful.	4.4	1A
117	Reference 2.2.67 ([DIRS 174605], file 1995, pp. 11 to 13)	Landing mishap	F-16C	88-0478	10-Feb-95	NA	NA	NA	Collision with other plane when landing. Successful ejection.	NA	0
118	Reference 2.2.67 ([DIRS 174605], file 1995, pp. 11 to 13)	Landing mishap	F-16D	83-1185	10-Feb-95	NA	NA	NA	Collision with other plane when landing. Successful landing.	NA	0
119	Reference 2.2.67 ([DIRS 174605], file 1995, pp. 14 and 15)	Loss of control during maneuvering	F-15E	89-0504	18-Apr-95	Unknown	Unknown	NA	Night flight. Aircraft impacted water.	Unknown	0
120	Reference 2.2.68 ([DIRS 172743] p. 131); Reference 2.2.104 ([DIRS 175353] p. 5)	Engine failure, mechanical	F-16B	78-0093	15-May-95	2000 AGL	Unknown	NA	Ejection was successful. Insufficient information to determine distance to crash.	Unknown	1A

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
121	Reference 2.2.67 ([DIRS 174605], file 1995, pp. 16 and 17)	Controlled flight into terrain	A-10A	80-0268	19-May-95	0	0	NA	No ejection.	NA	0
122	Reference 2.2.67 ([DIRS 174605], file 1995, pp. 18 to 21)	Take-off mishap	F-15C	79-0068	30-May-95	NA	NA	NA	Crashed on runway during take-off.	NA	0
123	Reference 2.2.68 ([DIRS 172743] pp. 68 and 69); Reference 2.2.105 ([DIRS 175354] p. 3)	Engine failure, fire	F-16C	87-0273	25-Jun-95	2000 AGL	Unknown	NA	Ejection was successful. Insufficient information to determine distance to crash. .	Unknown	1B
124	Reference 2.2.67 ([DIRS 174605], file 1995, pp. 22 to 27)	Engine failure, mechanical	F-16A	82-1018	13-Jul-95	2000 AGL	2.4	Lat, Long	Ejection was successful. Distance to crash determined from longitude and latitude using the canopy and pilot positions and crash site.	6.34	1A
125	Reference 2.2.67 ([DIRS 174605], file 1995, pp. 28 and 29)	Loss of control during maneuvering	F-15C	78-0537	03-Aug-95	Unknown	Unknown	NA	Uncontrolled flight that led to ejection. Insufficient information on ejection altitude and distance to crash.	Unknown	0
126	Reference 2.2.68 ([DIRS 172743] pp. 57 to 59); Reference 2.2.106 ([DIRS 175388] p. 5)	Engine failure, mechanical	F-16CG	88-0455	21-Aug-95	4500 AGL	1.7	Text	Distance to crash given from ejection location to aircraft impact. Several engine restarts attempted.	2.0	1A
127	Reference 2.2.67 ([DIRS 174605], file 1995, pp. 30 to 32)	Aircraft fire	A-10A	80-0157	29-Aug-95	900 AGL	0.46	Map	The initiating event altitude is taken as the ejection altitude. Distance to crash is rounded up from the average between the seat and canopy locations to the crash site.	2.7	1B
128	Reference 2.2.67 ([DIRS 174605], file 1995, pp. 33 to 36)	Spatial disorientation	A-10A	79-0200	10-Oct-95	2000 AGL	0.4	Text	Ejection after pilot experienced Instrumental Meteorological conditions.	1.06	0
129	Reference 2.2.67 ([DIRS 174605], file 1995, pp. 37 and 38)	Landing mishap	F-15A	76-0061	09-Nov-95	NA	NA	NA	Unable to stop on landing; ejection was successful.	NA	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
130	Reference 2.2.67 ([DIRS 174605], file 1995, pp. 39 to 45)	Loss of control during maneuvering	F-16CG	88-0426	28-Nov-95	8280 MSL	Unknown	NA	Engine stall during maneuvering. Insufficient information to determine distance to crash.	Unknown	0
131	Reference 2.2.67 ([DIRS 174605], file 1995, pp. 46 to 52); Reference 2.2.68 ([DIRS 172743] pp. 48 and 49); Reference 2.2.107 ([DIRS 175356] p. 4)	Engine failure, mechanical	F-16C	84-1250	21-Dec-95	1750 AGL	0.93	Lat, Long	Distance is difference between ejection seat at 34 57 29.22N 110 55 49.9W and impact crater at 34 57 59.5N 110 55 03.6W. Ejection altitude taken as average of range given.	2.81	1A
132	Reference 2.2.67 ([DIRS 174605], file 1996, pp. 1 to 5)	Engine failure, fuel emergency	F-16C	89-2079	20-Jan-96	410 AGL	0.125	Map	Distance to crash is mean distance from canopy and seat to crash site.	1.6	1B
133	Reference 2.2.68 ([DIRS 172743] pp. 127 and 128); Reference 2.2.108 ([DIRS 175357] p. 1)	Engine failure, mechanical	F-16C	86-0361	19-Mar-96	2000 AGL	Unknown	NA	Ejection was successful. Insufficient information to determine distance to crash.	Unknown	1A
134	Reference 2.2.68 ([DIRS 172743] pp. 101 to 103)	Take-off mishap	F-15C	82-0023	21-Mar-96	NA	NA	NA	Excessive sink rate.	NA	0
135	Reference 2.2.68 ([DIRS 172743] pp. 129 and 130); Reference 2.2.109 ([DIRS 175358] p. 2)	Engine failure, mechanical	F-16C	85-1545	07-Jun-96	1550 AGL	1.1	Map	Altitude take as mean of the altitudes given in the two sources. Distance to crash from ejection to aircraft impact; map distances transposed to Reference 2.2.72 ([DIRS 172083] p. 89) and scaled. Return to airport attempted, restarts attempted.	3.75	1A
136	Reference 2.2.68 ([DIRS 172743] pp. 114 and 115)	Engine failure, mechanical	F-16CJ	91-0354	11-Jul-96	209 AGL	0.1	Impact Angle	Distance to crash from ejection to impact based on tangent of impact angle and ejection altitude. Angle of descent was taken as average of range provided (18 to 25 degrees).	2.53	1A

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
137	Reference 2.2.67 ([DIRS 174605], file 1996, pp. 9 and 10)	Take-off mishap	F-16CG	89-2093	31-Jul-96	NA	NA	NA	Pilot ejected just before plane left runway.	NA	0
138	Reference 2.2.68 ([DIRS 172743] pp. 95 to 98); Reference 2.2.110 ([DIRS 175359] pp. 1 to 4)	Engine failure, mechanical	F-16CG	89-2101	03-Aug-96	5400 AGL	3.82	Lat, Long	Plane at 26° 24.95’N, 49° 57.81’E. Pilot at 26° 22.1’N, 49° 59.7’ E. Ejection was successful.	3.74	1A
139	Reference 2.2.67 ([DIRS 174605], file 1996, pp. 11 and 12)	Controlled flight into terrain	A-10A	78-0636	22-Aug-96	0	0	NA	No ejection.	NA	0
140	Reference 2.2.67 ([DIRS 174605], file 1996, pp. 13 to 15)	Engine failure, mechanical	F-15C	86-0150	26-Aug-96	Unknown	Unknown	NA	Low-level tactical training. Successful ejection.	Unknown	1A
141	Reference 2.2.67 ([DIRS 174605], file 1996, pp. 16 to 18); Reference 2.2.68 ([DIRS 172743] pp. 60 and 61)	Engine failure, mechanical	F-16A	82-1020	21-Nov-96	4500 AGL	0.47	Lat, Long	Restart attempted; pilot ejected. Canopy at 36° 21.488’N, 96° 00.856’W, Seat at 36° 21.505’N, 96° 00.754’W and plane at 36° 21.626’N 96° 01.283’W.	0.55	1A
142	Reference 2.2.67 ([DIRS 174605], file 1996, pp. 19 to 23)	Engine failure, mechanical	F-16D	87-0372	27-Nov-96	2000 AGL	0.43	Lat, Long	Successful ejection. Distance to crash is the mean two pilot seats and canopy to the impact point.	1.14	1A
143	Reference 2.2.67 ([DIRS 174605], file 1997, pp. 1 and 2)	Controlled flight into terrain	F-16A	81-0684	07-Jan-97	0	0	NA	No ejection.	NA	0
144	Reference 2.2.67 ([DIRS 174605], file 1997, pp. 3 to 5)	Take-off mishap	F-15C	85-0099	10-Jan-97	NA	NA	NA	No ejection.	NA	0
145	Reference 2.2.67 ([DIRS 174605], file 1997, pp. 6 to 8); Reference 2.2.68 ([DIRS 172743] pp. 116 to 118); Reference 2.2.111 ([DIRS 175361] p. 2)	Engine failure, mechanical	F-16C	83-1134	29-Jan-97	855 AGL	0.58	Lat, Long	Restart attempted; pilot ejected. Distance to crash measured from impact crater at 32 50 05.437N 112 42 37.69W and seat at 32 49 35.24N and 112 42 40.3W.	3.58	1A

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
146	Reference 2.2.68 ([DIRS 172743] pp. 122 to 124); Reference 2.2.112 ([DIRS 175362] p. 4)	Engine failure, mechanical	F-16D	87-0385	04-Feb-97	6200 AGL	2.5	Map	Distance based on ejection location to impact site. Distances extrapolated from map provided and scaled (Reference 2.2.72 [DIRS 172083] p. 97). Multiple restarts attempted.	2.13	1A
147	Reference 2.2.67 ([DIRS 174605], file 1997, pp. 16 to 18)	Mid-air collision	F-16C	86-0257	18-Mar-97	Unknown	Unknown	NA	Other plane returned to base.	Unknown	0
148	Reference 2.2.67 ([DIRS 174605], file 1997, pp. 19 and 20)	Landing mishap	A-10A	80-0156	28-Mar-97	NA	NA	NA	No ejection; flight into ground while landing.	NA	0
149	Reference 2.2.67 ([DIRS 174605], file 1997, pp. 21 to 23)	Controlled flight into terrain	A-10A	80-0170	17-Apr-97	1040 AGL	0.32	Map	While landing, struck a tower 1040 ft tall and then ejected. Took ejection altitude as the height of the tower. Distance taken as mean distance of seat and canopy to the NW edge of impact crater.	1.62	0
150	Reference 2.2.68 ([DIRS 172743] pp. 141 and 142)	Engine failure, mechanical	F-16CG	89-2095	21-Apr-97	1500 AGL	0.36	Map	Distance to crash calculated as mean of distances from approximate center of impact area to canopy and ejection seat; scaled from map.	1.3	1A
151	Reference 2.2.67 ([DIRS 174605], file 1997, pp. 24 to 32)	Engine failure, mechanical	F-16CG	89-2153	12-May-97	497 AGL	0.15	Map	Low-level flight. Mean of canopy and ejection seat to crash site.	1.6	1A
152	Reference 2.2.67 ([DIRS 174605], file 1997, pp. 33 and 34)	Controlled flight into terrain	A-10A	78-0690	27-May-97	0	0	NA	No apparent ejection.	NA	0
153	Reference 2.2.67 ([DIRS 174605], file 1997, pp. 35 to 40); Reference 2.2.113 ([DIRS 175363] pp. 4 and 5)	Abandoned aircraft during maneuvering	F-16C	84-1255	20-Jun-97	9461 AGL	0.73	Lat, Long	Loss of situational awareness during maneuvering. Distance to crash taken as mean of seat and canopy to impact.	0.4	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
154	Reference 2.2.67 ([DIRS 174605], file 1997, pp. 41 to 44)	Engine failure, mechanical	F-15E	89-0491	11-Jul-97	2800 AGL	1.66	Map	Distance to crash is from ejection seat to crash site.	3.13	1A
155	Reference 2.2.67 ([DIRS 174605], file 1997, pp. 45 to 47); Reference 2.2.68 ([DIRS 172743] pp. 42 and 43)	Engine failure, mechanical	F-16B	82-1037	22-Aug-97	1200 AGL	0.90	Lat, Long	Distance from ejection seats to impact location using given coordinates.	4.0	1A
156	Reference 2.2.68 ([DIRS 172743] p. 143)	Mid-air collision	F-16D	84-1320	16-Sep-97	Unknown	Unknown	NA	Second aircraft damaged but returned to base. Pilots ejected successfully.	Unknown	0
157	Reference 2.2.67 ([DIRS 174605], file 1997, pp. 58 to 64); Reference 2.2.114 ([DIRS 175364] p. 8)	Loss of control during maneuvering	F-16C	85-1564	06-Nov-97	4500 AGL	Unknown	NA	Stall. Pilot safely ejected.	Unknown	0
158	Reference 2.2.67 ([DIRS 174605], file 1997, pp. 65 to 67)	Loss of control during maneuvering	F-15C	83-0033	24-Nov-97	Unknown	Unknown	NA	Crashed at sea during air acrobatics; elevation and distances unknown. Successful ejection.	Unknown	0
159	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 1 to 8)	Mid-air collision	F-16CG	88-0449	07-Jan-98	Unknown	0.98	Map	Other plane returned to base. Average distance from impact crater to seat and canopy.	Unknown	0
160	Reference 2.2.68 ([DIRS 172743] pp. 50 and 51)	Engine failure, mechanical	F-16CG	89-2131	08-Jan-98	1700 AGL	0.87	Map	Distance to crash calculated as mean of distances (indicated on map) from edge of aircraft impact area to canopy and seat.	2.7	1A
161	Reference 2.2.115 ([DIRS 175365] p. 1)	Landing mishap	F-16C	89-2067	23-Mar-98	NA	NA	NA	Landing gear collapsed. Pilot ejected on runway.	NA	0
162	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 9 to 11)	Abandoned aircraft during maneuvering	F-16DG	90-0792	25-Mar-98	Unknown	Unknown	NA	Defensive maneuver during simulated attack. Ejected close to water, crashed at sea.	Unknown	0
163	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 12 and 13)	Controlled flight into terrain	F-16CG	88-0473	22-Apr-98	0	0	NA	No ejection.	NA	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
164	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 14 to 19); Reference 2.2.116 ([DIRS 175366] pp. 3 and 4)	Bird Impact	F-16C	85-1550	13-May-98	830 AGL	1	Text	Bird strike at about 830 ft AGL. Ejection was immediate.	6.4	0
165	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 20 to 22)	Loss of control during maneuvering	A-10A	80-0271	14-May-98	Unknown	0.07	Map	During execution of 1G landing attitude stall test, pilot lost control of plane and ejected close to ground. Distance calculated as mean of distance from nose impact point to seat and canopy.	Unknown	0
166	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 23 to 28)	Take-off mishap	F-15A	77-0120	05-Jun-98	NA	NA	NA	Aborted takeoff; ejected just after takeoff.	NA	0
167	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 29 to 31)	Take-off mishap	F-15E	91-0327	16-Jun-98	NA	NA	NA	No ejection. Stopped plane and safely egressed.	NA	0
168	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 32 and 33)	Take-off mishap	F-16D	90-0798	19-Jun-98	NA	NA	NA	Aborted takeoff; ejected while on runway.	NA	0
169	Reference 2.2.68 ([DIRS 172743] pp. 125 and 126)	Engine failure, mechanical	F-16CJ	91-0397	22-Jul-98	3000 AGL	Unknown	NA	Ejection was successful. Plane crashed at sea.	Unknown	1A
170	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 34 and 35)	Take-off mishap	F-16CJ	90-0804	24-Jul-98	NA	NA	NA	Aborted takeoff; ejected while on runway.	NA	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
171	Reference 2.2.68 ([DIRS 172743] pp. 65 to 67)	Engine failure, mechanical	F-16CG	88-0519	24-Aug-98	1100 AGL	1.5	Map	Two maps provided. One (without scale) shows the ejection location above the shoreline and indicates that aircraft was flying true North at time of ejection. The other map (with scale) shows coast outline with debris field in sea. Distance from ejection to crash site was calculated as distance, on a line North/South, from shoreline to center of debris field and scaled.	7.20	1A
172	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 36 to 40)	Abandoned aircraft during maneuvering	F-16C	86-0324	01-Sep-98	300 AGL	0.15	Map	G-induced loss of consciousness. Distance to crash measured from mean of seat impact and canopy to initial aircraft impact. Plane performing in-flight acrobatics.	2.64	0
173	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 41 and 42)	Controlled flight into terrain	F-16D	86-0040	12-Sep-98	0	0	Text	While performing surface attack tactics, pilot ejected, but ejection seat did not clear the aircraft before aircraft impacted with the ground.	NA	0
174	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 43 and 44)	Controlled flight into terrain	F-15E	89-0497	21-Oct-98	0	0	NA	No ejection.	NA	0
175	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 45 to 47)	Take-off mishap	F-16C	90-0730	22-Oct-98	NA	NA	NA	Collision with other plane during takeoff.	NA	0
176	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 45 to 47)	Take-off mishap	F-16C	88-0414	22-Oct-98	NA	NA	NA	Collision with other plane during takeoff.	NA	0
177	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 48 and 49)	Controlled flight into terrain	F-16CG	88-0450	09-Nov-98	0	0	NA	No ejection.	NA	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
178	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 50 to 53)	Engine failure, mechanical	F-16C	85-1489	17-Nov-98	1400 AGL	Unknown	NA	Ejection at 2200 ft MSL.	Unknown	1A
179	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 54 to 59)	Engine failure, mechanical	F-16CJ	93-0538	19-Nov-98	Unknown	1.59	Text	Loss of thrust, followed by ejection.	Unknown	1A
180	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 60 and 61)	Engine failure, mechanical	F-16D	87-0389	04-Dec-98	Unknown	Unknown	NA	Successful ejection.	Unknown	1A
181	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 62 to 68); Reference 2.2.117 ([DIRS 175367] p. 4)	Engine failure, mechanical	F-16C	84-1314	15-Dec-98	1600 AGL	1.31	Lat, Long	Crash following climb-out from low level maneuvering. Distance to crash is mean of distance from seat and canopy to plane impact from coordinates given on map.	4.32	1A
182	Reference 2.2.67 ([DIRS 174605], file 1998, pp. 69 and 70)	Landing mishap	A-10A	81-0971	29-Dec-98	NA	NA	NA	Collapse of landing gear. Pilot egressed after landing.	NA	0
183	Reference 2.2.68 ([DIRS 172743] pp. 183 to 185); Reference 2.2.118 ([DIRS 175369] p. 6)	Engine failure, mechanical	F-16DG	88-0154	07-Jan-99	600 AGL	0.05	Map	Engine malfunction on takeoff. Distance to crash calculated as mean of distances from approximate center of aircraft impact point to canopy and front seat; scaled from map.	0.44	1A
184	Reference 2.2.68 ([DIRS 172743] pp. 3 and 4)	Loss of control	A-10A	78-0628	21-Jan-99	11,000	4.1	Lat, Long	Distance to crash based on estimated map coordinates for pilot recovery and aircraft impact location. Altitude basis (AGL or MSL) unknown. Assumed to be AGL.	2.0	1B
185	Reference 2.2.68 ([DIRS 172743] pp. 180 to 182)	Controlled flight into terrain	F-16CJ	92-3900	21-Jan-99	Unknown	0.28	Map	Distance to crash calculated as mean of distances from location of ejection seat and canopy to final aircraft impact location; scaled on map. Engine failed after aircraft struck trees on a ridgeline.	Unknown	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
186	Reference 2.2.68 ([DIRS 172743] p. 176)	Mid-air collision	F-15C	84-0011	28-Jan-99	Unknown	Unknown	NA	Midair collision. Both pilots ejected. Insufficient information in report for altitude and distance to crash.	Unknown	0
187	Reference 2.2.68 ([DIRS 172743] p. 176)	Mid-air collision	F-15C	82-0020	28-Jan-99	Unknown	Unknown	NA	Midair collision. Both pilots ejected. Insufficient information in report for altitude and distance to crash.	Unknown	0
188	Reference 2.2.67 ([DIRS 174605], file 1999, pp. 17 to 19); Reference 2.2.68 ([DIRS 172743] pp. 177 to 179)	Engine failure, fire	F-16C	84-1304	03-Feb-99	2650 AGL	2.2	Lat, Long	Distance calculated as mean of distances from point of impact to canopy and seat, based on longitude/latitude coordinates. In flight fire after engine failure.	4.37	1B
189	Reference 2.2.67 ([DIRS 174605], file 1999, pp. 20 to 25); Reference 2.2.68 ([DIRS 172743] pp. 206 to 208)	Engine failure, fire	F-16C	88-0490	26-Mar-99	2175 AGL	0.73	Map	Distance calculated as mean of distances from first impact point to canopy and ejection seat, indicated on map.	1.77	1B
190	Reference 2.2.67 ([DIRS 174605], file 1999, pp. 26 to 28); Reference 2.2.68 ([DIRS 172743] pp. 204 and 205)	Landing mishap	F-16DG	89-2175	26-Apr-99	3720 AGL	1.6	Map	Landing gear buckled forcing the pilot to take off again. Aircraft ran out of fuel. Although a landing mishap, ejection altitude and distance to crash are provided because they are large enough to yield relevant information.	2.3	0
191	Reference 2.2.67 ([DIRS 174605], file 1999, pp. 29 to 35); Reference 2.2.68 ([DIRS 172743] pp. 79 to 83);	Mid-air collision	F-15C	82-0008	16-Jun-99	3050 AGL	Unknown	NA	Maps are provided but scales, given under a text format (1”=100’ and 1”=200’) are not usable since maps may have been resized for formatting into the compilation report. Ejection was successful.	Unknown	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
192	Reference 2.2.67 ([DIRS 174605], file 1999, pp. 29 to 35); Reference 2.2.68 ([DIRS 172743] pp. 79 to 83)	Mid-air collision	F-15D	79-0013	16-Jun-99	3375 AGL	Unknown	NA	Maps are provided but scales, given under a text format (1”=100’ and 1”=200’) are not usable since maps may have been resized for formatting into the compilation report. Ejection was successful.	Unknown	0
193	Reference 2.2.68 ([DIRS 172743] pp. 192 and 193)	Engine failure, mechanical	F-16DG	87-0396	18-Jun-99	1490 AGL	1.3	Map	Distance to crash calculated as mean of distances from ejection seat and canopy to approximate center of impact area; scaled from map.	4.6	1A
194	Reference 2.2.68 ([DIRS 172743] p. 191)	Controlled flight into terrain	F-16C	84-1268	01-Jul-99	0	0	NA	Pilot did not eject.	NA	0
195	Reference 2.2.68 ([DIRS 172743] pp. 186 to 190)	Engine failure, mechanical	F-16C	86-0284	12-Jul-99	1600 AGL	Unknown	NA	Map provided but without sufficient information to estimate ejection to crash site distance. Ejection was successful.	Unknown	1A
196	Reference 2.2.67 ([DIRS 174605], file 1999, pp. 36 to 38); Reference 2.2.68 ([DIRS 172743] pp. 201 to 203)	Mid-air collision	F-16C	88-0403	11-Aug-99	400 AGL	Unknown	NA	Second plane involved in collision landed uneventfully. Ejection altitude taken as collision altitude.	Unknown	0
197	Reference 2.2.67 ([DIRS 174605], file 1999, pp. 39 to 44); Reference 2.2.68 ([DIRS 172743] p. 200)	Mid-air collision	F-15A	76-0117	19-Aug-99	11000 AGL	1.7	Text	Distance calculated as mean distances from crash site to canopy and ejection seat, indicated in text. Second plane involved in collision returned to base. Approximate elevation of crash site is about 1000 ft.	0.82	0
198	Reference 2.2.67 ([DIRS 174605], file 1999, pp. 45 and 46)	Landing mishap	F-16D	83-1179	20-Sep-99	NA	NA	NA	Failed to stop on landing. Ejected while on ground.	NA	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
199	Reference 2.2.68 ([DIRS 172743] pp. 194 to 196)	Mid-air collision	F-16C	87-0240	17-Nov-99	Unknown	1.1	Map	Distance to crash calculated as mean of distances from canopy and ejection seat to crash site; map distances transposed to Reference 2.2.72 ([DIRS 172083], p. 29) and scaled. Given uncertainties, value calculated is taken as the average of distance range found (0.9 mi to 1.3 mi). Second plane involved in collision returned to base.	Unknown	0
200	Reference 2.2.67 ([DIRS 174605], file 1999, pp. 47 and 48)	Landing mishap	A-10A	81-0985	22-Nov-99	NA	NA	NA	Failed to stop on landing. Ejected while on ground.	NA	0
201	Reference 2.2.68 ([DIRS 172743] p. 5)	Controlled flight into terrain	A-10A	80-0266	20-Jan-00	0	0	NA	Pilot did not eject. Crash was 12 miles from destination airfield.	NA	0
202	Reference 2.2.68 ([DIRS 172743] pp. 210 to 212)	Engine failure, mechanical	F-16D	90-0794	16-Feb-00	2300 AGL	1.1	Map	Distance to crash from impact point to seat location. Scaled from map. Three restarts attempted.	2.53	1A
203	Reference 2.2.68 ([DIRS 172743] pp. 213 to 215)	Engine failure, mechanical	F-16CG	89-2094	16-Feb-00	2000 AGL	0.72	Lat, Long	Distance based on coordinates provided for flight data recorder (near canopy) and impact site.	1.9	1A
204	Reference 2.2.67 ([DIRS 174605], file 2000, pp. 1 and 2); Reference 2.2.68 ([DIRS 172743] p. 209)	Controlled flight into terrain	F-16CJ	93-0534	19-Mar-00	0	0	NA	Pilot did not eject.	NA	0
205	Reference 2.2.119 ([DIRS 175416])	Take-off mishap	F-15E	88-1682	31-May-00	NA	NA	NA	Aborted take-off. Pilot did not eject.	NA	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
206	Reference 2.2.68 ([DIRS 172743] pp. 218 and 219); Reference 2.2.120 ([DIRS 175426])	Engine failure from pilot error	F-16C	84-1311	16-Jun-00	2700 AGL	2.9	Map	Distance to crash calculated as mean of distances from seat and canopy to approximate center of main crash site; scaled from map. Pilot shut-off throttle during defensive move in combat training.	5.7	0
207	Reference 2.2.68 ([DIRS 172743] pp. 216 and 217), Reference 2.2.121 ([DIRS 175592])	Bird Impact	F-16CG	87-0357	21-Jun-00	2200 AGL	2.3	Map	Distance from ejection seat to impact crater scaled from map. Bird strike at 2,200 ft AGL.	5.52	0
208	Reference 2.2.67 ([DIRS 174605], file 2000, pp. 3 to 8); Reference 2.2.68 ([DIRS 172743] pp. 23 to 25)	Loss of control during maneuvering	F-15C	86-0173	03-Aug-00	5300 AGL	0.1	Map and scale	Aircraft entered spin condition. Loss of control occurred during aggressive maneuvering. Distance is mean of seat and canopy to cockpit.	0.10	0
209	Reference 2.2.67 ([DIRS 174605], file 2000, pp. 9 to 13); Reference 2.2.68 ([DIRS 172743] pp. 18 to 22)	Mid-air collision	F-16CG	88-0542	08-Aug-00	6840 AGL	0.43	Map	Distance to crash calculated as mean of distances from canopy and ejection seat to crash debris as indicated on map. Second aircraft returned to base.	0.33	0
210	Reference 2.2.68 ([DIRS 172743] p. 228)	Controlled flight into terrain	F-16C	85-1456	28-Aug-00	0	0	NA	Pilot did not eject.	NA	0
211	Reference 2.2.67 ([DIRS 174605], file 2000, pp. 14 and 15); Reference 2.2.68 ([DIRS 172743] p. 222)	Engine failure, mechanical	F-16C	83-1138	31-Aug-00	1700 AGL	Unknown	NA	Ejection was successful.	Unknown	1A
212	Reference 2.2.67 ([DIRS 174605], file 2000, pp. 16 to 18)	Landing mishap	F-15E	96-0203	12-Sep-00	NA	NA	NA	No ejection. Landing gear collapse.	NA	0
213	Reference 2.2.68 ([DIRS 172743] pp. 220 and 221)	Engine failure, mechanical	F-16CG	89-2088	12-Oct-00	12,600 AGL	0.42	Impact angle	Distance to crash based on ejection altitude and angle of impact.	0.18	1A

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
214	Reference 2.2.122 ([DIRS 175427])	Take-off mishap	F-15C	78-0489	03-Nov-00	NA	NA	NA	Engine ingested a binder containing orders shortly after takeoff while pilot was raising landing gear. Pilot landed without problems.	NA	0
215	Reference 2.2.68 ([DIRS 172743] pp. 224 to 227)	Mid-air collision	F-16CJ	90-0811	13-Nov-00	Unknown	Unknown	NA	Aircraft and ejected pilot both landed in sea.	Unknown	0
216	Reference 2.2.68 ([DIRS 172743] pp. 224 to 227)	Mid-air collision	F-16CJ	90-0801	13-Nov-00	0	0	NA	Pilot apparently did not eject. Plane crashed into sea.	NA	0
217	Reference 2.2.67 ([DIRS 174605], file 2000, pp. 19 to 23); Reference 2.2.68 ([DIRS 172743] pp. 250 to 252)	Mid-air collision	F-16CG	89-2104	16-Nov-00	2000 AGL	0.12	Map	Distance to crash calculated as mean of distances from ejection seat and canopy to approximate center of crash area (ventral fin), scaled from map. Collision involved light civil aircraft. Ejection altitude taken as collision altitude.	0.32	0
218	Reference 2.2.68 ([DIRS 172743] pp. 229 and 230)	Engine failure, fire	F-16C	86-0313	13-Dec-00	11,000 AGL	10.5	Map	Distance to crash from ejection to approximate center of radar crash plots and debris accumulated on sandbar; map distances transposed to Reference 2.2.72 ([DIRS 172083] p. 23) and scaled. Given uncertainties, value calculated is taken as the average of distance range found (10 mi to 11 mi).	5.00	1B

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
219	Reference 2.2.68 ([DIRS 172743] pp. 277 to 279)	Engine failure, mechanical	A-10A	80-0158	12-Jan-01	Unknown	Unknown	NA	Scaling from map was not performed because scale is given under a text form (1”=75’). Because map may have been resized when formatted into the compilation report, this form of scaling cannot be verified for estimating distances.	Unknown	1A
220	Reference 2.2.68 ([DIRS 172743] pp. 253 to 256)	Engine failure, mechanical	F-16C	87-0330	21-Mar-01	2,000 AGL	1.1	Map	Distance to crash calculated as mean of distances from canopy and ejection seat to initial impact. Scaled from map.	2.90	1A
221	Reference 2.2.67 ([DIRS 174605], file 2001, pp. 1 to 7); Reference 2.2.68 ([DIRS 172743] pp. 261 to 263)	Controlled flight into terrain	F15-C	86-0169	26-Mar-01	0	0	NA	No ejection.	NA	0
222	Reference 2.2.67 ([DIRS 174605], file 2001, pp. 1 to 7); Reference 2.2.68 ([DIRS 172743] pp. 261 to 263)	Controlled flight into terrain	F15-C	86-0180	26-Mar-01	0	0	NA	No ejection.	NA	0
223	Reference 2.2.68 ([DIRS 172743] pp. 280 to 282)	Engine failure, mechanical	F-16D	90-0837	03-Apr-01	Unknown	~0	Map	Ejection seat located in wreckage area.	NA	1A
224	Reference 2.2.68 ([DIRS 172743] pp. 283 to 286)	Loss of control during maneuvering	F-16CG	89-2063	12-Jun-01	NA	~0	Text	Loss of control during flight maneuvers at low altitude. Ejection was attempted but interrupted by ground impact.	NA	0
225	Reference 2.2.68 ([DIRS 172743] pp. 264 to 266); Reference 2.2.123 ([DIRS 175428])	Abandoned aircraft during maneuvering	F-16CJ	90-0815	06-Jul-01	1500 AGL	0.02	Map	G-induced loss of consciousness. Distance to crash (indicated on map) based on location of ejection seat and center of debris field.	0.07	0
226	Reference 2.2.68 ([DIRS 172743] pp. 316 to 319)	Controlled flight into terrain	F-16B	78-0100	17-Jul-01	0	0	Text	Ejection was attempted but interrupted by ground impact.	NA	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
227	Reference 2.2.67 ([DIRS 174605], file 2001, pp. 10 to 15); Reference 2.2.68 ([DIRS 172743] pp. 267 to 271)	Engine failure, mechanical	F-16CG	89-2050	18-Jul-01	2000 AGL	1.5	Map	Distance to crash (indicated on map) based on location of seat and canopy and initial impact.	4.0	1A
228	Reference 2.2.68 ([DIRS 172743] pp. 320 to 325)	Engine failure, fire	F-16DG	88-0167	23-Jul-01	6200 AGL	Unknown	NA	Ejection was successful.	Unknown	1B
229	Reference 2.2.68 ([DIRS 172743] pp. 272 to 276)	Engine failure, mechanical	F-16C	86-0226	26-Jul-01	6600 AGL	1.6	Map	Distance to crash calculated as mean of distances from canopy and seat to impact; map distances transposed to Reference 2.2.72 ([DIRS 172083] p. 29) and scaled. Given uncertainties, value calculated is taken as the average of distance range found (1.5 to 1.7 mi). Ground elevation is approximately 500 ft.	1.3	1A
230	Reference 2.2.67 ([DIRS 174605], file 2001, pp. 16 and 17)	Controlled flight into terrain	A-10A	78-0676	03-Sep-01	Unknown	Unknown	NA	Low altitude training. Pilot ejected.	NA	0
231	Reference 2.2.67 ([DIRS 174605], file 2001, pp. 18 and 19)	Take-off mishap	F-16CG	88-0533	17-Oct-01	NA	NA	NA	Ejection during takeoff while on ground.	NA	0
232	Reference 2.2.67 ([DIRS 174605], file 2001, pp. 20 and 21)	Landing mishap	F-16C	84-1217	25-Oct-01	NA	NA	NA	Landing gear collapse. Ejected while on ground.	NA	0
233	Reference 2.2.67 ([DIRS 174605], file 2002, pp. 1 to 5)	Abandoned aircraft during maneuvering	F-16C	83-1133	10-Jan-02	3700 AGL	Unknown	NA	Negative G flight while maneuvering. Insufficient information to determine distance to crash.	Unknown	0
234	Reference 2.2.68 ([DIRS 172743] pp. 346 to 350)	Mid-air collision	A-10A	80-0233	17-Jan-02	Unknown	0.52	Lat, Long	Distance to crash calculated as mean of distances from location of aircraft to canopy and ejection seat.	Unknown	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
235	Reference 2.2.68 ([DIRS 172743] pp. 346 to 350)	Mid-air collision	A-10A	79-0085	17-Jan-02	Unknown	1.01	Lat, Long	Distance to crash based on location of aircraft and ejection seat.	Unknown	0
236	Reference 2.2.68 ([DIRS 172743] pp. 339 to 343)	Controlled flight into terrain	F-16CJ	91-0415	20-Mar-02	0	0	NA	Pilot did not eject.	NA	0
237	Reference 2.2.68 ([DIRS 172743] pp. 344 and 345)	Engine failure, mechanical	F-16CJ	92-3919	15-Apr-02	Unknown	Unknown	NA	Ejection was successful. Crashed at sea.	Unknown	1A
238	Reference 2.2.68 ([DIRS 172743] pp. 326 to 329)	Loss of control during testing	F-15C	80-0022	30-Apr-02	0	0	NA	High-speed dive; airframe failure. No apparent ejection.	NA	0
239	Reference 2.2.67 ([DIRS 174605], file 2002, pp. 6 to 12)	Engine failure, fire	F-16 CJ	96-5027	29-May-02	12,000 AGL	3.32	Lat, Long	Ejected successfully. Mean distance from canopy and seat to crash site using coordinates estimated from the map.	1.46	1B
240	Reference 2.2.68 ([DIRS 172743] pp. 330 and 331)	Controlled flight into terrain	A-10A	82-0655	27-Jun-02	0	0	NA	Pilot did not eject.	NA	0
241	Reference 2.2.67 ([DIRS 174605], file 2002, pp. 13 to 15); Reference 2.2.68 ([DIRS 172743] pp. 351 and 352)	Loss of control during maneuvering	F-15C	78-0541	21-Aug-02	Unknown	Unknown	NA	Loss of control during maneuvers. Ejection was successful. Crashed at sea.	Unknown	0
242	Reference 2.2.67 ([DIRS 174605], file 2002, pp. 16 to 18)	Landing mishap	F-15C	80-0015	03-Sep-02	NA	NA	NA	Landing gear struck a trench short of the runway.	NA	0
243	Reference 2.2.68 ([DIRS 172743] pp. 332 and 333)	Loss of control during maneuvering	F-16C	87-0316	09-Sep-02	0	0	NA	Pilot did not eject.	NA	0
244	Reference 2.2.67 ([DIRS 174605], file 2002, pp. 19 to 21); Reference 2.2.68 ([DIRS 172743] pp. 334 to 338),	Engine failure, mechanical	F-16C	86-0348	11-Sep-02	249 AGL	0.32	Text	Distance to crash based on locations of ejected pilot and crash site relative to end of runway.	6.79	1A

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
245	Reference 2.2.68 ([DIRS 172743] pp. 11 to 17)	Mid-air collision	F-16CG	89-2006	25-Oct-02	27800 AGL	1.24	Lat, Long	Distance to crash based on coordinates provided for pilot location and crash site. Ejection altitude taken as altitude of impact. Ground level approximately 4200 ft from map.	0.24	0
246	Reference 2.2.68 ([DIRS 172743] pp. 11 to 17); Reference 2.2.124 ([DIRS 175615])	Mid-air collision	F-16CG	89-2111	25-Oct-02	27800 AGL	2.50	Lat, Long	Distance to crash based on coordinates provided for pilot location and crash site. Ejection altitude taken as altitude of impact. Ground level approximately 4200 ft from map.	0.47	0
247	Reference 2.2.68 ([DIRS 172743] p. 27)	Controlled flight into terrain	F-16C	88-0397	13-Nov-02	0	0	NA	Pilot did not eject.	NA	0
248	Reference 2.2.68 ([DIRS 172743] pp. 6 to 9)	Mid-air collision	A-10A	80-0225	04-Dec-02	0	0	Text	Ejection was initiated but was unsuccessful. Map shows wreckage of the two aircraft involved in the mishap. Ejection seat is shown inside wreckage of plane.	NA	0
249	Reference 2.2.68 ([DIRS 172743] pp. 6 to 9)	Mid-air collision	A-10A	79-0191	04-Dec-02	740 AGL	0.02	Map	Map shows wreckage of the two aircraft involved in the mishap. Distance to crash based on location of ejection seat and impact crater of the aircraft that does not contain the ejection seat. Distance to crash scaled from map. Ejection altitude taken as altitude of collision.	0.14	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
250	Reference 2.2.68 ([DIRS 172743] pp. 132 to 134, and 241 to 243)	Mid-air collision	F-15C	80-0040	17-Mar-03	Unknown	0.06	Map	Distance to crash calculated as mean of distances from approximate center of impact crater (cockpit) to ejection seat and canopy. Scaled from map (horizontal and vertical axes do not have the same scale). Second aircraft damaged but returned to base.	Unknown	0
251	Reference 2.2.68 ([DIRS 172743] pp. 236 to 240)	Bird impact	F-16C	89-2052	29-May-03	320 AGL	Unknown	NA	Catastrophic engine failure immediately after takeoff, most likely due to bird strike.	Unknown	0
252	Reference 2.2.68 ([DIRS 172743] pp. 360 to 362)	Loss of control during maneuvering	F-15E	87-0186	04-Jun-03	9,080 MSL	Unknown	NA	Map is supplied but uncertainties about exact locations of canopy and seat are too significant to derive a meaningful ejection distance.	Unknown	0
253	Reference 2.2.68 ([DIRS 172743] pp. 138 to 140)	Engine failure, mechanical	F-16C	88-0451	10-Jun-03	1120 AGL	0.56	Map	Distance to crash based on mean of distances from point of aircraft impact to canopy and ejection seat. Scaled from map.	2.64	1A
254	Reference 2.2.67 ([DIRS 174605], file 2003, pp. 4 to 6); Reference 2.2.68 ([DIRS 172743] pp. 119 to 121)	Engine failure, mechanical	F-16CG	88-0424	12-Jun-03	5800 AGL	Unknown	NA	Ejection was successful. Ground level approximately 600 ft.	Unknown	1A
255	Reference 2.2.67 ([DIRS 174605], file 2003, pp. 7 to 13)	Bird Impact	F-16C	85-1445	13-Jun-03	1270 AGL	0.43	Map	Bird strike at 425 ft AGL causing engine failure. Distance to crash is mean distance from canopy and ejection seat to point of impact.	1.8	0
256	Reference 2.2.68 ([DIRS 172743] p. 26); Reference 2.2.125 ([DIRS 175431])	Controlled flight into terrain	F-16CG	89-2084	09-Sep-03	400 AGL	Unknown	NA	Crash into sea.	Unknown	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
257	Reference 2.2.67 ([DIRS 174605], file 2003, pp. 14 to 17); Reference 2.2.68 ([DIRS 172743] pp. 135 to 137)	Abandoned aircraft during maneuvering	F-16C	87-0327	14-Sep-03	140 AGL	~0	Map	Pilot ejected when he determined maneuver could not be successfully completed. Canopy located in crash debris field.	Unknown	0
258	Reference 2.2.68 ([DIRS 172743] pp. 355 and 356)	Engine failure, fire	F-16C	84-1303	22-Sep-03	4,000 AGL	1.95	Lat, Long	Distance to crash calculated as mean of distances from center of crater impact to ejection seat and canopy. Although text describes the end part of coordinates as seconds of arc, they clearly are decimal fractions of minutes because they are greater than 60.	2.6	1B
259	Reference 2.2.68 ([DIRS 172743] pp. 353 and 354); Reference 2.2.126 ([DIRS 175432])	Engine failure, mechanical	A-10A	79-0143	18-Nov-03	2,000 AGL	0.12	Map	Speed brakes stuck open, hence, categorized as 1B. Distance to crash based on location of canopy and fuselage; scaled from map.	0.32	1B
260	Reference 2.2.68 ([DIRS 172743] pp. 357 to 359)	Loss of control	A-10A	78-0700	25-Feb-04	0	0	NA	Pilot did not eject.	NA	1B
261	Reference 2.2.67 ([DIRS 174605], file 2003, pp. 18 to 20); Reference 2.2.68 ([DIRS 172743] p. 287)	Bird Impact	F-15E	88-1701	06-May-04	Unknown	Unknown	NA	Bird strike at 700 ft AGL. Ejection was successful.	Unknown	0
262	Reference 2.2.68 ([DIRS 172743] pp. 288 to 311)	Mid-air collision	F-16C	85-1555	17-May-04	0	0	NA	Pilot did not eject.	NA	0
263	Reference 2.2.68 ([DIRS 172743] pp. 288 to 311)	Mid-air collision	F-16C	86-0260	17-May-04	Unknown	Unknown	NA	Ejection was successful.	Unknown	0

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
264	Reference 2.2.68 ([DIRS 172743] pp. 312 to 314); Reference 2.2.127 (DIRS 175434])	Inadvertent ejection	F-15C	81-0027	21-May-04	14,500 AGL	12	Map	Distance to crash measured from ejection to aircraft impact; map distances transposed to Reference 2.2.72 ([DIRS 172083] p. 23) and scaled. Given uncertainties in scaling from two maps, ejection distance is rounded off to the closest mile.	4.40	1B
265	Reference 2.2.68 ([DIRS 172743] p. 315)	Engine failure, mechanical	F-15C	79-0054	04-Jun-04	Unknown	Unknown	NA	Ejection was successful.	Unknown	1A
266	Reference 2.2.128 ([DIRS 177050], pp. 1, 7 to 9)	Take-off mishap	F-22	00-4014	20-Dec-04	NA	NA	NA	Ejection was successful. Inoperative flight control system rendered the aircraft unflyable.	NA	0
267	Reference 2.2.129 ([DIRS 177051], Executive Summary, pp. 1, 7 and 8)	Take-off mishap	F-16D	92-3927	18-Mar-05	NA	NA	NA	Ejection was successful. Throttle stuck in after burner due to shifting of cargo in cockpit, which is in violation of procedure.	NA	0
268	Reference 2.2.33 ([DIRS 177052], Executive Summary, pp. 1, 2, 8 to 10)	Loss of control during maneuvering	F-15C	80-0052	25-Mar-05	1750 AGL	Unknown	NA	Ejection was successful. Initiating event was during maneuvers. Ejection altitude is average of range given.	NA	0
269	Reference 2.2.130 ([DIRS 177053], pp. Executive Summary, pp. 1, 2, 5 to 8)	Engine failure, mechanical	F-16D	91-0469	18-Apr-05	1160 MSL	Unknown	NA	Engine failure. Several restart attempts. Ejection was successful.	Unknown	1A
270	Reference 2.2.36 ([DIRS 177054], Executive Summary, pp. 1, 5 to 8)	Engine fire	F-16C	87-0337	28-Jun-05	0	NA	NA	Engine fire. Pilot landed the plane and ejected on the runway. Classified as 1A since the pilot flew 53 NM to the landing site, which showed that the pilot was in control of the plane.	NA	1A

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]
271	Reference 2.2.131 ([DIRS 177055], Executive Summary, pp. 1 and 2)	Landing mishap	F-16C	86-0624	9-Oct-05	NA	NA	NA	Tire failure on landing. Pilot egressed from plane after stopping.	NA	0
272	Reference 2.2.132 ([DIRS 177056], Executive Summary, pp. 1 to 8)	Mid-air collision	F-16C	85-1469	28-Oct-05	NA	NA	NA	Mid-air collision with F-16C and the refueling boom during air-to-air refueling. Both planes returned to base for successful landing. No ejection.	NA	0
273	Reference 2.2.133 ([DIRS 177003])	Engine failure, mechanical	F-15C	78-0498	17-Jan-06	Unknown	Unknown	NA	Ejection was successful.	Unknown	1A
274	Reference 2.2.134 ([DIRS 181788])	Loss of control	F-16CG	89-2099	14-Mar-06	1760 AGL	Unknown	NA	Ejection was successful.	Unknown	1B
275	Reference 2.2.135 ([DIRS 181789])	Engine failure, mechanical	F-16CG	89-2115	30-Mar-06	Unknown	Unknown	NA	Ejection was successful.	Unknown	1A
276	Reference 2.2.136 ([DIRS 181790])	Abandoned aircraft during maneuvering	FC-16CJ	93-0542	5-Apr-06	6720 AGL	0.22	Angle of descent	G-induced loss of consciousness. Ejection was successful.	0.17	0
277	Reference 2.2.137 ([DIRS 181791])	Engine failure, mechanical	F-16C	83-1164	11-Apr-06	Unknown	Unknown	NA	Ejection was successful.	Unknown	1A
278	Reference 2.2.138 ([DIRS 181792])	No crash	F-16D	84-1326	26-May-06	NA	NA	NA	No crash. Incentive Flyer loss of life.	NA	0
279	Reference 2.2.139 ([DIRS 181793])	Controlled bailout	F-16CJ	91-0337	14-Sep-06	Unknown	Unknown	NA	Struck antenna and damaged landing gear during take-off. Performed a controlled bailout.	NA	0
280	Reference 2.2.140 ([DIRS 181794])	Take-off mishap	F-16C	84-1296	26-Oct-06	NA	NA	NA	Exited aircraft on runway. Engine fire on runway before takeoff.	NA	0
281	Reference 2.2.141 ([DIRS 181795])	Controlled flight into terrain	F16CG	90-0776	27-Nov-06	0	0	NA	Controlled flight into ground. No ejection.	NA	0
282	Reference 2.2.142 ([DIRS 181796])	Engine failure, mechanical	F-16D	84-1319	4-Dec-06	Unknown	Unknown	NA	Ejection was successful.	Unknown	1A

Table III-1 (continued). Information Extracted from Air Force Aircraft Mishap Reports

No.	Source[a]	Initiating Event Description	Aircraft Type	Aircraft Serial No.	Date	Ejection Altitude (ft)[b]	Distance to Crash (mi)[c]	Distance Method[d]	Comment	Glide Ratio[e]	Initiating Event Type[f]

NOTES: [a] Information is extracted from the sources listed. Reference 2.2.67 ([DIRS 174605]) is an electronic copy of excerpts organized in electronic files by years. The citations for Reference 2.2.67 ([DIRS 174605]) are by file name, given by year, followed by the page number.

[b] The "Altitude/Elevation" provided in the Aircraft Flight Mishap Report form provided in most of the safety reports did not always correspond to the ejection altitude. Thus, it was not used to determine altitude at ejection except when it seemed appropriate from the context of the event. In case of take-off or landing mishaps, NA was used in this column, with the exception of Event 190. When no ejection occurred for events other than take-off or landing mishaps, a value of zero (0) was used.

[c] The ejection-to-crash distances are shown with the number of significant digits that can be obtained from the data of the relevant event. In case of take-off and landing mishaps, NA was used in this column, with the exception of Event 190. When no ejection occurred for events other than take-off or landing mishaps, a value of zero (0) was used.

[d] The abbreviation, Lat, Long, is used for the ninth column, using latitude and longitude coordinates given in accident report text or on maps.

[e] The dimensionless glide ratio is calculated as (distance to crash in mi)(5,280 ft/mi) / (ejection altitude in ft AGL). When there was no ejection, the glide ratio is considered undefined.

[f] Event type is described in Assumption 3.2.17.

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Table III-2. Summary Information Derived from the Crash Data

Description[a]	**Value (dimensionless)**	**Fraction of Applicable Events (Type 1A or Type 1B)**
Number of Type 1A events	76	0.73
Number of Type 1B events	28	0.27

SOURCE: Table III-1.

NOTES: [a] See Assumption 3.2.17 for a discussion of event types.

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ATTACHMENT IV.

DERIVATION OF SMALL MILITARY AIRCRAFT CRASH RATE

The purpose of this attachment is to derive the updated crash rate for the small military aircraft. The methodology used to determine an updated crash rate for the F-16 aircraft in *Aircraft Crash Impact Hazard at the Private Fuel Storage Facility: Report to Nuclear Regulatory Commission, Revision 4* (Reference 2.2.143 [DIRS 157607], Tab D) will be used. The Nuclear Regulatory Commission found this methodology acceptable in *Safety Evaluation Report Concerning the Private Fuel Storage Facility, Docket No. 72-22* (Reference 2.2.30 [DIRS 154930], Section 15.1.2.11), thus it is deemed appropriate for this application.

F-16 Crash Rate

Table IV-1 provides F-16 information from Reference 2.2.29 ([DIRS 137367], Tables 4.7 and 4.8), which is used, along with the data provided in Table IV-2, to update the F-16 crash rate provided in Table 4.8 of Reference 2.2.29 ([DIRS 137367]).

Table IV-1 F-16 Flight Data from Kimura (Reference 2.2.29)

	Estimated Miles		**Mishaps**		**Mishap Rate/mile**
Normal Flight	8.3×10^{8}[a]	47.16%	32[a]	15.09%	3.86×10^{-8}[a]
Special Operations	9.3×10^{8}[a]	52.84%	104[a]	49.06%	1.12×10^{-7}[a]
Take offs /landing mishaps	-	-	76[a]	35.85%	-
Total	1.76×10^{9}	100%	212	100%	-
F-16 flew 3,730,000 hours[a]					
Derived flight miles/flight hours	471.85	(1.76×10^{9} miles/3.73×10^{6} hours)			

[a] Reference 2.2.29 [DIRS 137367], Tables 4.7 and 4.8

Table IV- 2. F-16 Annual Flight Safety Statistics

Year	Mishaps (yr^{-1})	Flight Hours (yr^{-1})
FY89	15	385,179
FY90	17	408,078
FY91	23	461,451
FY92	19	445,201
FY93	20	433,949
FY94	18	400,474
FY95	11	386,429
FY96	13	374,517
FY97	11	367,038
FY98	15	360,245
FY99	21	352,275
FY00	15	343,085
FY01	19	337,315
FY02	10	368,707
FY03	17	355,557
FY04	8	343,198
FY05	9	324,238
FY06	12	327,979

SOURCE: Reference 2.2.144 [DIRS 181797], pp. 1 and 2

The aircraft data presented in Table III-1 is from 1990 to 2006; therefore, the same data range is used to determine an updated crash rate. The methodology for determining the updated crash rate is presented below. This same methodology is used to determine the crash rates for various 10-year periods.

Updated for 1990 – 2006 (17-Year Crash Rate for Normal Flight)

Total Mishaps (1990 – 2006)	258	(From Table IV-2)
Total Flight Hours	6,389,736	(From Table IV-2)

Consider flight miles/flight hours constant (471.85 from Table IV-1)

Total Flight miles	3.02×10^9	(Total flight hours x 471.85)

Consider percentage of normal flight miles to total flight miles is constant (47.16% from Table IV-1)

Normal Flight miles	1.42×10^9	(Total flight miles x 47.16%)

Consider percentage normal flight mishaps to total mishaps is constant (15.09% from Table IV-1)

Normal Flight mishaps	38.9	Total mishaps x 15.09%

17-Year Adjusted F-16 accident rate in Normal Flight (mi^{-1}) 2.74×10^{-8} (mishaps/mile)

Table IV-3 presents the updated crash rate for rolling 10-year periods. The 1989-1998 period was also included as a comparison to the crash rate presented in Reference 2.2.30 ([DIRS 154930], Section 15.1.2.11), which was found acceptable by the Nuclear Regulatory Commission.

Table IV-3. F-16 Rolling 10-year Updated Crash Rates

Years	**Crash rate (mi^{-1})**
FY89-FY98	2.73×10^{-8}
FY90-FY99	2.86×10^{-8}
FY91-FY00	2.87×10^{-8}
FY92-FY01	2.89×10^{-8}
FY93-FY02	2.79×10^{-8}
FY94-FY03	2.79×10^{-8}
FY95-FY04	2.65×10^{-8}
FY96-FY-05	2.65×10^{-8}
FY97-FY06	2.67×10^{-8}

The FY89-FY98 value of 2.73×10^{-8} compares well with 2.736×10^{-8}, which is the updated F-16 crash rate used in Reference 2.2.30 ([DIRS 154930], Section 15.1.2.11). As can be seen in Table IV-3, the rolling 10-year updated crash rate increases and then decreases with the last 10-year period increasing slightly. However, to be consistent with the aircraft crash data set presented in Table III-1 and to avoid the possibility of statistical aberrations, the average crash rate for the entire period of 1990 to 2006 previously calculated will be used. The resultant crash rate is 2.74×10^{-8} mi^{-1}, as shown above.

Updating for 1990 – 2006 (17-year Crash Rate for Special Operations Flight)

Total Mishaps (1990-2005) 258 (From Table IV-2)

Total Flight Hours 6,389,736 (From Table IV-2)

Consider flight miles/flight hours constant (471.85)
Total Flight miles 3.02×10^9

Consider percentage of special operations miles to total flight miles is constant (52.84%)
Special Operations Flight miles 1.59×10^9

Consider percentage special operations flight mishaps to total mishaps is constant (49.06%)
Special Operations Flight mishaps 126.6

17-Year Adjusted F-16 accident rate in Special Operations Flight 7.95×10^{-8} (mishaps/mile)

The updated special operations crash rate is used in the sensitivity analysis found in Attachment VI.

F-15 Crash Rate

Table IV-4 provides F-15 information from Reference 2.2.29 ([DIRS 137367], Tables 4.7 and 4.8), which is used, along with the data provided in Table IV-5, to update the F-15 crash rate provided in Table 4.8 of Reference 2.2.29 ([DIRS 137367]).

Table IV- 4 F-15 Flight Data from Kimura (Reference 2.2.29)

	Estimated Miles		**Mishaps**		**Mishap Rate/mile**
Normal Flight	6.4×10^{8}[a]	47.41%	4[a]	4.26%	6.25×10^{-9}[a]
Special Operations	7.1×10^{8}[a]	52.59%	60[a]	63.83%	8.45×10^{-8}[a]
Take offs /landing mishaps	-	-	30[a]	31.91%	-
Total	1.35×10^{9}	100%	94	100%	-
F-15 flew 2,864,000 hours[a]					
Derived flight miles/flight hours		471.37	(1.35×10^{9} miles/2.864×10^{6} hours)		

[a] Reference 2.2.29 [DIRS 137367], Tables 4.7 and 4.8

Table IV- 5 F-15 Annual Flight Safety Statistics

Year	**Mishaps (yr^{-1})**	**Flight Hours (yr^{-1})**
FY89	5	214,592
FY90	13	227,617
FY91	5	276,393
FY92	7	220,866
FY93	8	217,539
FY94	7	210,231
FY95	9	206,640
FY96	6	200,758
FY97	8	192,073
FY98	8	188,205
FY99	17	189,109
FY00	25	179,372
FY01	21	183,706
FY02	10	194,847
FY03	14	193,611
FY04	12	189,596
FY05	12	169,158
FY06	13	168,854

SOURCE: Reference 2.2.145 [DIRS 181800], pp. 1 and 2

The methodology for determining the updated crash rate is presented below. This same methodology is used to determine the crash rates the 17-year period of interest as well as for various 10-year periods.

Updated for 1990 – 2006 (17-Year Crash Rate for Normal Flight)

Total Mishaps (1990-2006)	195	(From Table IV-5)
Total Flight Hours	3,408,575	(From Table IV-5)

Consider flight miles/flight hours constant (471.37 from Table IV-4)

Total Flight miles	1.61×10^9	(Total flight hours x 471.37)

Consider percentage of normal flight miles to total flight miles is consistent (47.41% from Table IV-4)

Normal Flight miles	7.62×10^8	(Total flight miles x 47.41%)

Consider percentage normal flight mishaps to total mishaps is constant (4.26% from Table IV-4)

Normal Flight mishaps	8.31	Total Mishaps x 4.26%

17-Year Adjusted F-15 accident rate in Normal Flight (mi^{-1}) 1.09×10^{-8} (mishaps/mile)

Table IV-6 presents the updated crash rate for the rolling 10-year periods.

Table IV- 6 F-15 Rolling 10-year Updated Crash Rates

Years	Crash rate (mi^{-1})
FY89-FY98	6.72×10^{-9}
FY90-FY99	7.88×10^{-9}
FY91-FY00	9.16×10^{-9}
FY92-FY01	1.11×10^{-8}
FY93-FY02	1.16×10^{-8}
FY94-FY03	1.23×10^{-8}
FY95-FY04	1.29×10^{-8}
FY96-FY05	1.35×10^{-8}
FY97-FY06	1.44×10^{-8}

As can be seen in Table IV-6, the 10-year crash rates for F-15s are lower than the 10-year crash rates for F-16s shown in Table IV-3. Therefore, conservatively, the F-16 crash rate is used to represent the small military aircraft crash rate.

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ATTACHMENT V.

EFFECTIVE TARGET AREAS AND BEATTY CORRIDOR CRASH FREQUENCY

V.1 EFFECTIVE AREAS

As discussed in Assumption 3.2.7, a number of structures and areas are included in the effective-area calculation, indexed by *n* varying from 1 through 11 as follows. The dimensions are found in Section 6.1.2, Table 12.

$n \equiv 1 .. 11$

1 Initial Handling Facility (IHF)
2 Canister Receipt and Closure Facility (CRCF)
3 Receipt Facility (RF)
4 Wet Handling Facility (WHF)
5 Aging Pad 17P
6 Aging Pad 17R
7 Rail Car Staging Area
8 Truck Staging Area
9 Loaded site transporter
10 Not Used
11 Not Used

This calculation considers three CRCFs and two generic transporters carrying waste packages or aging casks. To allow for duplicates, the vector *Q* gives the numbers of each structure or area to be included. Additional vectors specify, in ft, the lengths *L*, widths *W*, and heights *H* of the relevant structures and areas.

$$Q \equiv \begin{pmatrix} 1 \\ 3 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 1 \\ 2 \\ 0 \\ 0 \end{pmatrix} \qquad L \equiv \begin{pmatrix} 300 \\ 419 \\ 318 \\ 385 \\ 1152 \\ 1511 \\ 800 \\ 300 \\ 23 \\ 1 \\ 1 \end{pmatrix} \qquad W \equiv \begin{pmatrix} 167 \\ 318 \\ 282 \\ 299 \\ 1030 \\ 750 \\ 80 \\ 150 \\ 18 \\ 1 \\ 1 \end{pmatrix} \qquad H \equiv \begin{pmatrix} 105 \\ 100 \\ 100 \\ 100 \\ 22 \\ 22 \\ 17 \\ 17 \\ 23 \\ 1 \\ 1 \end{pmatrix}$$

The effective-area formula is simplified by defining the diagonal *D* (in ft) across the floor of each structure or area.

$$D \equiv \sqrt{L^2 + W^2}$$

The effective areas depend on characteristics of the aircraft types included. Subscripts distinguish the aircraft characteristics and the effective areas for each aircraft type as follows (Section 6.2.1).

$m \equiv 1 .. 7$

1	Small military aircraft
2	Large military aircraft
3	General aviation, piston-engine
4	General aviation, turboprop
5	General aviation, turbojet
6	Commercial air taxi (14 CFR Part 135)
7	Commercial air carrier (14 CFR Part 121)

The wingspans *G* (ft), cotangents *C* of the approach angle from horizontal (dimensionless), and mean skid distances *K* (ft) according to aircraft type are as follows (Section 6.2.1):

$$G \equiv \begin{pmatrix} 78 \\ 223 \\ 50 \\ 73 \\ 50 \\ 59 \\ 98 \end{pmatrix} \qquad C \equiv \begin{pmatrix} 8.4 \\ 7.4 \\ 8.2 \\ 8.2 \\ 8.2 \\ 10.2 \\ 10.2 \end{pmatrix} \qquad K \equiv \begin{pmatrix} 246 \\ 780 \\ 60 \\ 60 \\ 60 \\ 1440 \\ 1440 \end{pmatrix}$$

The effective areas of each structure or area (indexed by n=1,..., 11) and for each type of aircraft (indexed by m=1,..., 7) are given by Equations 12 and 13 as follows, with a conversion to mi^2:

$$Y_{n,m} \equiv \left[L_n \cdot W_n \cdot \left(1 + 2 \cdot \frac{G_m}{D_n} \right) + \left(G_m + D_n \right) \cdot H_n \cdot C_m + \left(D_n + G_m \right) \cdot \left(K_m \right) \right] \cdot \frac{Q_n}{5280^2}$$

Y

	1	2	3	4	5	6	7
1	$1.97\cdot10^{-2}$	$3.58\cdot10^{-2}$	$1.53\cdot10^{-2}$	$1.63\cdot10^{-2}$	$1.53\cdot10^{-2}$	$3.87\cdot10^{-2}$	$4.26\cdot10^{-2}$
2	$8.92\cdot10^{-2}$	$1.49\cdot10^{-1}$	$7.16\cdot10^{-2}$	$7.50\cdot10^{-2}$	$7.16\cdot10^{-2}$	$1.72\cdot10^{-1}$	$1.85\cdot10^{-1}$
3	$2.40\cdot10^{-2}$	$4.19\cdot10^{-2}$	$1.90\cdot10^{-2}$	$2.00\cdot10^{-2}$	$1.90\cdot10^{-2}$	$4.68\cdot10^{-2}$	$5.09\cdot10^{-2}$
4	$2.75\cdot10^{-2}$	$4.66\cdot10^{-2}$	$2.19\cdot10^{-2}$	$2.31\cdot10^{-2}$	$2.19\cdot10^{-2}$	$5.33\cdot10^{-2}$	$5.75\cdot10^{-2}$
5	$7.19\cdot10^{-2}$	$1.15\cdot10^{-1}$	$5.91\cdot10^{-2}$	$6.05\cdot10^{-2}$	$5.91\cdot10^{-2}$	$1.42\cdot10^{-1}$	$1.46\cdot10^{-1}$
6	$7.17\cdot10^{-2}$	$1.16\cdot10^{-1}$	$5.80\cdot10^{-2}$	$5.93\cdot10^{-2}$	$5.80\cdot10^{-2}$	$1.48\cdot10^{-1}$	$1.52\cdot10^{-1}$
7	$1.50\cdot10^{-2}$	$3.69\cdot10^{-2}$	$8.69\cdot10^{-3}$	$8.99\cdot10^{-3}$	$8.69\cdot10^{-3}$	$5.26\cdot10^{-2}$	$5.51\cdot10^{-2}$
8	$8.13\cdot10^{-3}$	$2.19\cdot10^{-2}$	$4.85\cdot10^{-3}$	$5.24\cdot10^{-3}$	$4.85\cdot10^{-3}$	$2.50\cdot10^{-2}$	$2.76\cdot10^{-2}$
9	$3.57\cdot10^{-3}$	$1.77\cdot10^{-2}$	$1.54\cdot10^{-3}$	$2.00\cdot10^{-3}$	$1.54\cdot10^{-3}$	$1.07\cdot10^{-2}$	$1.55\cdot10^{-2}$
10	$0.00\cdot10^{0}$	$0.00\cdot10^{0}$	$0.00\cdot10^{0}$	$0.00\cdot10^{0}$	$0.00\cdot10^{0}$	$0.00\cdot10^{0}$	$0.00\cdot10^{0}$
11	$0.00\cdot10^{0}$	$0.00\cdot10^{0}$	$0.00\cdot10^{0}$	$0.00\cdot10^{0}$	$0.00\cdot10^{0}$	$0.00\cdot10^{0}$	$0.00\cdot10^{0}$

The total effective areas (mi^2) of the relevant surface structures and areas by aircraft type are given by

$$A_m : \sum_n Y_{n,m}$$

A

	1
1	$3.31\cdot10^{-1}$
2	$5.80\cdot10^{-1}$
3	$2.60\cdot10^{-1}$
4	$2.71\cdot10^{-1}$
5	$2.60\cdot10^{-1}$
6	$6.89\cdot10^{-1}$
7	$7.32\cdot10^{-1}$

The fractional contributions to the effective area from each structure or area by aircraft type are given by:

$$Z_{n,m} \equiv \frac{Y_{n,m}}{\left[\sum_{n} \left(Y_{n,m}\right)\right]}$$

Z

	1	2	3	4	5	6	7
1	0.06	0.06	0.06	0.06	0.06	0.06	0.06
2	0.27	0.26	0.28	0.28	0.28	0.25	0.25
3	0.07	0.07	0.07	0.07	0.07	0.07	0.07
4	0.08	0.08	0.08	0.09	0.08	0.08	0.08
5	0.22	0.2	0.23	0.22	0.23	0.21	0.2
6	0.22	0.2	0.22	0.22	0.22	0.21	0.21
7	0.05	0.06	0.03	0.03	0.03	0.08	0.08
8	0.02	0.04	0.02	0.02	0.02	0.04	0.04
9	0.01	0.03	0.01	0.01	0.01	0.02	0.02
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0

V.2 CRASH FREQUENCY CONTRIBUTION FROM BEATTY CORRIDOR

The frequency of crashes into repository facilities for each aircraft type on the Beatty Corridor depends on the crash rate per mile λ, (Section 6.2.2 and Assumption 3.2.13) and annual flight frequencies N (Section 3.2.10).

$$\lambda \equiv \begin{pmatrix} 2.74\cdot 10^{-8} \\ 1.9\cdot 10^{-9} \\ 2.233\cdot 10^{-7} \\ 3.557\cdot 10^{-8} \\ 3.067\cdot 10^{-9} \\ 3.25\cdot 10^{-8} \\ 3.094\cdot 10^{-10} \end{pmatrix} \qquad N \equiv \begin{pmatrix} 14300 \\ 11000 \\ 26800 \\ 89000 \\ 57100 \\ 55700 \\ 454700 \end{pmatrix}$$

In addition, the distance d (Assumption 3.2.8) to the airway in miles and the width w of the airway in miles are needed.

$$d \equiv 5$$

$$w \equiv 26$$

The exponential decay constants γ in mi^{-1} for each aircraft type are needed to compute the edge adjustment factors ρ for the Beatty Corridor calculation (Section 4.3.1.2).

$$\gamma := \begin{pmatrix} 1 \\ 1 \\ 2 \\ 2 \\ 2 \\ 1.6 \\ 1.6 \end{pmatrix} \quad .$$

The edge adjustment factors ρ_m indexed by aircraft type are given by the bracketed part of Equation 4 as follows:

$$\rho_m := \frac{exp\left(-\gamma_m \cdot d\right)\cdot\left(1 - exp\left(-\gamma_m \cdot w\right)\right)}{2}$$

ρ

	1
1	$3.37 \cdot 10^{-3}$
2	$3.37 \cdot 10^{-3}$
3	$2.27 \cdot 10^{-5}$
4	$2.27 \cdot 10^{-5}$
5	$2.27 \cdot 10^{-5}$
6	$1.68 \cdot 10^{-4}$
7	$1.68 \cdot 10^{-4}$

Using Equation 4 and the effective target areas that were computed above, the estimated annual crash frequencies for each aircraft type in the Beatty Corridor are given by:

$$F_m := \frac{\left(N_m \cdot \lambda_m \cdot \rho_m\right)}{w} \cdot A_m$$

F

	$1.68 \cdot 10^{-8}$
	$1.57 \cdot 10^{-9}$
	$1.36 \cdot 10^{-9}$
	$7.48 \cdot 10^{-10}$
	$3.98 \cdot 10^{-11}$
	$8.05 \cdot 10^{-9}$
	$6.64 \cdot 10^{-10}$

The total crash frequency due to aircraft on the Beatty Corridor is

$$\sum_{m} F_m \quad 2.92 \times 10^{-8}$$

ATTACHMENT VI.

SENSITIVITY CALCULATIONS

This attachment presents the sensitivity calculations. There are three contributors to the overall aircraft impact frequency: flights from the Beatty Corridor, overflights of the flight-restricted airspace, and flights from outside the flight-restricted airspace. The inputs for the frequency of impacts from flights in the Beatty Corridor include the number of flights, the crash rates for each type of aircraft, the area of concern, the width of the airway, the distance from the airway, and the gamma factor used in the Solomon model. Sensitivity analyses are performed for all inputs except the area and width of the airway. The width of the airway is constrained by the locations of the special use airspaces and the area of concern is the highest calculated area based on the repository design. A sensitivity study on this parameter will result only in reducing the crash frequency.

The inputs for the frequency of impacts from overflights of the flight-restricted airspace include the number of flights, the crash rate, the categorization of events in Attachment III, the glide ratio, the altitude, the radius of the flight-restricted airspace, and the area of concern. All parameters except the radius and area of concern have been included in the sensitivity study. The radius of the flight-restricted airspace is an established parameter. The area of concern is the highest calculated area based on the repository design.

The inputs for the frequency of impacts from flights outside of the flight-restricted airspace include the number of crashes over the time span, the distance to crash, and the area of concern. The number of crashes, the time span, and the distance to crash, have been included in the sensitivity study. The area of concern is the highest calculated area based on the repository design.

In addition to the parameters discussed above, sensitivity analyses are also performed for pilot action, honoring the flight-restricted airspace, and phase construction. Therefore, the sensitivity study includes all significant parameters as well as showing the conservatism in several assumptions. The sensitivity study for parameters based on empirical data was performed on a range believed to encompass the uncertainty in the parameters.

All sensitivity calculations start with the calculated results reported in Section 6.5.4 of the analysis.

Beatty Corridor	2.9×10^{-8} y^{-1}
Over the Flight-restricted Airspace	8.5×10^{-8} y^{-1}
Outside Flight-restricted Airspace	4.8×10^{-7} y^{-1}
Total	5.9×10^{-7} y^{-1}

Pilot Action:

Taking credit for pilot action could potentially reduce the calculated crash frequency. From Table III-2, 73% of applicable events are Type 1A and 27% are Type 1B. Section 3.2.17 defines Type 1A events as those events where immediate pilot ejection is unlikely and Type 1B are events where immediate ejection is likely due to the complete loss of controllability. The percentages for Type 1A and Type 1B can be reasonably applied to flights outside of the flight-restricted airspace since aggressive flight maneuvers, which are not included in Type 1 events, occur far from the repository as seen in the trace plots of aircraft activity during Red Flag exercises at the NTTR (Reference 2.2.32 [DIRS 169894], Attachments 7 and 8). In addition, the military flights to the south of the flight-restricted airspace, Figure 1, are in the Beatty Corridor where flights are considered straight and parallel to the edge of the flight corridor (Assumption 3.2.2). Thus, if pilots successfully took appropriate action for all the Type 1A events, the crash frequency for flights outside of the flight-restricted airspace would be:

$$\left(4.8\times10^{-7}\right)\times\left(1-0.73\right) \quad 1.3\times10^{-7}\ \mathrm{y}^{-1}$$

A more realistic estimate of the fraction of overflights that could pose a hazard to the surface facility would account for the time required to make a decision regarding ejection or landing during a Type 1A event, whichever appears to be the safest course of action. Because so little time is required to fly 6.6 mi [(4.9NM × 1.1508 mi/NM) + 1.0 mi)] or less, at cruising speed, the fraction of Type 1A initiating events that may result in a crash inside the flight-restricted airspace is near zero. From Section 4.3.2, 10.5% of Type 1 events could endanger the facilities. Thus, for a more realistic case, the fraction of crashes that occur during overflight of the repository is estimated as:

$$(0.73)(0) + (0.27)(0.105) = 0.03.$$

Using the more realistic fraction of aircraft of 0.03, the crash frequency from overflights of the flight-restricted airspace would be:

$$\begin{aligned} F_{\mathrm{o}} \quad & \frac{N\lambda p_{\mathrm{c}}}{2R}A \\ & \frac{(1{,}000\ \mathrm{y}^{-1})(2.74\times10^{-8}\,\mathrm{mi}^{-1})\,(0.03)}{2\,(5.6\ \mathrm{mi})}(0.33\ \mathrm{mi}^2) \\ & 2.4\times10^{-8}\,\mathrm{y}^{-1}\,. \end{aligned}$$

where

R = flight-restricted airspace of radius 5.6 mi (Section 3.3.1)
λ = crash rate of 2.74×10^{-8} (mi^{-1}) (Section 3.2.13)
p_{c} = 3% of events assumed to result in a crash (above)
A = effective target area of 0.33 mi^2 for small military aircraft (Table 19)
N = 1,000 overflights per year (Assumption 3.3.2)

Adding the three contributors, the overall crash frequency is:

Beatty Corridor	2.9×10^{-8} y^{-1}
Over the Flight-restricted Airspace	2.4×10^{-8} y^{-1}
Outside Flight-restricted Airspace	1.3×10^{-7} y^{-1}
Total	1.8×10^{-7} y^{-1}

Thus, the overall crash frequency would be reduced by about 70% to 1.8×10^{-7} y^{-1} if pilot action were credited in the analysis.

Altitude of Overflights:

Flights over the flight-restricted airspace are assumed to be at the lowest allowable elevation, 14,000 ft, resulting in the quickest descent to the ground in case of pilot ejection (Assumption 3.2.5). This altitude and the derived glide ratios from Table III-1 are used in Section 4.3.2 to determine the fraction of flights that pose a risk to the surface facilities.

Varying the altitude of the overflights of the flight-restricted airspace changes the fraction of flights that either have the capability to glide past the facilities or do not have sufficient glide capability to reach the facilities. Thus, the fraction of events that pose a risk to the facility changes with the altitude that the plane is flying. Using the same methodology developed in Section 4.3.2, the following demonstrates this relationship.

Table VI-1 Altitude Sensitivity

Altitude (ft MSL)	Largest Glide Ratio	Smallest Glide Ratio	Fraction of Type 1 Events Endangering Facilities (without rounding)
14000	3.48	0.34	0.105
15000	3.17	0.31	0.101
16000	2.90	0.28	0.088
17000	2.68	0.26	0.077
18000	2.49	0.24	0.070
19000	2.32	0.23	0.065
20000	2.18	0.21	0.061
21000	2.05	0.20	0.056
22000	1.94	0.19	0.047
23000	1.83	0.18	0.046
24000	1.74	0.17	0.037
25000	1.66	0.16	0.037

As can be see in the above table, the fraction of Type 1 flights decreases by about 65% when the altitude is changed from 14,000 ft MSL to 25,000 ft MSL. Using 0.061 as an example (overflights at 20,000 ft MSL), the crash frequency from overflights of the flight-restricted airspace would be:

$$\begin{aligned} F_{\mathrm{o}} \quad & \frac{N\lambda p_{\mathrm{c}}}{2R} A \\ & \frac{(1{,}000\ \mathrm{y}^{-1})(2.74\times 10^{-8}\,\mathrm{mi}^{-1})\,(0.061)}{2\,(5.6\ \mathrm{mi})}(0.33\ \mathrm{mi}^2) \\ & 4.9\times 10^{-8}\,\mathrm{y}^{-1}\,. \end{aligned}$$

where

R = flight-restricted airspace of radius 5.6 mi (Section 3.3.1)
λ = crash rate of 2.74×10^{-8} (mi^{-1}) (Section 3.2.13)
p_{c} = 6.1% of events assumed to result in a crash (Above)
A = effective target area of 0.33 mi^2 for small military aircraft (Table 19)
N = 1,000 overflights per year (Assumption 3.3.2)

Thus, adding the three contributors, the overall crash frequency is reduced about 6% if all the military overflights were at 20,000 ft MSL instead on 14,000 ft MSL.

Beatty Corridor	2.9×10^{-8} y^{-1}
Over the Flight-restricted Airspace	4.9×10^{-8} y^{-1}
Outside Flight-restricted Airspace	4.8×10^{-7} y^{-1}
Total	5.6×10^{-7} y^{-1}

F-16 Crash Rate For All Small military Aircraft

About 28% of the flights in the NTS are F-15s (Section 3.2.12). The updated crash rate, 1.09×10^{-8} mi^{-1}, for the F-15 (Attachment IV) is less than half the updated F-16 crash rate of 2.74×10^{-8} mi^{-1} (Section 3.2.13), which is conservatively used in the analysis. Assuming that 28% of the flights are F-15s and the balance of the flights are F-16s, the weighted average of the crash rates is:

	%	**Crash rate (mi^{-1})**	**% Crash (mi^{-1})**
F-16	0.72	2.74×10^{-8}	1.97×10^{-8}
F-15	0.28	1.09×10^{-8}	3.05×10^{-9}
		Total	2.28×10^{-8}

The change in the crash rate changes the frequency from overflights of the flight-restricted airspace.

$$F_{\mathrm{o}} \quad \frac{N\lambda p_{\mathrm{c}}}{2R} A$$

$$\frac{(1{,}000\ \mathrm{y}^{-1})(2.28\times10^{-8}\,\mathrm{mi}^{-1})\ (0.105)}{2\ (5.6\ \mathrm{mi})}(0.33\mathrm{mi}^{2})$$

$$7.1\times10^{-8}\,\mathrm{y}^{-1}\ .$$

where

R = flight-restricted airspace of radius 5.6 mi (Section 3.3.1)
λ = crash rate of 2.28×10^{-8} (mi^{-1}) (above)
p_{c} = 10.5% of events assumed to result in a crash (Section 4.3.2)
A = effective target area of 0.33 mi^2 for small military aircraft (Table 19)
N = 1,000 overflights per year (Assumption 3.3.2)

The frequency contribution from flights outside of the flight-restricted airspace does not change from Section 6.5.3.

For the Beatty Corridor, the crash rate for small military aircraft was changed to $2.28 \times 10^{-8}\ \mathrm{mi}^{-1}$.

$m \equiv 1\,..\,7$

1	Small military aircraft
2	Large military aircraft
3	General aviation, piston-engine
4	General aviation, turboprop
5	General aviation, turbojet
6	Commercial air taxi (that is, 14 CFR Part 135 flights)
7	Commercial air carrier (that is, 14 CFR Part 121 flights)

)

$$\lambda \equiv \begin{pmatrix} 2.28\cdot10^{-8} \\ 1.9\cdot10^{-9} \\ 2.233\cdot10^{-7} \\ 3.557\cdot10^{-8} \\ 3.067\cdot10^{-9} \\ 3.25\cdot10^{-8} \\ 3.094\cdot10^{-10} \end{pmatrix}$$

$$F_m := \frac{\left(N_m \cdot \lambda_m \cdot \rho_m\right)}{w} \cdot A_m$$

F

	1
1	$1.40 \cdot 10^{-8}$
2	$1.57 \cdot 10^{-9}$
3	$1.36 \cdot 10^{-9}$
4	$7.48 \cdot 10^{-10}$
5	$3.98 \cdot 10^{-11}$
6	$8.05 \cdot 10^{-9}$
7	$6.64 \cdot 10^{-10}$

The total crash frequency due to aircraft on the Beatty Corridor is

$$\sum_{m} F_m \quad 2.64 \times 10^{-8}$$

Adding the three contributors, the overall crash frequency is:

Beatty Corridor	2.6×10^{-8} y^{-1}
Over the Flight-restricted Airspace	7.1×10^{-8} y^{-1}
Outside Flight-restricted Airspace	4.8×10^{-7} y^{-1}
Total	5.8×10^{-7} y^{-1}

Thus the overall frequency is reduced slightly by using a weighted average of the crash frequency for F-15s and F-16s.

Distance to the Edge of the Beatty Corridor

A realistic distance from the surface facilities to the edge of the Beatty Corridor is about 8 mi, approximately 3 mi farther than the assumed distance of 5 mi (Section 3.2.8). Changing the distance to the edge of the Beatty Corridor from 5 miles to 8 miles only affects the crash frequency from the Beatty Corridor.

$$d \equiv 8$$

The edge adjustment factors ρ_m indexed by aircraft type are given by the bracketed part of Equation 4 as follows:

$$\rho_m := \frac{exp(-\gamma_m \cdot d) \cdot (1 - exp(-\gamma_m \cdot w))}{2}$$

ρ

	1
1	$1.68 \cdot 10^{-4}$
2	$1.68 \cdot 10^{-4}$
3	$5.63 \cdot 10^{-8}$
4	$5.63 \cdot 10^{-8}$
5	$5.63 \cdot 10^{-8}$
6	$1.38 \cdot 10^{-6}$
7	$1.38 \cdot 10^{-6}$

Using Equation 4 and the effective target areas that were computed above, the estimated annual crash frequencies for each aircraft type in the Beatty Corridor are given by:

$$F_m := \frac{(N_m \cdot \lambda_m \cdot \rho_m)}{w} \cdot A_m$$

F

	1
1	$8.36 \cdot 10^{-10}$
2	$7.83 \cdot 10^{-11}$
3	$3.37 \cdot 10^{-12}$
4	$1.85 \cdot 10^{-12}$
5	$9.86 \cdot 10^{-14}$
6	$6.62 \cdot 10^{-11}$
7	$5.47 \cdot 10^{-12}$

The total crash frequency due to aircraft on the Beatty Corridor is

$$\sum_m F_m \quad 9.91 \times 10^{-10}$$

Thus, adding the three contributors, the overall crash frequency is:

Beatty Corridor	9.9×10^{-10} y^{-1}
Over the Flight-restricted Airspace	8.5×10^{-8} y^{-1}
Outside Flight-restricted Airspace	4.8×10^{-7} y^{-1}
Total	5.7×10^{-7} y^{-1}

The frequency of crash has been reduced by about 4%.

Categorizing Events

This section evaluates the effect of misclassifying events on the crash frequency for flights over the flight-restricted airspace. Section 3.2.17 describes the process of categorizing the mishaps listed in Table III-1 and Section 4.3.2 describes how the categories were used to determine the fraction of events that pose a threat to the facilities based on glide ratios. Because both Type 1A and 1B events are treated the same, only the effect of classifying an event as Type 1 or Type 0 is addressed.

Type 1 to Type 0

Ten percent of the Type 1 events, 10 events, were randomly chosen and changed to Type 0 events; Table III-1 event numbers 6, 15, 27, 36, 39, 51, 57, 61, 95, and 258. Some of the events had known glide ratios and some of the events did not. This changed the number of Type 1 events to 94 with 51 with known glide ratios. Using the same methodology presented in 4.3.2, the fraction of Type 1 events that could endanger the facilities is 0.107. This is about a 2% increase in the value derived in Section 4.3.2, which results in increasing the contribution to the frequency due to overflights to 8.6×10^{-8} y^{-1}, which increases the overall frequency to 6.0×10^{-7} y^{-1}. Thus, changing 10% of the Type 1 events to Type 0 events results in a negligible increase in the overall crash frequency.

Type 0 to Type 1

Ten percent of the Type 0 events, 18 events, were randomly chosen and changed to Type 1A events; Table III-1 event numbers 20, 41, 44, 67, 90, 103, 130, 149, 157, 173, 176, 190, 206, 210, 225, 245, 250, and 272. This changed the number of Type 1 events to 122 with 65 with known glide ratios. Using the same methodology presented in Section 4.3.2, the fraction of Type 1 events that could endanger the facilities is 0.108, which results in increasing the contribution to the frequency due to overflights to 8.7×10^{-8} y^{-1}, which increases the overall frequency to 6.0×10^{-7} y^{-1}. Thus, changing 10% of the Type 0 events to Type 1 events results in a negligible increase in the overall crash frequency.

All Type 0 to Type 1

The last sensitivity study performed on categorizing events was to make all events applicable to the repository, that is, all events are Type 1. This is not realistic since Type 0 events include landing mishaps, take-off mishaps, and activities associated with aggressive maneuvering which does not take place near the reporsitory. This changed the number of Type 1 events to 282 with 88 with known glide ratios. Using the same methodology presented in Section 4.3.2, the fraction of Type 1 events that could endanger the facilities is 0.118. This is about an 12% increase in the 10.5% value derived in Section 4.3.2.

Using 0.118, the change in the percent changes the frequency from overflights of the flight-restricted airspace.

$$
\begin{aligned}
F_\text{o} \quad & \frac{N\lambda p_\text{c}}{2R} A \\
& \frac{(1{,}000\ \text{y}^{-1})(2.74\times10^{-8}\,\text{mi}^{-1})\ (0.118)}{2\ (5.6\ \text{mi})}(0.33\text{mi}^2) \\
& 9.5\times10^{-8}\,\text{y}^{-1}\ .
\end{aligned}
$$

where

R = flight-restricted airspace of radius 5.6 mi (Section 3.3.1)
λ = crash rate of 2.74×10^{-8} (mi^{-1}) (Section 3.2.13)
p_c = 11.8% of events assumed to result in a crash (above)
A = effective target area of 0.33 mi^2 for small military aircraft (Table 19)
N = 1,000 overflights per year (Assumption 3.3.2)

Thus, adding the three contributors, the overall crash frequency is increased slightly to:

Beatty Corridor	$2.9 \times 10^{-8}\ \text{y}^{-1}$
Over the Flight-restricted Airspace	$9.5 \times 10^{-8}\ \text{y}^{-1}$
Outside Flight-restricted Airspace	$4.8 \times 10^{-7}\ \text{y}^{-1}$
Total	$6.0 \times 10^{-7}\ \text{y}^{-1}$

Thus the frequency of aircraft crash is insensitive to the categorization of military crashes.

Glide Ratios/Distance to Crash

The glide ratios for the 58 Type 1 events with known glide ratios range from 0.04 to 11.2 with the average glide ratio of 3.1. For comparison, the glide ratio for an F-16 is about 8.5, derived from a glide ratio of 7 nautical miles for every 5,000 ft of altitude lost (Reference 2.2.36 [DIRS 177054], p. 5). To determine the sensitivity to the glide ratio, the glide ratios were increased and decreased by 10% by increasing or decreasing the distance to crash.

Increasing the Glide Ratio by Increasing the Distance to Crash

Using the same methodology presented in Section 4.3.2, the fraction of Type 1 events that could endanger the facilities is 0.10, when the glide ratios were increased by 10%.

Using 0.10 in the above equation for the crash frequency from overflights of the flight-restricted airspace gives a crash frequency of:

$$\begin{aligned} F_{\mathrm{o}} &\quad \frac{N\lambda p_{\mathrm{c}}}{2R} A \\ &\quad \frac{(1{,}000\ \mathrm{y}^{-1})(2.74\times 10^{-8}\,\mathrm{mi}^{-1})\,(0.10)}{2\,(5.6\ \mathrm{mi})}(0.33\mathrm{mi}^{2}) \\ &\quad 8.1\times 10^{-8}\,\mathrm{y}^{-1}\ . \end{aligned}$$

where

R = flight-restricted airspace of radius 5.6 mi (Section 3.3.1)
λ = crash rate of 2.74×10^{-8} (mi^{-1}) (Section 3.2.13)
p_{c} = 10% of events assumed to result in a crash (above)
A = effective target area of 0.33 mi^2 for small military aircraft (Table 19)
N = 1,000 overflights per year (Assumption 3.3.2)

Section 4.3.3 determined the sample distribution function for travel after the pilot ejections from the aircraft. Increasing the distance traveled by 10% (same as increasing the glide ratio by 10%) changes the cumulative probability of exceeding 4.6 miles to 3.9%.

Applying Equation 11, the crash frequency density at the center of the flight-restricted airspace is

$$\begin{aligned} \Phi_{\mathrm{c}} &\quad 0.75\,\Phi_0[1-F_n(4.6\ \mathrm{mi})] \\ &\quad 0.75\,(7.5\times 10^{-5}\,\mathrm{crashes}/\mathrm{y}/\mathrm{mi}^2)(0.039) \\ &\quad 2.19\times 10^{-6}\,\mathrm{crashes}/\mathrm{y}/\mathrm{mi}^2. \end{aligned}$$

where

Φ_0 = 7.5×10^{-5} crashes/y/mi^2 (Section 4.3.3)
$[1-F_n(4.6\ \mathrm{mi})]$ = 0.039 (above)

The effective target area of the surface facilities as seen by small military aircraft (Table 19) is 0.33 mi^2. Thus, the estimated crash frequency due to flights outside the radius of the flight-restricted airspace is:

$$(2.19 \times 10^{-6} \text{ crashes / y / mi}^2)(0.33 \text{ mi}^2) = 7.2 \times 10^{-7} \text{ crashes / y.}$$

Thus, the crash frequency contribution from flights outside the flight-restricted airspace increases. The contribution from the Beatty Corridor does not change. Summing the three contributors results in:

Beatty Corridor	2.9×10^{-8} y^{-1}
Over the Flight-restricted Airspace	8.1×10^{-8} y^{-1}
Outside Flight-restricted Airspace	7.2×10^{-7} y^{-1}
Total	8.3×10^{-7} y^{-1}

Thus, increasing the glide ratios by 10% by increasing the distance to crash, results in an overall crash frequency of 8.3×10^{-7} y^{-1}.

Decreasing the Glide Ratio by Decreasing the Distance to Crash

When the glide ratios were decreased by 10%, the fraction of Type 1 events that could endanger the facilities is 0.112. Using the value of 0.112, the frequency from overflights increases slightly to 9.0×10^{-8} y^{-1}, calculated above.

Decreasing the distanced traveled by 10% (same as decreasing the glide ratio by 10%), does not change the cumulative probability of exceeding 4.6 miles, thus the frequency flights outside of the flight-restricted airspace does not change.

The contribution from the Beatty Corridor also does not change. Thus, adding the three contributors, the overall crash frequency is:

Beatty Corridor	2.9×10^{-8} y^{-1}
Over the Flight-restricted Airspace	9.0×10^{-8} y^{-1}
Outside Flight-restricted Airspace	4.8×10^{-7} y^{-1}
Total	6.0×10^{-7} y^{-1}

Decreasing the glide ratio by 10% resulted in a slight increase in the overall crash frequency.

Solomon Model Gamma Factor

The discussion of the Solomon model (Reference 2.2.55 [DIRS 173314], p. 5) applied to the flights in the Beatty Corridor is presented in Section 4.3.1.2.

To show the relationship between the gamma factor, γ, and the crash frequency, the crash frequency was determined with all aircraft types using the same value for γ. The change in the gamma factor for the Solomon model only affects the crash frequency for the Beatty Corridor. For γ=1, the crash frequency for the Beatty Corridor is 5.1×10^{-7} y^{-1}.

Thus, adding the three contributors, the overall crash frequency is:

Beatty Corridor	5.1×10^{-7} y^{-1}
Over the Flight-restricted Airspace	8.5×10^{-8} y^{-1}
Outside Flight-restricted Airspace	4.8×10^{-7} y^{-1}
Total	1.1×10^{-6} y^{-1}

For γ=1.6, the contribution from the Beatty Corridor is 2.6×10^{-8} y^{-1}.

Thus, adding the three contributors, the overall crash frequency is:

Beatty Corridor	2.6×10^{-8} y^{-1}
Over the Flight-restricted Airspace	8.5×10^{-8} y^{-1}
Outside Flight-restricted Airspace	4.8×10^{-7} y^{-1}
Total	5.9×10^{-7} y^{-1}

For γ=2, the crash frequency for the Beatty Corridor is 3.5×10^{-9} y^{-1}.

Thus, adding the three contributors, the overall crash frequency is:

Beatty Corridor	3.5×10^{-7} y^{-1}
Over the Flight-restricted Airspace	8.5×10^{-8} y^{-1}
Outside Flight-restricted Airspace	4.8×10^{-7} y^{-1}
Total	5.7×10^{-7} y^{-1}

Using γ=2 for all aircraft, the crash frequency reduces to 5.7×10^{-7} y^{-1}. For γ=1.6 for all aircraft, the crash frequency remains the same at 5.9×10^{-7} y^{-1}. And using γ=1 for all aircraft, the crash frequency increases to 1.1×10^{-6} y^{-1}. Thus, there is a slight or no impact to the crash frequency if the gamma factor were 1.6 or 2, and an increase in the crash frequency if γ=1 were applied to all aircraft. This shows that the Solomon model is somewhat sensitive to the gamma factor when all aircraft use the γ=1. Applying a γ=1 to non-military aircraft would be overly conservative because of the differences in aircraft and flight characteristics as discussed in Section 4.3.1.2.

Honoring the Flight-restricted Airspace

This sensitivity study will take the calculated overall crash frequency, 5.9×10^{-7} y^{-1} (Section 7), and after imposing some assumptions used only in this sensitivity study, determines the number of additional flights through the flight-restricted airspace that will have to occur in order to increase the crash frequency above the threshold of 2.0×10^{-6} y^{-1}. The purpose of this study is to determine the sensitivity of pilots honoring the flight-restricted airspace.

The elevation of the surface facilities is less than 4,000 ft MSL (Reference 2.2.4) and the elevation of the surrounding mountains is about 6,000 ft MSL (Reference 2.2.12 [DIRS 158638]). Assuming that any flight that violates the flight-restricted airspace flies at an elevation of 6,500 ft MSL to avoid the mountains, the flights would be at 2,500 ft AGL. The fraction of flights that pose a threat to the facility from the glide ratios is 0.176 at an altitude of 2,500 ft AGL (6,500 ft MSL) using the same methodology as in Section 4.3.2.

For additional conservatism, assume that all of the flights that violate the flight-restricted airspace are performing exercises or acrobatics. If the special operations crash rate for F-16s were updated for the period of interest from 1990 to 2006 using the methodology in Attachment IV, the crash rate would be 7.95×10^{-8} mi^{-1}. Using Equation 7, the updated special operations crash rate for F-16s, and the fraction 0.176 of flights that pose a hazard to the facility, the number of flights flying at 6,500 ft MSL would have to be about 3,400 per year to result in a total crash frequency greater than the Category 2 event sequence screening threshold.

$$\begin{aligned} F_{\mathrm{o}} \quad & \frac{N\lambda p_{\mathrm{c}}}{2R} A \\ & \frac{(3400\ \mathrm{y}^{-1})(7.95\times10^{-8}\,\mathrm{mi}^{-1})\,(0.176)}{2\,(5.6\ \mathrm{mi})}(0.33\ \mathrm{mi}^{2}) \\ & 1.4\times10^{-6}\,\mathrm{y}^{-1}\,. \end{aligned}$$

where

R = flight-restricted airspace of radius 5.6 mi (Section 3.3.1)
λ = crash rate of 7.95×10^{-8} mi^{-1} (above and Attachment IV)
p_{c} = 17.6% of events assumed to result in a crash (above)
A = effective target area of 0.33 mi^{2} for small military aircraft (Table 19)
N = 3,400 overflights per year (derived)

Even if the lifetime special operations crash rate of 1.12×10^{-7} mi^{-1} (Table 14) were used instead of the updated crash rate of 7.95×10^{-8} mi^{-1}, it would still take about 2,425 flights at an altitude of 6,500 ft MSL, in addition to the 1,000 flights over the flight-restricted airspace, the flights outside of the flight-restricted airspace and the contribution from the Beatty Corridor, to exceed the Beyond Category 2 event sequence screening threshold of 2.0×10^{-6} y^{-1}. Thus, it is unlikely to have about 2,425 flights per year violating the flight-restricted airspace, and doing so would be a total disregard of the flight-restricted airspace.

Phased Construction

Construction of the surface facilities (Table 1) will likely be staged so that some of the surface structures may not be present during the initial part of the emplacement period. The aging pads, even if fully available over the entire emplacement period, will take years to be filled and emptied. The amount of waste in the staging areas will also fluctuate over time. For an example of the effect of phased construction on the crash frequency, assume that the WHF and two of the three CRCFs become operational 10 years after the beginning of surface operations, which represents an 80% capacity factor for these facilities over the 50-year emplacement period. Also assume that the aging pads and the staging areas are at an average of 80% capacity over the emplacement period. Using these assumptions, the effective target area is reduced to about 0.28 mi^2, which results in a crash frequency of $5.1 \times 10^{-7}\ \text{y}^{-1}$, or a 14% decrease in the overall frequency.

Military Crash Density

The crash frequency density used for determining the crash rate for military flights outside of the flight-restricted airspace (Section 3.2.14) is based on the number of crashes that occurs in the NTTR and the MOAs over the time period of interest. As stated in Section 3.2.14, the calculated frequency density can change over time because crashes are random from year to year and the density will be different when the time span changes. Thus, this sensitivity looks at how the crash density can change with respect to time and the assumed number of crashes per year.

For this sensitivity, starting in 2007, it is assumed that a specified number of crashes occur every year for 10 years. The number of crashes are zero, one, and two crashes per year as well as the average crash rate of 1.09 crashes/yr over the 16.5 years from 1990 to 2006 used in the crash frequency (18 crashes/16.5 yrs = 1.09 crashes/yr). Using the same methodology described in the rationale of Assumption 3.2.14 and the given number of crashes per year, the crash density is calculated in Excel and presented in Table VI-2.

Table VI-2. Estimated Crash Density

Time Span	0 crashes/yr (Crashes/yr/mi^2)	1 crash /yr (Crashes/yr/mi^2)	1.09 crashes/yr (Crashes/yr/mi^2)	2 crashes/yr (Crashes/yr/mi^2)
1990-2007	6.86×10^{-05}	7.24×10^{-05}	7.27×10^{-05}	7.62×10^{-05}
1990-2008	6.49×10^{-05}	7.21×10^{-05}	7.27×10^{-05}	7.93×10^{-05}
1990-2009	6.15×10^{-05}	7.18×10^{-05}	7.27×10^{-05}	8.21×10^{-05}
1990-2010	5.85×10^{-05}	7.15×10^{-05}	7.27×10^{-05}	8.46×10^{-05}
1990-2011	5.58×10^{-05}	7.13×10^{-05}	7.27×10^{-05}	8.68×10^{-05}
1990-2012	5.33×10^{-05}	7.11×10^{-05}	7.27×10^{-05}	8.89×10^{-05}
1990-2013	5.11×10^{-05}	7.09×10^{-05}	7.27×10^{-05}	9.08×10^{-05}
1990-2014	4.90×10^{-05}	7.07×10^{-05}	7.27×10^{-05}	9.25×10^{-05}
1990-2015	4.71×10^{-05}	7.06×10^{-05}	7.27×10^{-05}	9.41×10^{-05}
1990-2016	4.53×10^{-05}	7.04×10^{-05}	7.27×10^{-05}	9.56×10^{-05}

This table shows that the crash frequency density changes over time when the number of crashes assumed in each year is the same. With zero and one crash per year assumed, the frequency density trends down with each additional year. With the average of 1.09 crashes per year, the crash frequency remains the same over the years. With two crashes assumed per year, the crash frequency density increases with each additional year because two crashes per year is greater than the average crash rate used in the analysis.

Even using the highest crash density of 9.56×10^{-5} crashes / y / mi^2, the overall crash frequency is 7.3×10^{-7} crashes / y.

From Table 8, from 1990 to 2006,

- 7 years had 0 crashes
- 3 years had 1 crash
- 6 years had 2 crashes
- 1 year had 3 crashes (1993).

Thus, it is considered improbable that there would be 2 crashes in the NTTR and MOAs each year for the next ten years.

Military Crash Density of Nevada Test Site

Section 3.2.14 determines the crash density used for determining the crash rate for military flights outside of the flight-restricted airspace. The crash density is based on the number of crashes that occurs in the NTTR and the MOAs over the time period of interest even though the type of flight that contributed to the crashes in the NTTR and MOAs occurs well beyond 30 miles of the North Portal. The crash frequency density determined using the area of concern, within 30 miles of the North Portal, was determined using one crash even though there has not been a crash within the area. Using the Nevada Test Site crash density (4.3×10^{-5} crashes / y / mi^2) instead of the crash density based on the number of crashes in the NTTR and MOA (7.5×10^{-7} crashes / y / mi^2), the overall crash frequency is 3.9×10^{-7} y^{-1}, a reduction of almost 34% in the crash frequency.

Counts in the Beatty Corridor

To evaluate the potential increase in flights in the Beatty Corridor, the estimated annual flight counts were increased by a factor of five for use in the analysis (Assumption 3.2.10). For this sensitivity analysis, the counts used in the analysis were further increased by a factor of two and a factor of ten. All other inputs remain the same. For an increase by a factor of two, the overall frequency increases by about 4%.

Beatty Corridor	5.8×10^{-8} y^{-1}
Over the Flight-restricted Airspace	8.5×10^{-8} y^{-1}
Outside Flight-restricted Airspace	4.8×10^{-7} y^{-1}
Total	6.2×10^{-7} y^{-1}

For an increase by a factor of ten, the overall frequency increases by about 45%.

Beatty Corridor	2.9×10^{-7} y^{-1}
Over the Flight-restricted Airspace	8.5×10^{-8} y^{-1}
Outside Flight-restricted Airspace	4.8×10^{-7} y^{-1}
Total	8.6×10^{-7} y^{-1}

As shown in Section 3.2.10, the assumed counts used in the frequency analysis (Table 2) already increases the annual counts by a factor of five and it reasonably represents the growth trend at the McCarran International airport.