BSC

Calculation/Analysis Change Notice

Complete only applicable items.

1. QA: QA
2. Page 1 of 11

000-00C-WHS0-00200-000-00F-CACN001

3. Document Identifier:	4. Rev.:	5. CACN:
000-00C-WHS0-00200-000	00F	001

6. Title:
Frequency Analysis of Aircraft Hazards for License Application

7. Reason for Change:
Incorporate and address comments from LP-7-21Q-OCRWM review.

8. Supersedes Change Notice: ☐ Yes If, Yes, CACN No.: ____ ☒ No

9. Change Impact:

Inputs Changed:	☐ Yes	☒ No	Results Impacted:	☐ Yes	☒ No
Assumptions Changed:	☐ Yes	☒ No	Design Impacted:	☐ Yes	☒ No

10. Description of Change:

1) – Page 14 was revised to update Reference 2.2.4.
2) – Page 15 was revised to update Reference 2.2.9.
3) – Page 18 was revised to update Reference 2.2.49.
4) – Page 33 was revised to remove an extraneous asterisk from Table 4.
5) – Page 42 was revised to add clarification to the rationale for classifying the use of piddle pack as a Type 0 Event.
6) – Page 46 was revised to remove the citation of Section 2.2.2.8 from Reference 2.2.9.
7) – Figure 3 on page 51 was revised to remove arrows and add a legend to the figure.
8) – Page 66 and Page III-1 were revised to remove a sentence from the description of the process for gathering USAF data.
9) – Page VI-12 was revised to correct a typographical error.

The revisions to the references and the text have not resulted in any change in the inputs to or results of this analysis.

11. REVIEWS AND APPROVAL

Printed Name	Signature	Date
11a. Originator: K. L. Ashley	K.L. Ashley	10/31/2007
11b. Checker: Pierre Macheret	P. Machet	10/31/2007
11c. EGS: M. Frank	[signature]	11/5/07
11d. DEM: Mark Wisenburg	[signature]	11/5/2007
11e. Design Authority: B. Rusinko	B Rusinko	11/6/07

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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: Reference2.2.19 [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]

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 but a special activity for personal comfort for pilot urination, which can include loosening or removal of seat restraints. Straight and normal flight 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)

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, Section 2.2.2.7).

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 $\exp(-\gamma d) / 2$		
	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

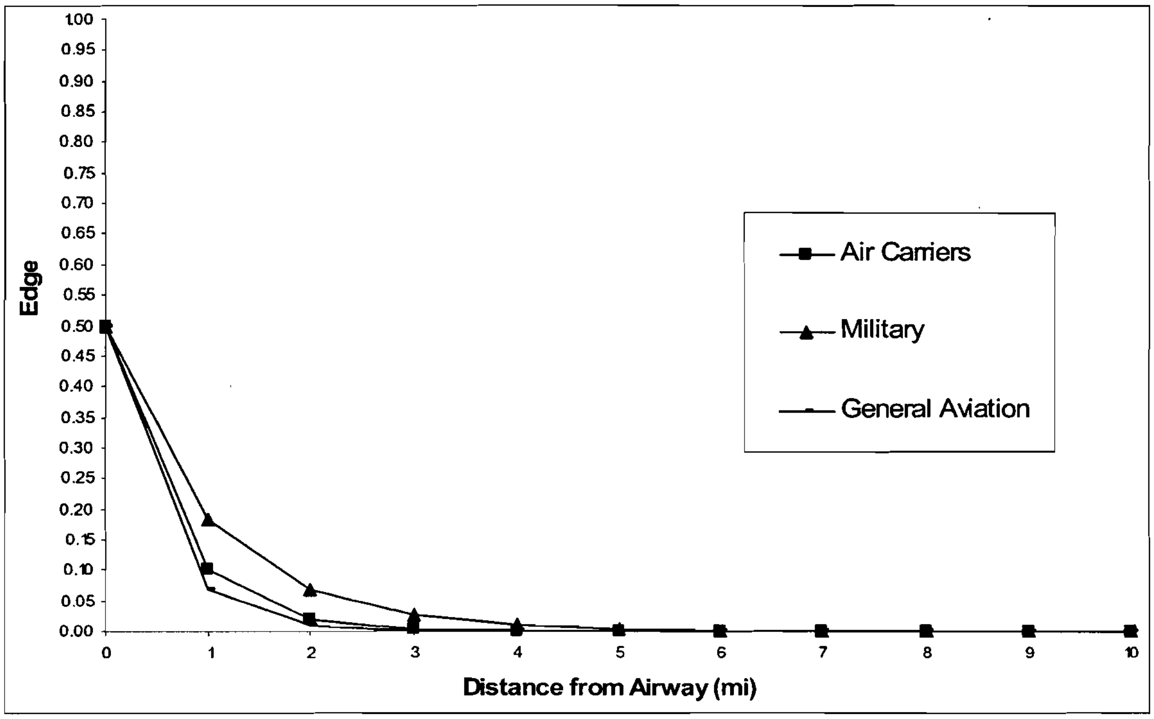

Figure 3. Illustration of Exponential Airway Models

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. 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.

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. 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).

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

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

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

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

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

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

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

Beatty Corridor	$3.5 \times 10^{-9}\ y^{-1}$
Over the Flight-restricted Airspace	$8.5 \times 10^{-8}\ y^{-1}$
Outside Flight-restricted Airspace	$4.8 \times 10^{-7}\ y^{-1}$
Total	$5.7 \times 10^{-7}\ y^{-1}$

Using γ=2 for all aircraft, the crash frequency reduces to $5.7 \times 10^{-7}\ y^{-1}$. For γ=1.6 for all aircraft, the crash frequency remains the same at $5.9 \times 10^{-7}\ y^{-1}$. And using γ=1 for all aircraft, the crash frequency increases to $1.1 \times 10^{-6}\ y^{-1}$. 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, $5.9 \times 10^{-7}\ y^{-1}$ (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 $2.0 \times 10^{-6}\ y^{-1}$. The purpose of this study is to determine the sensitivity of pilots honoring the flight-restricted airspace.