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**ASSESSMENT OF AIRCRAFT IMPACT
POSSIBILITIES AT THE IDAHO CHEMICAL
PROCESSING PLANT ON THE INEL SITE**

**L. G. Lee
J. M. Mines
B. B. Webb**

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**Westinghouse Idaho
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EXECUTIVE SUMMARY

The concern of this study was the possibility of an aircraft collision with facilities at the Idaho Chemical Processing Plant (ICPP). Two sets of data were combined in calculating the probability of this event. The first was from the Nuclear Regulatory Commission. The Nuclear Regulatory Commission data is used to check the adequacy of nuclear power plant location relative to aircraft crashes. For neighboring airport scenarios, the accepted rate unit is fatal crashes per square mile. For in-flight crash scenarios, a total loss of control crash rate (where the pilot was completely out of control) is used for evaluating nuclear reactors. Numbers were given per linear mile of flight. The other set of data was obtained from the National Transportation Safety Board's annual review. These data points show higher crash frequencies because crashes in which the pilot maintained some control have not been excluded. By including this data set, the evaluation gained two advantages. First, the data are separated by type of aircraft, which makes frequencies for specific flight paths more meaningful. Second, the data are given year by year over a ten-year time span. Therefore, it is possible to gain a sense of the variability in crash frequencies from one year to another.

Once crashes per unit area for various types of aircraft were known, knowledge of the ICPP's target area, closeness of flight paths, and frequency of flights led to the calculation of impact frequencies at the ICPP. It was found that the Protection Technology of Idaho (PTI) helicopters flying over a facility and during landing and takeoff maneuvers poses the greatest threat from aircraft impact. The probability of impact including the 90% confidence for these vehicles is $5.9 \times 10^{-4} \text{ y}^{-1}$ for overflights and $3.8 \times 10^{-6} \text{ y}^{-1}$ for airport maneuvers. This equates to once every 1700 years to 260,000 years. Limiting the number of flights over the ICPP to one per year would reduce the overflight impact to incredible. For the landing and takeoff maneuvers, restricting the number of flights to less than 211, relocating the rotocraft airport farther from the plant, or restricting takeoff and

landing by procedures in a direction away from the ICPP would reduce the crash frequency to incredible.

The FAA aircraft tests have a crash potential of $2 \times 10^{-6}/y$. Where the aircraft tests are conducted less than once every two years, the crash frequency is less than incredible.

All other local flight paths were computed to frequencies less than $1 \times 10^{-6}/y$, which assigned them the designation of incredible event. Therefore, it can be concluded that an air crash at the ICPP is extremely unlikely before the plant reaches the end of its design life.

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1. INTRODUCTION

The Idaho Chemical Processing Plant (ICPP) is located on the Idaho National Engineering Laboratory (INEL) site. The ICPP stores and prepares radiological materials for disposal. As such, the external event of an airplane impact that could allow the release of these materials is a concern in reviewing the existing hazards and when siting new facilities. Such an external issue is just one of the items included in the safety analysis conducted on all facilities. Safety analysis is used to evaluate the hazards at U.S. Department of Energy (DOE) facilities that are not routinely accepted by the public that may impact those who operate the facility, or that affect the public or the environment that surrounds the facility. DOE Order 5481.1B requires that potential hazards be systematically identified and reviewed. In safety analysis reports, airplane crash potential is discussed when the frequency of impact releasing hazardous agents is high enough to pose a significant hazard. This report supports the safety analysis effort by analyzing the frequency of potential aircraft impact with ICPP facilities.

The ICPP and potential crash target facilities are discussed in this report first and then air traffic in the surrounding area, including airports, flights, and flight paths. The Nuclear Regulatory Commission (NRC) Standard Review Plan is explained as the benchmark criteria for the analysis. The inadequacies of the NRC plan are discussed, and estimates are made to apply the plan to the ICPP facility. Further adjustments are made using the National Transportation Safety Board (NTSB) crash statistics to develop accident rates for small air taxi and helicopter aircraft relevant to the ICPP site review. The NRC plan equation was corrected for flight path width. Estimated from NTSB crash statistics, year-to-year variability was added as it applies to the ICPP situation.

1.1 ICPP

The ICPP is in the south-central portion of the INEL in Butte County, about 67 km (42 mi) west of Idaho Falls. In 1949, the U.S. Atomic Energy Commission established the INEL as the National Reactor

Testing Station (NRTS) for testing various types of nuclear reactors and associated equipment. The INEL is next to the western edge of the Upper Snake River Plain in southeastern Idaho. It contains 2305 km² (890 mi² or 570,000 acres) with an average elevation of 1480 m (4850 ft) above sea level. Figure 1 shows the relative location of the ICPP and the INEL boundary.

The ICPP mission is to receive, store, and prepare many types of spent nuclear fuels for disposal as assigned by the DOE. Until recently, the ICPP processed spent, highly enriched nuclear reactor fuels for recovery of residual uranium. Nuclear liquid waste from that processing is presently converted into solid granules in the New Waste Calcine Facility (NWCF). Liquid and gaseous waste streams from plant equipment are contained and treated to comply with DOE and environmental standards.

The ICPP is remote from major population centers, waterways, and transportation routes. The INEL has no permanent residents, and ingress and egress of site personnel for performance of their duties and of visitors on official business are closely controlled. No casual visitations are permitted. There are no recreational activities within the INEL, and agriculture consists only of limited grazing. For national security purposes, the INEL has an FAA advisory specifying a flight altitude above 1950 meters (6400 ft) mean sea level (MSL) for aircraft. Aircraft usually fly around the INEL.

The restricted area of the ICPP, which is composed of several facilities containing potential release contaminants, encloses 0.49 km² (0.19 mi² or 120 acres) of the total ICPP area of 0.59 km² (0.23 mi² or 147 acres). The mean elevation of the ICPP where the facilities are located is 1498.6 m (4916.6 ft) above sea level. Materials with release potential from aircraft crash incidents could include solidified granules of waste in storage, process streams, and waste streams.

The ICPP plant has several areas that factor into plane crash scenarios. The overall restricted area of 0.49 km² (120 acres) is of interest in comparison to the INEL to provide a general likelihood of

Figure 1. Location of the ICPP

crash scenarios at future facilities. Specific ICPP facilities that are of interest relative to plane impacts are listed in table 1. The main stack is included as a storage area because of the stack's potential of falling into adjacent storage areas after an aircraft impact.

1.2 AIRPORTS

Airports near the INEL include the Idaho Falls Airport (80 km or 50 mi from the INEL), the Pocatello Airport (97 km or 60 mi from the INEL), Burley airport (110 km or 70 mi from the INEL), the Twin Falls Airport (145 km or 90 mi from the INEL), and other agricultural landing strips. Because these airports are a significant distance from the INEL, any flights over the INEL site would be in the in-flight or cruise mode of flight.

The Idaho Fall airport has about 45,000 operations per year. Of this, approximately 11,000 operations are for air taxis (small wingspan commercial aircraft), 4000 operations for air carriers (large wingspan commercial aircraft), and 30,000 operations for general aviation (small wingspan noncommercial aircraft). There are four air taxi flights a day between Boise and Idaho Falls. Air taxi flights include two operations a day for five days of the week between Idaho Falls and Salmon.¹

The Pocatello airport averages 52,000 operations per year. Two-thirds of this number (35,000 operations per year) is general aviation and one-third (17,000 operations per year) is air taxi. Most of the traffic is to Boise and Salt Lake City.²

The Burley airport maintains aircraft operations and passing aircraft contacts. The airport has approximately 23,000 operations and contacts with passing aircraft a year. General aviation accounts for 19,000 per year, air taxis account for 3000 per year, air carriers 100 per year, and military flights account for 600 per year.³

The Twin Falls airport averages approximately 45,000 operations per year. General aviation accounts for 32,000 operations per year, air taxis account for 12,000 operations per year, air carriers account for

Table 1. ICPP Facilities Crash Targets of Interest

FACILITY	FACILITY DIMENSIONS		
	LENGTH m (ft)	WIDTH m (ft)	HEIGHT m (ft)
ICPP (total area)	914.4 (3000)	548.6 (1800)	NA
CPP-601 Processing Bldg	74.4 (244)	31.1 (102)	11.9 (38)
CPP-602 Lab Bldg	51.8 (170)	44.2 (145)	4.6 (15)
CPP-627 Remote Analytical Facility	26.8 (88)	27.1 (89)	6.4 (21)
CPP-640 Headend Processing	20.1 (66)	27.1 (89)	10.4 (34)
CPP-659 NWCF	76.2 (250)	44.2 (145)	13.1 (43)
CPP-604 Waste Treatment	50.6 (166)	27.4 (90)	12.2 (40)
CPP-605 Waste Treatment	13.7 (45)	19.8 (65)	12.2 (40)
CPP-603 Decon Area South	6.1 (20)	4.6 (15)	11.0 (36)
RADIOLOGICAL MATERIALS STORAGE AREAS			
CPP-603 Fuel Receiving & Storage	61.0 (200)	8.8 (29)	11.0 (36)
CPP-603 Storage Basin North and middle	24.4 (80)	18.2 (60)	4.0 (13) (Storage underground)
CPP-603 Storage Basin South	13.7 (45)	26.8 (88)	11.0 (36) (Storage underground)
CPP-651 Unirradiated Fuel Storage	13.7 (45)	12.8 (42)	4.0 (13) (Bermed storage)
CPP-603 Graphite Fuel Storage	25.9 (85)	38.1 (125)	11.0 (36)
CPP-708 Main Stack	20 (6.1)	20 (6.1)	76.2 (250)
CPP-749 Peach Bottom Fuel Storage	109.7 (360)	100.6 (330)	(Storage underground)
FAST	133.5 (438)	23.2 (76)	14.6 (48)
5th BIN SET	5.2 (17)	5.2 (17)	8.8 (29) (Storage underground)
6th BIN SET	18.6 (61)	18.6 (61)	19.5 (64) (Storage underground)
7th BIN SET	18.6 (61)	18.6 (61)	19.5 (64) (Storage underground)
Tank Farm Storage Area	173.7 (570)	109.7 (360)	(Storage underground)

160 operations per year, and military accounts for 900 operations per year.⁴

Several small gravel-surface landing strips are located near the INEL, the largest of which is in Atomic City, 18 km (11 mi) southeast of the ICPP. Most of the crop-dusting aircraft around the INEL use only the INEL boundary fringe for turning the aircraft. Aircraft do not routinely cross over the site. But a few times a year aircraft must be moved across the site. The INEL Flight Department approves 60 to 100 overflights per year by crop-dusting and other similar aircraft. The flights are too few to impact the results of this report and are not considered a concern.

1.3 AIRWAYS

The types of traffic near the INEL are air taxis and general aviation. The most significant of the two types are the air taxi flights between Idaho Falls and Boise. These flights cross over the INEL about 5 km (3 mi) south of the ICPP stack. An average of two or three flights a day are made between these two cities for a total of 1000 flights per year.

Flights (V269) from Idaho Falls to Pocatello, Burley, and Twin Cities are also air taxi and approach to within 30 km (19 mi) of the facility. About six flights a day are made for a total of 2000 flights per year.

General aviation flights (V269) from Pocatello to Salmon cross the INEL site and are 15 km (9 mi) from the ICPP stack. Very few flights a year travel this path. Aviation flights from Pocatello to Boise (V269) and from Pocatello to Idaho Falls (V21) as already mentioned each totals 2,000 flights/year.

Military paths (IR 302 and 314) pass within 40 km (25 mi) of the ICPP and pass over the Craters of the Moon National Monument. IR 302 has 800 operations per year, and IR 314 has three operations per year.⁵

The rest of the flight paths are at least 40 km (25 mi) from the INEL site and are not a concern in this report.

1.4 PROTECTION TECHNOLOGY IDAHO (PTI) HELICOPTER

The INEL security helicopter is a turbine-powered rotocraft used to patrol the INEL site boundary and the areas within. Because the helicopter lands and takes off on-site and patrols the INEL site, 95 percent of the total flight time is over the INEL site. The flight time of the helicopter amounts to a total of 1200 hours each year. For a typical 90-minute flight, the INEL helicopter spends 5 minutes in takeoff, 5 minutes in landing, and 80 minutes in flight. Approximately 800 flights are made each year. The helicopter pad is located 5 km (3 mi) from the ICPP.

1.5 FAA AIRCRAFT TESTS

The FAA has tested the air flow pattern of new commercial air craft at the INEL. NOAA has a 61-m (200-ft) aluminum tower north of the ICPP, which is used to measure turbulence created by aircraft wings. The test data are used to establish safe distances between aircraft on takeoff and landing.

From September through October of 1990, four new aircraft types were tested: Boeing 767, 757-200, 747-400, and the French Air Bus A300. Flights were from the southeast to northwest and passed the tower on the northeast side. With the craft in landing configuration, each aircraft made 36 passes by the tower for a total of 144 passes.⁶

The NOAA tower is about 2.4 km (1.5 mi) north of the ICPP. Smoke grenades are placed at 11 levels of the tower. As the planes passes, the smoke is entrained in the vortex created by the passing wing. The 200 anemometers on the tower measure the windspeed inside the vortices. Tests have been conducted over the INEL once every three or four years on an as-needed basis since 1970.

2. CRITERIA

The selection criteria that are used in siting nuclear reactors is provided in 10 CFR Part 100, Reactor Site Criteria. The criteria are also used for siting other radiological facilities. Section 100.10 requires a low risk of public exposure.⁷ A similar approach is specified in DOE orders for nonnuclear facilities. DOE Order 5481.1B requires potential hazards including aircraft impact potentials to be systematically identified and reviewed. Scenarios may be excluded from analysis if the frequency of occurrence is low enough. According to WINCO safety analysis procedures, if the likelihood of an event is less than one in a million years (occurrence frequency of $1 \times 10^{-6}/y$), it is classed as "incredible" and no further review is required.⁸

2.1 BASIC EQUATIONS

The basic equations used to calculate aircraft impact frequency per year take the accident statistics collected and apportion the rate according to the area of the impact target building and the area for which the statistics were collected. Statistics collected for accidents around airports are rates with a denominator of a square mi. This is multiplied directly with the target area to obtain the impact frequency for the target.

Statistics used for flight paths and corridors are reported with a denominator of flight miles. The denominator of flight miles used with commercial carrier rates is converted to a denominator of area by dividing the rate by the flight path width (typically 9 mi) and then multiplying by the target area to get the impact frequency for the target. If the target is outside the flight path, the flight width divided into the rate is increased on both sides of the path until the target area is included in the area. This compensates for the aircraft's possible deviation on either side of the flight path. This distance is twice the distance from the center of the flight path to the target area. In each case the denominator units are converted to area units before multiplying by the target area.

The typical flight path rate calculation, which is estimated as a uniform distribution within the 9-mi flight path and with a uniform extension of flight path statistics to targets outside the flight path, is not supported by data. Crash frequency appears to decrease exponentially from the center of the flight path. The typical flight path rate calculation underestimates the rate for the middle of the path and overestimates the rate outside the path. Comparison with an exponential flight path calculation is used to determine the deviation of the NRC calculations from what should be expected.

The Nuclear Regulatory Commission (NRC) Standard Review Plan does provide benchmark criteria and methods acceptable in analyzing air crash potential. For example, the plan provides crash frequency statistics around airports and the in-flight crash frequency for commercial aircraft acceptable to the NRC. The in-flight statistics correspond to crashes with total loss of control (TLOC) of the aircraft. Therefore, a controlled crash where the pilot can direct the direction of the crash would not be included as an in-flight accident. The airport statistics include only crashes resulting in fatalities. The shortcomings of the plan include an absence of crash rates for airport and in-flight noncommercial aircraft and a lack of variability data on the rates provided.

Extrapolation of the NTSB to NRC accident frequencies is used to fill in some of the criteria gaps in the NRC standard review plan. The assumption that TLOC in-flight accidents are proportional to NTSB crash statistics is used to estimate TLOC accidents for general aviation and the other categories from the commercial aircraft crash frequency in the NRC plan. The hours per mi ratio is determined from the NTSB data for air carriers and air taxis. The ratio for air taxis is used to convert the general aviation and turbine helicopter data from NTSB accidents per hour to accidents per mi. This is appropriate because the wing spans for the aircraft are approximately the same length. The ratio of air carrier total loss of control accidents versus NTSB accidents per mi is used to convert the derived NTSB accident rates for general aviation, turbine helicopters, and air taxis to total loss of control accidents per mile.

Tuning the NRC airport frequency rate to specific aircraft like air taxis or helicopters is accomplished by use of derived TLOC accident rates. The relative fractions of complete loss of control of the aircraft is assumed proportional with the NRC airport fatal accidents in determining the airport accident rates for helicopter and air taxi aircraft.

Year-to-year variability of the NRC plan rates is estimated as proportional to the variability of the NTSB year-to-year rates. Specifically, the NTSB coefficient of variations is directly applied to the frequencies obtained from the NRC and NTSB data.

2.2 NRC STANDARD REVIEW PLAN

In reviewing applications of nuclear reactor sites, the NRC uses a Standard Review Plan for reviewing aircraft hazards.⁹ Acceptance criteria for frequency of aircraft hazards are met if the frequency of aircraft accidents resulting in radiological consequences that are greater than guidelines in 10 CFR Part 100 is less than about 10^{-7} per year (1/10th of the incredible level). This requirement may be met by inspection using proximity criteria or by using frequency calculations in an aircraft hazards assessment.

A proposed reactor site is considered to meet the requirements by inspection if the following criteria are met:

1. The plant-to-airport distance D is between 5 and 10 statute miles and the projected annual number of operations is less than $500 \times D^2$, or the plant-to-airport distance D is greater than 10 statute mi and the projected annual number of operations is less than $1000 \times D^2$;
2. The plant is at least 5 statute mi from the edge of military training routes, including low-level training routes, except those associated with usage greater than 1000 flights per year, or where activities may create an unusual stress situation; and

3. The plant is at least 2 statute mi beyond the nearest edge of a federal airway, holding pattern, or approach pattern.

If a site fails to meet the criteria by inspection, an aircraft hazards assessment is required. The aircraft hazards assessment includes frequency calculations for nearby airways, airports, designated airspaces, and holding patterns.

The airways frequency calculation for a proposed site, P_{FA} calculated below, is obtained by multiplying the in-flight crash rate for the aircraft by the number of trips and by the ratio of the target area with the area under the airway on both sides to up to the distance of the target. The crash rate is per flight-mi. Dividing the crash rate by the width of the path under the plane gives the crash rate per flight per unit area. If the target plant site is farther than 4.5 mi (half the 9-mi airway width), then the crash rate is further reduced by adding twice the target distance to the path width in the denominator. If the target is within the airway, the width is set at 9 mi. This is a simplification that does not agree with the decreasing exponential distribution of air crash potentials as the distance from the center of the air way increases.

$$P_{FA} = C \times N \times A/w$$

where:

- P_{FA} = airway frequency per year,
- C = in-flight crash rate per mi for aircraft using the airway,
- w = width of airway plus twice the distance from the airway edge to the site in miles when the site is outside the airway, or width of airway in miles when the site is within the airway,
- N = number of flights per year along the airway, and
- A = effective area of plant in square miles.

A value of $C = 4 \times 10^{-10}$ per aircraft mi is used in the NRC Standard Review Plan¹⁰ for in-flight calculations as provided in congressional

testimony.¹¹ This accident rate is for commercial aircraft en route. It is based on one catastrophic in-flight failure occurring in the United States per year. In such an accident the plane will lose altitude with no pilot directional control of the aircraft. No rate is provided for general, military, air taxi, or helicopter air traffic. Crash rates must be estimated for other types of aircraft when applying the NRC plan to these specific aircraft.

Airport frequency calculations for civilian, military, and helicopter traffic are determined, as shown below, by multiplying the fatal crash frequency per square mile by the number of flights and the target area for each type of aircraft. The frequency per square mi used as shown in table 2,^{12, 13} varies with the distance from the airport and is specified for general, commercial, and military flights. As the distance from the airport increases, the frequency per square mi decreases. The total frequency, P_A , is the sum of all the flight frequencies:

$$P_A = \sum_{i=1}^L \sum_{j=1}^M C_j \times N_{ij} \times A_j$$

where:

- P_A = airport frequency per year,
- M = number of different types of aircraft using the airport,
- L = number of flight paths affecting the site,
- C_j = frequency per square mile of a crash per aircraft movement,
- N_{ij} = number (per year) of movements by the j th aircraft type along the i th flight path, and
- A_j = effective plant area for the j th aircraft type.

Holding patterns outside an airport distance of 5 mi are converted into equivalent in-flight aircraft airways taking into account the operations and orientation of the pattern with respect to the target reactor plant.

Table 2. Fatal Crashes per Square Mile per Aircraft Movement

MILES FROM AIRPORT	AIR CARRIER	GENERAL AVIATION	USN & USMC	USAF
1	1.67E-7	8.4E-7	8.3E-8	5.7E-8
2	4.0E-8	1.5E-7	1.1E-8	2.3E-8
3	9.6E-9	6.2E-8	3.3E-9	1.1E-8
4	6.8E-9	3.8E-8	3.1E-9	4.2E-9
5	2.7E-9	1.2E-8	2.0E-9	4.0E-9
6	0	NA	NA	NA
7	0	NA	NA	NA
8	0	NA	NA	NA
9	1.4E-9	NA	NA	NA
10	1.2E-9	NA	NA	NA

2.3 EFFECTIVE TARGET AREA

All of the crash frequency calculations in the standard review plan use a target area that is actually larger than a facility's horizontal cross-sectional area. The target area is an effective impact area, A, which includes: 1) the shadow area from crash angle, 2) the skid area of a plane in front of the target building, 3) the expanded area of the buildings, which accounts for the wing or rotor span of the aircraft, and 4) the horizontal cross-section area of the target affected by aircraft crashes.

The shadow area is the building elevation projected upon the horizontal plane (behind the building from the projected impact). Typically, the crash angle is 20 degrees but varies from 0 to 30 degrees. The shadow area depends upon the assumed crash angle for the various aircraft and the angle of approach relative to the broadside (θ) of the building target. The area is greatest when the angle is straight onto the building's opposite corner diagonal. A facility that is underground or that has no height would not have a shadow area included in the target. A plane passing above the ground would miss a target with no height.

The skid area around the plant is a characteristic of each type of aircraft. A skid length of 100 m is used for general aviation aircraft and similarly sized aircraft. A length of 500 m is used for commercial aircraft and other large aircraft. Artificial berms or other barriers in the skid area can also be taken into account and may reduce the skid area. A facility that is underground would not be impacted by a plane skidding along the ground.

The expanded area is the area around the top of a facility that accounts for a vehicle's wing span or the tip of the wing hitting the target. The expanded area is larger for large aircraft with long wing spans. A wing span of 12 m is used for general aviation and similarly sized aircraft and a wing span of 60 m for commercial and similarly sized aircraft.

The target areas are the safety-related parts of the target that are susceptible to impact or fire damage as a result of aircraft crashes. This area is typically the horizontal cross-sectional footprint of the building.

The aircraft effective crash area is based upon the sum of three area factors. First is the shadow area.

$$A_{\text{shadow}} = h \cdot \left(\frac{w_{\text{large}} \cdot \cos(-\theta) - w_{\text{small}} \cdot \sin(-\theta) + 2 \cdot \frac{\text{span}}{2}}{\tan(-\phi)} \right)$$

- θ = the angle from the building broadside as the plane approaches the target
- h = the height of the facility
- w = the length of the sides of the facility
- ϕ = the angle of impact measured from the horizon
- span = the aircraft wing span

Next is skid area where the distance that an aircraft may skid and reach a building is accounted for.

$$A_{skid} = d \cdot \left(w_{large} \cdot \cos(-\theta) - w_{small} \cdot \sin(-\theta) + 2 \cdot \frac{span}{2} \right)$$

d = distance this type of aircraft is expected to skid
and finally expanded area including the length of the aircraft wings
where

$$A_{expanded} = (w_{large} \cdot w_{small}) + 2 \cdot \frac{span}{2} (w_{small} \cdot \cos(-\theta) - w_{large} \cdot \sin(-\theta))$$

3. CORRECTIONS TO THE NRC STANDARD REVIEW PLAN

The following sections estimate and extrapolate to fill the gaps in the NRC Standard Review Plan needed to evaluate the ICPP crash potential. The in-flight crash rates for air taxis and turbine helicopters are missing for total loss of control crashes in-flight. Also crash rates for airport scenarios for air taxis and turbine helicopters are missing. These inadequacies are addressed by the following steps.

1. Determining the in-flight crash frequencies for general aviation, air taxis, and for turbine helicopters from the air carrier TLOC crash rate using NTSB data,
2. Determining the airport fatal accident rates for air taxi and turbine helicopters using derived TLOC rates,
3. Adding the year-to-year variability from NTSB data and applying it to the NRC derived rates, and
4. Correcting the flight path for decreasing exponential crashes as the target distance from the center of the flight path increases.

3.1 IN-FLIGHT FREQUENCY RATES FOR GENERAL AVIATION, AIR TAXIS, AND TURBINE HELICOPTERS

The National Transportation Safety Board (NTSB) accident data source was used to develop ratio correction factors and crash frequencies for general aviation, air taxis, and turbine helicopters because it has accident statistic segregated in these categories. The NTSB also has several years of data available for estimating the data variability. A larger data base is used in the NTSB rates by including all fatal accidents instead of just the in-flight total loss of control aircraft crashes as used in the NRC Standard Review Plan. Therefore, a direct comparison of accident rates cannot be made. Ratios between subgroups of data within the NTSB data and, of importance to the ICPP crash frequency determination, the total loss of control rates are assumed to be

consistent for determining the crash frequency for general aviation, air taxis, and turbine helicopters.

The National Transportation Safety Board tabulates and publishes aircraft accident rates on a periodic basis. Annual reviews are published for U.S. commercial carrier operations¹⁴ and for U.S. general aviation.¹⁵ The air carrier information is collected for air taxis, nonscheduled air taxis, and air carriers. The general aviation information is collected for general aviation, fixed-wing, and rotocraft types of aircraft. The statistics collected include groupings of unscheduled landings, property damage, serious injury, and fatal accidents. Fatal accidents are used in this section for use in aircraft impact frequency calculations.

Table 3 contains NTSB statistics for air carriers. The total accidents are used to calculate the fatal accident rate. The table contains the total fatal accidents, the numbers of hours and miles flown, and the tabulated fatal accidents per flight hours for air carrier and air taxi operations. The air taxi fatal accident rate is five times greater than the rate for air carriers. The ratio of operating hours to flight miles is 5.41 for air taxis and 2.45 for air carriers. This ratio is used to determine the in-flight TLOC accident rate for air carriers, general aviation and turbine helicopters.

Table 4 contains statistics for general aviation accidents. The NTSB data does not provide the accident rate per miles flown as in the air carrier data. The table contains the fatal accident rates per flight hours for general aviation types of aircraft. The rotocraft types of aircraft have the highest accident rates with single-engine fixed-wing aircraft next highest. The turboprop and turbojet have the lowest accident rates.

Table 5 contains the extrapolated total loss of control crash rates for general aviation, air taxis, and turbine helicopters calculated from the NTSB rates and the air carrier rate of 4×10^{-10} /mi flown. The miles

Table 3. Air Carrier Fatal Accidents per Flight Hours

	AIR TAXI	NONSCHEDULED AIR TAXI	AIR CARRIER
FATAL ACCIDENTS	2	31	2
FLIGHT HOURS	1,738,239	2,903,358	9,924,292
FATAL ACCIDENTS PER HOUR	1.2E-6	1.1E-5	2.0E-7
MILES FLOWN	321,629	NOT AVAILABLE	4,055,547
FATAL ACCIDENTS PER MILES FLOWN	6.2E-6	NOT AVAILABLE	4.9E-7
RATIO OF HOURS TO MILES	5.40	NA	2.45

Table 4. General Aviation Fatal Accidents by Type of Aircraft

	TYPE OF AIRCRAFT								
	GENERAL AVIATION	ALL FIXED WING	SINGLE ENGINE	MULTI- PLE ENGINE	TURBO- PROP	TURBO- JET	ALL ROTO- CRAFT	RECI- PROCA- TING ROTO- CRAFT	TURBINE ROTO- CRAFT
FATAL ACCI- DENTS	487	437	368	54	12	3	39	21	18
FLIGHT HOURS	29,318,000	27,234	20,935	3,498	1,345	1,456	1,689	789	900,000
FATAL ACCI- DENTS PER HOURS	1.7E-5	1.6E-2	1.8E-2	1.5E-2	8.9E-3	2.1E-3	2.3E-2	2.7E-2	2.0E-5

per hour ratio from the air taxi NTSB data was used for general aviation and turbine helicopters because they are small aircraft like the air taxis and have similar lengths of wings and rotors. The fatal accident rate for general aviation, turbine helicopters, and air taxis was multiplied by the miles per hour ratio to give the fatal crash rate per million miles flown. The ratio of each craft fatal accident rate per mi was divided by the air carrier fatal accident per mi and multiplied by 4×10^{-10} /mi to give a total loss of control crash rate per miles.

Table 5. Total Loss of Control Crash Rates

	AIR CARRIER	AIR TAXI	GENERAL AVIATION	TURBINE HELICOPTER
FATAL CRASHES PER HOUR	2.02E-7	0.000001	1.66E-5	2.0E-5
HOURS PER MILE RATIO	2.45	5.40	5.40	5.40
FATAL CRASH RATE PER MILES FLOWN	4.9E-7	6.2E-6	9.0E-5	1.1E-4
TOTAL LOSS OF CONTROL CRASH RATE PER MILE	4.0E-10	5.0E-9	7.3E-8	8.8E-8

3.2 AIRPORT CRASH RATES FOR AIR TAXIS AND TURBINE HELICOPTERS

Table 6 contains the calculated airport fatal crash rate for air taxis and turbine helicopters. The rates were calculated such that the air taxi rate is proportionally between the air carrier and general aviation rates as the air carrier total loss of control crash rate is between the two rates in table 5. The turbine helicopter fatal crash rates in table 6 are proportionally above the air carrier and general aviation rates because the turbine helicopter rate is above the other two for total loss of control rates in table 5.

The NTSB accident data were also used to extrapolate the airport crash rate for air taxis and turbine helicopters from the NRC airport fatal crash rate for air carriers and general aviation.

3.3 YEAR-TO-YEAR VARIABILITY ESTIMATE OF ACCIDENT RATES

Tables 7 and 8 list the accident rates per hour flying for the kinds of flying for air carriers and kinds of flying and type of aircraft for U.S. general aviation. The accident rates in table 7 show that the air taxi rate has a decreasing accident trend. Nonscheduled and air carrier rates have remained about the same during the years listed. The coefficient of variation is the standard deviation divided by the mean.

Table 6. Calculated Airport Crash Rate for Air Taxis and Turbine Helicopters

DISTANCE FROM END OF RUN WAY (MILES)	FATAL CRASHES PER SQUARE MILE PER AIRCRAFT MOVEMENT			
	AIR CARRIER	AIR TAXI	GENERAL AVIATION	TURBINE HELICOPTER
0-1	1.67E-7	2.1E-7	8.4E-7	9.8E-7
1-2	4.0E-8	4.7E-8	1.5E-7	1.7E-7
2-3	9.6E-9	1.3E-8	6.2E-8	7.3E-8
3-4	6.8E-9	8.8E-9	3.8E-8	4.4E-8
4-5	2.7E-9	3.3E-9	1.2E-8	1.4E-8

If the variance is consistent for the NTSB and NRC type of data, the coefficient of variation can be applied to in-flight rates to determine the in-flight crash variability upper and lower limit on the mean accident rate.

Table 8 contains the fatal accident rate per flight hours by year for general aviation type of aircraft. The accident rates for types of aircraft do not show a changing trend in rates. The coefficient of variation contains the year-to-year variability used to develop the upper and lower limits on the mean accident rates.

Tables 9 and 10 have the mean accident rates and the upper and lower limits for the accident rates. The yearly variability of the mean rate will be below the upper limit of the accident rate 90 percent of the time. The year-to-year variability is determined by using the $t = 1.833$ for the Student's t distribution with 9 degrees of freedom and a 90% confidence interval. The maximum and minimum are calculated by adding or subtracting the following variability from the crash rate:

$$\pm (t_9) \times (\text{crash rate}) \times (\text{Coefficient of Variation})$$

The calculated TLOC crash rate including the average, upper limit, and lower limit are listed in table 9. The airport crash rates including average, upper limit and lower limit are listed in table 10. The use of

Table 7. Air Carrier Fatal Accidents per Aircraft Hours by Year

YEAR	KINDS OF FLYING		
	AIR TAXI	NONSCHEDULED AIR TAXI	AIR CARRIER
88	9.6E-7	9.5E-6	1.8E-7
87	5.2E-6	1.0E-5	3.8E-7
86	1.2E-6	1.1E-5	2.0E-7
85	4.0E-6	1.3E-5	8.0E-7
84	4.0E-6	7.5E-6	1.2E-7
83	1.3E-6	1.1E-5	5.5E-7
82	3.9E-6	9.5E-6	5.7E-7
81	7.3E-6	1.4E-5	5.6E-7
80	6.8E-6	1.3E-5	1.4E-7
79	1.3E-5	8.1E-6	7.3E-7
MEAN	4.7E-6	1.1E-5	4.2E-7
STANDARD DEVIATION	3.6E-6	2.0E-6	2.5E-7
STANDARD DEVIATION OF THE MEAN	1.1E-6	6.4E-7	8.0E-8
COEFFICIENT OF VARIATION	0.24	0.06	0.19

the upper limit in the crash rate removes the concern of year-to-year variability of the rate in accident analysis.

3.4 COMPARISON OF PATH CALCULATIONS USING EXPONENTIAL CRASH DISTRIBUTION

The flight path width used in the NRC frequency calculation provides a conservative cushion if the target is near the edge or outside the flight path. If the target is at the center of the flight path, the frequency calculated is understated. This is because of 1) assigning the total accidents to the flight path area used in the calculation even though accidents also occur outside the flight path and 2) assigning accident rates to the flight path uniformly even though accidents will decrease as the distance from the center of the path increases.

Table 8. General Aviation Fatal Accidents per Aircraft Hour by Year

YEAR	GENERAL AVIATION	ALL FIXED WING	SINGLE ENGINE	MULTIPLE ENGINE	TURBO-PROP	TURBO-JET	ALL ROTO-CRAFT	RECIPRO-CATING ROTO-CRAFT	TURBINE ROTO-CRAFT
88	1.5E-5	1.5E-5	1.6E-5	2.0E-5	6.4E-6	2.7E-6	1.1E-5	2.8E-5	3.6E-6
87	1.5E-5	1.5E-5	1.6E-5	1.4E-5	6.4E-6	4.4E-6	1.8E-5	2.5E-5	1.2E-5
86	1.6E-5	1.6E-5	1.7E-5	1.5E-5	8.9E-6	2.1E-6	2.3E-5	2.7E-5	2.0E-5
85	1.6E-5	1.6E-5	1.7E-5	1.8E-5	1.2E-5	3.4E-6	2.1E-5	2.2E-5	2.1E-5
84	1.7E-5	1.7E-5	1.8E-5	1.9E-5	7.1E-6	3.8E-6	2.4E-5	3.8E-5	1.6E-5
83	1.8E-5	1.7E-5	1.9E-5	1.9E-5	6.8E-6	2.8E-6	2.2E-5	3.5E-5	1.5E-5
82	1.8E-5	1.8E-5	2.0E-5	1.9E-5	5.9E-6	1.5E-6	2.5E-5	3.5E-5	2.0E-5
81	1.8E-5	1.8E-5	1.9E-5	1.9E-5	1.1E-5	3.0E-6	1.3E-5	2.4E-5	6.3E-6
80	1.7E-5	1.7E-5	1.7E-5	2.2E-5	7.2E-6	2.4E-6	2.1E-5	3.1E-5	1.5E-5
79	1.6E-5	1.6E-5	1.6E-5	2.1E-5	1.0E-5	2.7E-6	2.2E-5	2.3E-5	2.0E-5
MEAN	1.7E-5	1.6E-5	1.7E-5	1.9E-5	8.2E-6	2.9E-6	2.0E-5	2.9E-5	1.5E-5
STANDARD DEVIATION	1.2E-6	1.1E-6	1.3E-6	2.5E-6	2.1E-6	8.3E-7	4.7E-6	5.8E-6	5.9E-6
STANDARD DEVIATION OF THE MEAN	3.7E-7	3.6E-7	4.0E-7	8.0E-7	6.7E-7	2.6E-7	1.5E-6	1.8E-6	1.9E-6
COEFFICIENT OF VARIATION	0.022	0.022	0.023	0.042	0.082	0.092	0.074	0.064	0.127

Table 9. Calculated Total Loss of Control Crash Rate Including Year-to-year Variability

	AIR CARRIER	AIR TAXI	GENERAL AVIATION	TURBINE HELICOPTER
TOTAL LOSS OF CONTROL CRASH RATE PER MILE	4.0E-10	5.0E-9	7.3E-8	8.8E-8
TOTAL LOSS OF CONTROL CRASH RATE PER MILE UPPER RATE	5.4E-10	7.3E-9	7.6E-8	1.1E-7

Total accidents are assigned to the flight path because reporting requirements begin with the first indication of problems, which is

Table 10. Calculated Airport Crash Rate Including Year-to-year Variability

DISTANCE FROM END OF RUNWAY KM (MILES)	FATAL CRASHES PER AIRCRAFT MOVEMENT PER KM ² (PER MI ²)							
	AIR CARRIER	UPPER RATE	AIR TAXI	UPPER RATE	AVIATION	UPPER RATE	HELI-COPTER	UPPER RATE
0-1.6 (0-1)	6.4E-8 (1.7E-7)	8.7E-8 (2.2E-7)	8.1E-8 (2.1E-7)	1.2E-7 (3.0E-7)	3.2E-7 (8.4E-7)	3.4E-7 (8.7E-7)	3.8E-7 (9.8E-7)	4.7E-7 (1.2E-6)
1.6-3.2 (1-2)	1.5E-8 (4.0E-8)	2.1E-8 (5.4E-8)	1.8E-8 (4.7E-8)	2.6E-8 (6.8E-8)	5.8E-8 (1.5E-7)	5.6E-8 (1.4E-7)	6.7E-8 (1.7E-7)	5.1E-8 (1.3E-7)
3.2-4.8 (2-3)	3.7E-9 (9.6E-9)	5.0E-9 (1.3E-8)	5.0E-9 (1.3E-8)	7.2E-9 (1.9E-8)	2.4E-8 (6.2E-8)	2.3E-8 (5.9E-8)	2.8E-8 (7.3E-8)	2.2E-8 (5.6E-8)
4.8-6.4 (3-4)	2.6E-9 (6.8E-9)	3.5E-9 (9.2E-9)	3.4E-9 (8.8E-9)	4.9E-9 (1.3E-8)	1.5E-8 (3.8E-8)	1.4E-8 (3.6E-8)	1.7E-8 (4.4E-8)	1.3E-8 (3.4E-8)
6.4-8 (4-5)	1.0E-9 (2.7E-9)	1.4E-9 (3.6E-9)	1.3E-9 (3.3E-9)	1.8E-9 (4.7E-9)	4.6E-9 (1.2E-8)	4.4E-9 (1.2E-8)	5.4E-9 (1.4E-8)	4.1E-9 (1.1E-8)

generally before the plane deviates from its flight path. The principle that accidents decrease as the distance from the flight path increases is used to screen potential flight paths for consideration for accident analysis as mentioned in section 2.2. If the target site is farther than a few miles from commercial airways or military airways, then it is not considered significant.

Accidents occur outside the flight path, but they are distributed at a decreasing rate from the center of the flight path. Thus a target directly under a flight path would have a greater accident exposure than a target four or five miles from the center of the flight path. Solomon¹⁸ characterized the spread by a decreasing exponential distribution that predicts the impact as the distance increases from the center of the flight path. The equation is used for distances up to 8 miles from the center of the flight path, with the distribution shown in figure 2.

Figure 2. Impact Distribution

$$f(d) = \frac{1}{2} \gamma \cdot \exp(-\gamma \cdot |d|)$$

where

- γ = 1.6/mile for air carrier, 1/mile for military, and 2/mile for general aviation including air taxi
- d = the distance from the flight path, miles
- $f(d)$ = density with units per mi

This distribution can be used to correct the NRC flight path calculations relative to the target facility location in the flight path.

Tables 11 and 12 and figure 3 contain the comparisons of the values obtained by the two methods for the values of gamma associated with air carriers and general aviation. At about one mile from the center of the airway (1.24 mi for air carrier and 1.1 mi for general aviation), the Solomon distribution is equal to the width calculation. Distributions of accidents within the equivalent distances are much greater for the Solomon distribution, indicating that the width calculation method is not conservative within one mi of the center of the flight path. Outside of the one-mi distance, the width calculation overestimates the number of accidents. The Solomon distribution decreases rapidly outside the airway, supporting the use of the screen test using the distance from a flight path.

For the ICPP, use of the width calculation provides a conservative number. The flight path from Idaho Falls to Boise is 5 km (3 mi) from the ICPP. Therefore, the flight path calculates a conservative factor 45 times greater than should be expected. The flight path from Idaho Falls to Pocatello, Burley, and Twin Cities is 30 km (19 mi) from the ICPP, calculating to more than 5.6×10^5 (for an 8-mi distance) times greater than should be expected. General aviation flights from Pocatello to Salmon are about 14.5 km (9 mi) from the ICPP, and are over 5.6×10^5 times greater than should be expected.

For the PTI helicopter, using the airway equation to calculate crash probabilities would under-predict if the flight path was within 1 mi of

Figure 3. Impact Distribution Versus Width Calculation

Table 11. Comparison of Solomon's Exponential Distribution with Airway Width GAMMA = 1.6 (AIR CARRIERS)

	DISTANCE FROM AIRWAY CENTER (MILES)	AIRWAY WIDTH EQUATION	SOLOMON'S EQUATION	SOLOMON'S /AIRWAY WIDTH EQUATION	AIRWAY WIDTH /SOLOMON'S EQUATION
EQUATIONS EQUAL > FAA TESTS > AIRWAY BOUNDARY >	0	0.11	8.0E-1	7.2E+00	1.4E-1
	1	0.11	1.6E-1	1.5E+00	6.9E-1
	1.1	0.11	1.4E-1	1.2E+00	8.1E-1
	1.24	0.11	1.1E-1	9.9E-1	1.0E+00
	1.5	0.11	7.3E-2	6.5E-1	1.5E+00
	2	0.11	3.3E-2	2.9E-1	3.4E+00
	3	0.11	6.6E-3	5.9E-2	1.7E+01
	4	0.11	1.3E-3	1.2E-2	8.4E+01
	4.5	0.11	6.0E-4	5.4E-3	1.9E+02
	5	0.10	2.7E-4	2.7E-3	3.7E+02
LIMIT OF APPLICATION >	6	0.08	5.4E-5	6.5E-4	1.5E+03
	6.5	0.08	2.4E-5	3.2E-4	3.2E+03
	7	0.07	1.1E-5	1.5E-4	6.5E+03
	8	0.06	2.2E-6	3.5E-5	2.8E+04
	9	0.06	NA	NA	NA
	9.5	0.05	NA	NA	NA
	10	0.05	NA	NA	NA

the ICPP. This under-prediction would range from being equal at 1 mi to about 10 percent of what should be expected if the helicopter flew over the ICPP.

4. CALCULATIONS FOR THE ICPP

The calculations using the NRC screening and frequency equations are presented in this section for the ICPP. Screening tabulations, frequency

Table 12. Comparison of Solomon's Exponential Distribution with Airway Width, GAMMA = 2 (GENERAL AVIATION AND AIR TAXIS)

	DISTANCE FROM AIRWAY CENTER (MILES)	AIRWAY WIDTH EQUATION	SOLOMON'S EQUATION	SOLOMON'S /AIRWAY WIDTH EQUATION	AIRWAY WIDTH /SOLOMON'S EQUATION
HELICOPTER >	0	1.1E-1	1.0E+00	9.0E+00	1.1E-1
	1	1.1E-1	1.4E-1	1.2E+00	8.2E-1
EQUATIONS EQUAL >	1.1	1.1E-1	1.1E-1	1.0E+00	1.0E+00
	1.24	1.1E-1	8.4E-2	7.5E-1	1.3E+00
	1.5	1.1E-1	5.0E-2	4.5E-1	2.2E+00
	2	1.1E-1	1.8E-2	1.6E-1	6.1E+00
PTI HELICOPTER >	3	1.1E-1	2.5E-3	2.2E-2	4.5E+01
	4	1.1E-1	3.4E-4	3.0E-3	3.3E+02
AIRWAY BOUNDARY >	4.5	1.1E-1	1.2E-4	1.1E-3	9.0E+02
	5	1.0E-1	4.5E-5	4.5E-4	2.2E+03
	6	8.3E-2	6.1E-6	7.4E-5	1.4E+04
	6.5	7.7E-2	2.3E-6	2.9E-5	3.4E+04
LIMIT OF APPLICATION >	7	7.1E-2	8.3E-7	1.2E-5	8.6E+04
	8	6.3E-2	1.1E-7	1.8E-6	5.6E+05
	9	5.6E-2	NA	NA	NA
	9.5	5.3E-2	NA	NA	NA
	10	5.0E-2	NA	NA	NA

calculations for the ICPP site, and building targets within the ICPP are presented.

4.1 NRC SCREENING CALCULATIONS FOR THE ICPP

The NRC screening calculations for the ICPP compares the number of nearby airport operations and airway distances from the ICPP site with NRC criteria. For the specified distance from the airport or flight path the NRC operations per year must not be exceeded for the ICPP site to pass the screening test.

Table 13 contains the distance of each airport from the ICPP, the operations per year at each airport, the NRC threshold operations per year, and the airport distance criteria for aircraft hazard

consideration. The PTI helicopter has been added to the table for comparison because the close proximity to the ICPP of the landing and takeoff pad. The FAA aircraft tests are included because the aircraft are flown in a landing configuration past the NOAA tower. For all airports, the number of operations per year are less than the NRC threshold. The conclusion from the screening comparison is that flights from nearby airports would not be a concern for plane crash impact at the ICPP. This conclusion applies to all general aviation including flights from these airports that fail to follow air corridors and flight paths.

The PTI helicopter and the FAA aircraft tests, unlike the airports, are too close to the ICPP to be excluded by the screening criteria and must be considered in frequency calculations.

Table 13. NRC Screening Calculation for ICPP Exposure

AIRPORT	DISTANCE FROM ICPP IN KM (MI)	OPERATIONS PER YEAR	NRC SCREEN OPERATIONS PER YEAR	NRC DISTANCE FROM AIRPORT KM (MI)
IDAHO FALLS	80 (50)	45,000	2,500,000	≥ 16 (10)
POCATELLO	95 (60)	52,000	3,600,000	≥ 16 (10)
BURLEY	112 (70)	23,000	4,900,000	≥ 16 (10)
TWIN FALLS	144 (90)	45,000	8,100,000	≥ 16 (10)
PTI HELICOPTER	5 (3)	800	NA	< 8 (5)
FAA AIRCRAFT TESTS	2.5 (1.5)	288	NA	< 8 (5)

Air corridors and flight paths are considered separately from the airport review. The NRC airway screen criteria for the various airways close to the ICPP are presented in table 14. The commercial airways listed are all farther than the 3-km (2 mi) threshold criterion for hazard analysis. The military paths are farther than 8 km (5 mi) and have fewer than 1000 flights per year. Even though the Idaho Falls - Boise flight is not an air corridor, it has been included in the airway list because the path is used by scheduled air taxis on a daily basis.

The PTI helicopter flying over the ICPP and the FAA aircraft tests in the table do not meet the screening criteria. Both are closer than

Table 14. NRC Screening Calculation for ICPP Exposure Airways

AIRWAYS	DISTANCE FROM ICPP KM (MI)	OPERATIONS PER YEAR	NRC THRESHOLD DISTANCE KM (MI)	NRC OPERATIONS PER YEAR CRITERIA
IDAHO FALL - BOISE	5 (3)	1,000	3.2 (2)	NL
POCATELLO - SALMON	14.4 (9)	2,000	3.2 (2)	NL
IDAHO FALL - POCATELLO - BURLEY - TWIN CITIES	30.4 (19)	2,000	3.2 (2)	NL
MILITARY PATH IR 302/314	40 (25)	3	8 (5)	1000
PTI HELICOPTER	0 (0)	800	3.2 (2)	NL
PTI HELICOPTER	5 (3)	800	3.2 (2)	NL
FAA AIRCRAFT TESTS	2.5 (1.5)	288	3.2 (2)	NL

NL = No limit

the 2-mi criterion. The operation per year in the table for the FAA aircraft tests is determined as twice the 144 passes by the NOAA tower because the aircraft must return for each flight past the tower. The conclusion from the NRC screening of the airways nearby the ICPP site is that only the PTI helicopter and the FAA aircraft tests are a concern and that the airways are not a concern because of the distance from the ICPP site and the low usage.

4.2 NRC FREQUENCY CALCULATIONS FOR THE ICPP

The tabulation of the frequency of aircraft accidents as done in an aircraft hazards assessment using NRC statistics provides an impact frequency that can be used to compare different flights as well as provide an overall impact frequency for ICPP impact scenarios. The restricted ICPP area of 0.49 km² (0.19 mi²) is used for the initial crash rate determinations. Only the PTI helicopter and FAA test flights are included. The PTI helicopter rates are tabulated for both airport and airway because of its takeoffs and landings on the ICPP site and its travel near the ICPP site.

The NRC airway calculations were tabulated for the PTI helicopter and the FAA aircraft tests as shown in table 15 using the extrapolated

in-flight crash rates presented in section 3.4. The PTI helicopter is included in the table because of the aircraft possibly flying adjacent to the ICPP site. A comparison of the values with the incredible value of 1×10^6 accidents per year indicates that the PTI helicopter rate is too great to exclude. But the FAA aircraft tests are incredible and can be excluded.

Table 15. NRC Airway Frequency Calculations for the ICPP

AIRWAY	DISTANCE TO ICPP PER KM (MI)	OPERATIONS PER YEAR (N)	ICPP AREA PER KM ² (MI ²) (A)	FLIGHT WIDTH PER KM (MI) (W)	TOTAL LOSS OF CONTROL CRASH RATE PER KM (PER MI) (C)	EXPONENTIAL PATH CORRECTION (S)	FREQUENCY PER YEAR (C*S*N*A/W)
PTI HELICOPTER OVER ICPP	0 (0)	800	0.49 (0.19)	14 (9)	6.7E-8 (1.1E-7)	9	1.3E-3
PTI HELICOPTER AT LANDING PAD	4.8 (3)	800	0.49 (0.19)	14 (9)	6.7E-8 (1.1E-7)	2.2E-2	3.3E-6
FAA AIRCRAFT TESTS	2.4 (1.5)	288	0.49 (0.19)	14 (9)	3.3E-10 (5.4E-10)	6.5E-1	1.7E-7

Table 16 lists airport calculations for the PTI helicopter and FAA aircraft tests using the NRC frequency statistics. The PTI helicopter frequency uses the extrapolating airport crash rates presented in section 3.3. The crash rates for both 3.2-4.8 km (2-3 mi) and 4.8-6.4 km (3-4 mi) distances from the airport, taken from table 10, are presented in the table for the PTI helicopter. The PTI helicopter and FAA aircraft tests are bordering on the incredible and cannot be dismissed.

4.3 EFFECTIVE TARGET AREA

In the previous ICPP crash frequency calculations, the target area has been the ICPP fenced area, which is actually larger than any one facility horizontal cross-sectional area. This section provides the effective target area for the various ICPP buildings and the buildings that may contain radiological materials storage as aircraft crash radiological release targets.

Table 16. NRC Airport Frequency Calculations for the ICPP

AIRPORT SCENARIO	DISTANCE FROM ICPP IN KM (MI)	OPERATIONS PER YEAR (N)	ICPP AREA IN KM ² (MI ²) (A)	FATAL CRASH RATE PER KM (PER MILE)	FREQUENCY PER YEAR (C*N*A)
PTI HELICOPTER (2-3 MILES)	5 (3)	800	0.49 (0.19)	3.5E-8 (5.6E-8)	8.5E-6
PTI HELICOPTER (3-4 MILES)	5 (3)	800	0.49 (0.19)	2.1E-8 (3.4E-8)	5.2E-6
FAA AIRCRAFT TESTS	2.5 (1.5)	288	0.49 (0.19)	3.3E-8 (5.4E-8)	2.9E-6

In table 17 and 18, effective target areas are calculated for individual buildings at the ICPP based upon the sum of the shadow area, skid area, and expanded and target areas. The ratio of the sum of these three areas to the area of the ICPP is provided for comparison and use in crash frequency calculations.

The crash frequency rate for each facility for both the PTI helicopter and the FAA aircraft tests are listed in table 19. PTI helicopter crash frequencies per year for the facility totals and the totals for the radiological materials storage areas cannot be excluded as incredible. PTI helicopter overflights of most of the various buildings have small frequencies but are not excluded as incredible.

The airport scenario for the FAA aircraft tests crash rate of $2 \times 10^{-6}/y$ would be reduced to incredible if the flights were restricted to once every two years. Because the FAA aircraft tests occurs only once every few years, this rate when averaged over several years drops to incredible.

Table 20 lists the building and total facilities and total radiological materials storage areas with a PTI helicopter impact

Table 17. Facility Area Ratio with ICPP Area for Turbine Helicopter

Page 1 of 2

WING SPAN = 12 M (39 FT), SKID LENGTH = 100 M (328 FT), IMPACT ANGLE = 20°						
BLDG	ANGLE FROM PARALLEL	BUILDING TARGET AREA [M ² (FT ²)]				AREA RATIO
		EXPANDED	SKID	SHADOW	TOTAL EFFECTIVE	
ICPP [total area]	NA	NA	NA	NA	501676 (5400000)	1.000
CPP-601 Processing Bldg	26	3032 (32635)	9234 (99390)	2939 (31637)	15205 (163662)	0.030
CPP-602 Lab Bldg	41	3091 (33268)	7997 (86077)	1005 (10815)	12092 (130160)	0.024
CPP-627 Remote Analytical Facility	45	1181 (2713)	5002 (53844)	880 (9471)	7063 (76028)	0.014
CPP-640 Headend Processing	38	933 (0039)	4564 (49123)	1300 (13990)	6796 (73153)	0.014
CPP-659 NWCF	33	4302 (6303)	9984 (07466)	3596 (38708)	17882 (192477)	0.036
CPP-604 Waste Treatment	31	1977 (1283)	6937 (74667)	2324 (25018)	11238 (120968)	0.022
CPP-605 Waste Treatment	36	542 (835)	3597 (38716)	1205 (12972)	5344 (57523)	0.011
CPP-603 Decon Area South	38	115 (241)	1950 (20990)	588 (6330)	2653 (28561)	0.005

**Table 17. (Contd.) Facility Area Ratio with ICPP Area for
Turbine Helicopter**

Page 2 of 2

WING SPAN = 12 M (39 FT), SKID LENGTH = 100 M (328 FT), IMPACT ANGLE = 20°						
BUILDING TARGET AREA [M ² (FT ²)]						
BLDG	ANGLE FROM PARALLEL	EXPANDED	SKID	SHADOW	TOTAL EFFECTIVE	AREA RATIO
RADIOLOGICAL MATERIALS STORAGE AREAS						
CPP-603 Fuel Receiving and Storage	13	804 (8657)	7325 (78850)	2209 (23778)	10339 (111285)	0.021
CPP-603 Storage Basin North and Middle	39	797 (8582)	4234 (45569)	0 (0)	5031 (54151)	0.010
CPP-603 Storage Basin South	30	669 (7196)	4196 (45169)	0 (0)	4865 (52365)	0.010
CPP-651 Unirradiated Fuel Storage	43	398 (4285)	3064 (32982)	0 (0)	3462 (37267)	0.007
CPP-603 Graphite Fuel Storage	36	15020 (16172)	5792 (62349)	1747 (18802)	9042 (97323)	0.018
CPP-708 Main Stack	0	110 (1180)	1798 (19352)	3765 (40525)	5672 (61057)	0.011
CPP-749 Peach Bottom Fuel Storage	43	12801 (137788)	16069 (172970)	0 (0)	28870 (310758)	0.058
Fast	15	3769 (40572)	14680 (158013)	5902 (63532)	24351 (262117)	0.049
5th Bin Set	45	114 (1227)	1921 (20678)	0 (0)	2035 (21904)	0.004
6th Bin Set	45	658 (7085)	3817 (41088)	0 (0)	4475 (48173)	0.009
7th Bin Set	45	658 (7085)	3817 (41088)	0 (0)	4475 (48173)	0.009
Tank Farm area	35	21317 (229451)	21709 (233669)	0 (0)	43025 (463120)	0.086
FACILITY TOTALS	NA	NA	NA	NA	223917 (2410224)	0.446
TOTAL - RADIOLOGICAL MATERIALS STORAGE AREAS	NA	NA	NA	NA	145643 (1567693)	0.290

Table 18. Facility Area Ratio with ICPP Area for Air Carriers

Page 1 of 2

WING SPAN = 60 M (197 FT), SKID LENGTH = 500 M (1640 FT), IMPACT ANGLE = 20°						
BLDG	ANGLE FROM PARALLEL	BUILDING TARGET AREA [M ² (FT ²)]			TOTAL EFFECTIVE	AREA RATIO
		EXPANDED	SKID	SHADOW		
ICPP [total area]	NA	NA	NA	NA	501676 (5400000)	1
CPP-601 Processing Bldg	27	6003 (64614)	70213 (755762)	4469 (48100)	80684 (868477)	0.161
CPP-602 Lab Bldg	41	6334 (68180)	64073 (689680)	1610 (17327)	72017 (775187)	0.144
CPP-627 Remote Analytical Facility	45	3018 (32488)	49097 (528474)	1727 (18588)	53842 (579550)	0.107
CPP-640 Headend Processing	38	2500 (26914)	46904 (504866)	2671 (28750)	52075 (560530)	0.104
CPP-659 NWCF	33	8085 (87030)	74012 (796654)	5330 (57374)	87427 (941058)	0.174
CPP-604 Waste Treatment	32	4395 (47305)	58745 (632331)	3936 (42363)	67076 (721999)	0.134
CPP-605 Waste Treatment	37	1645 (17711)	42061 (452744)	2818 (30331)	46525 (500787)	0.093
CPP-603 Decon Area South	39	472 (5076)	33830 (364145)	2040 (21956)	36342 (391177)	0.072

Table 18. (Contd.) Facility Area Ratio with ICPP Area for Air Carriers
Page 2 of 2

WING SPAN = 60 M (197 FT), SKID LENGTH = 500 M (1640 FT), IMPACT ANGLE = 20°						
BLDG	ANGLE FROM PARALLEL	BUILDING TARGET AREA [M^2 (FT^2)]				AREA RATIO
		EXPANDED	SKID	SHADOW	TOTAL EFFECTIVE	
RADIOLOGICAL MATERIALS STORAGE AREAS						
CPP-603 Fuel Receiving and Storage	14	1939 (20875)	60667 (653010)	3658 (39373)	66264 (713258)	0.132
CPP-603 Storage Basin North and Middle	39	2221 (23904)	45252 (487091)	0 (0)	47473 (510995)	0.095
CPP-603 Storage Basin South	31	1903 (20487)	45051 (484920)	0 (0)	46954 (505408)	0.094
CPP-651 Unirradiated Fuel Storage	43	1299 (13987)	39404 (424139)	0 (0)	40703 (438126)	0.081
CPP-603 Graphite Fuel Storage	36	3590 (38646)	53049 (571012)	3199 (34429)	59838 (644087)	0.119
CPP-708 Main Stack	0	403 (4340)	33071 (355971)	13847 (149051)	47321 (509362)	0.094
CPP-749 Peach Bottom Fuel Storage	43	19947 (214713)	104447 (1124257)	0 (0)	124394 (1338969)	0.248
Fast	16	6639 (71464)	97381 (1048197)	7829 (84268)	111849 (1203929)	0.223
5th Bin Set	45	467 (5025)	33687 (362601)	0 (0)	34154 (367626)	0.068
6th Bin Set	45	1925 (20716)	43170 (464677)	0 (0)	45094 (485392)	0.090
7th Bin Set	45	1925 (20716)	43170 (464677)	0 (0)	45094 (485392)	0.090
Tank Farm area	35	30444 (327701)	132650 (1427828)	0 (0)	163094 (1755530)	0.325
FACILITY TOTALS	NA	NA	NA	NA	1328220 (14296840)	2.648
TOTAL - RADIOLOGICAL MATERIALS STORAGE AREAS	NA	NA	NA	NA	832232 (8958075)	1.659

Table 19. ICPP Facility Airplane Crash Rate per Year

BLDG	PTI HELICOPTER FREQUENCY PER YEAR				FAA AIRCRAFT TEST FREQUENCY PER YEAR	
	TLOC/Y (0 MI)	TLOC/Y (3 MI)	AIRPORT/Y (2-3 MI)	AIRPORT/Y (3-4 MI)	TLOC/Y	AIRPORT/Y
ICPP [total area]	1.3E-3	3.3E-6	8.5E-6	5.2E-6	1.7E-7	3.0E-6
CPP-601 Processing Bldg	4.0E-5	1.0E-7	2.6E-7	1.6E-7	2.8E-8	4.7E-7
CPP-602 Lab Bldg	3.2E-5	7.9E-8	2.0E-7	1.2E-7	2.5E-8	4.2E-7
CPP-627 Remote Analytical Facility	1.9E-5	4.6E-8	1.2E-7	7.3E-8	1.9E-8	3.2E-7
CPP-640 Headend Processing	1.8E-5	4.5E-8	1.1E-7	7.0E-8	1.8E-8	3.1E-7
CPP-659 NWCF	4.7E-5	1.2E-7	3.0E-7	1.8E-7	3.0E-8	5.1E-7
CPP-604 Waste Treatment	3.0E-5	7.4E-8	1.9E-7	1.2E-7	2.3E-8	3.9E-7
CPP-605 Waste Treatment	1.4E-5	3.5E-8	9.0E-8	5.5E-8	1.6E-8	2.7E-7
CPP-603 Decon Area South	7.0E-6	1.7E-8	4.5E-8	2.7E-8	1.3E-8	2.1E-7
RADIOLOGICAL MATERIALS STORAGE AREAS						
CPP-603 Fuel Receiving and Storage	2.7E-5	6.8E-8	1.7E-7	1.1E-7	2.3E-8	3.9E-7
CPP-603 Storage Basin North and Middle	1.3E-5	3.3E-8	8.5E-8	5.2E-8	1.6E-8	2.8E-7
CPP-603 Storage Basin South	1.3E-5	3.2E-8	8.2E-8	5.0E-8	1.6E-8	2.8E-7
CPP-651 Unirradiated Fuel Storage	9.2E-6	2.3E-8	5.9E-8	3.6E-8	1.4E-8	2.4E-7
CPP-603 Graphite Fuel Storage	2.4E-5	5.9E-8	1.5E-7	9.3E-8	2.1E-8	3.5E-7
CPP-708 Main Stack	1.5E-5	3.7E-8	9.6E-8	5.9E-8	1.6E-8	2.8E-7
CPP-749 Peach Bottom Fuel Storage	7.7E-5	1.9E-7	4.9E-7	3.0E-7	4.3E-8	7.3E-7
Fast	6.5E-5	1.6E-7	4.1E-7	2.5E-7	3.9E-8	6.6E-7
5th Bin Set	5.4E-6	1.3E-8	3.4E-8	2.1E-8	1.2E-8	2.0E-7
6th Bin Set	1.2E-5	2.9E-8	7.6E-8	4.6E-8	1.6E-8	2.7E-7
7th Bin Set	1.2E-5	2.9E-8	7.6E-8	4.6E-8	1.6E-8	2.7E-7
Tank Farm area	1.1E-4	2.8E-7	7.3E-7	4.4E-7	5.6E-8	9.6E-7
FACILITY TOTALS	5.9E-4	1.5E-6	3.8E-6	2.3E-6	4.6E-7	8.0E-6
TOTAL - RADIOLOGICAL MATERIALS STORAGE AREAS	3.9E-4	9.6E-7	2.5E-6	1.5E-6	2.9E-7	5.0E-6

Table 20. ICPP Facility Airplane Crash Rate per Year

PTI HELICOPTER FREQUENCY PER YEAR				
BLDG	TLOC/Y (0 MI)	ALLOWABLE HELICOPTER TRIPS	TLOC/Y (3 MI)	ALLOWABLE HELICOPTER TRIPS
CPP-601 Processing Bldg	4.0E-5	20		
CPP-602 Lab Bldg	3.2E-5	25		
CPP-627 Remote Analytical Facility	1.9E-5	43		
CPP-640 Headend Processing	1.8E-5	44		
CPP-659 NWCF	4.7E-5	17		
CPP-604 Waste Treatment	3.0E-5	27		
CPP-605 Waste Treatment	1.4E-5	56		
CPP-603 Decon Area South	7.0E-6	114		
RADIOLOGICAL MATERIALS STORAGE AREAS				
CPP-603 Fuel Receiving and Storage	2.7E-5	29		
CPP-603 Storage Basin North and Middle	1.3E-5	60		
CPP-603 Storage Basin South	1.3E-5	62		
CPP-603 Graphite Fuel Storage	2.4E-5	33		
CPP-708 Main Stack	1.5E-5	53		
CPP-749 Peach Bottom Fuel Storage	7.7E-5	10		
Fast	6.5E-5	12		
5th Bin Set	5.4E-6	148		
6th Bin Set	1.2E-5	66		
7th Bin Set	1.2E-5	66		
Tank Farm area	1.1E-4	7		
FACILITY TOTALS	5.9E-4	1	1.5E-6	544
TOTAL - RADIOLOGICAL MATERIALS STORAGE AREAS	3.9E-4	2		
PTI HELICOPTER FREQUENCY PER YEAR				
	AIRPORT/Y (2-3 MI)	ALLOWABLE HELICOPTER TRIPS	AIRPORT/Y (3-4 MI)	ALLOWABLE HELICOPTER TRIPS
FACILITY TOTALS	3.8E-6	211	2.3E-6	346
TOTAL - RADIOLOGICAL MATERIALS STORAGE AREAS	2.5E-6	325	1.5E-6	532
FAA TESTS FREQUENCY PER YEAR				
	AIRPORT/Y	ALLOWABLE FAA FLIGHTS		
FACILITY TOTALS	8.0E-6	18		
TOTAL - RADIOLOGICAL MATERIALS STORAGE AREAS	5.0E-6	28		

concern. The crash rate with the individual buildings can be reduced to incredible by restricting the number of flights over the building to less than the allowable helicopter trips listed in the table. The total radiological materials storage and building areas are the largest areas and thus have the smallest allowable number of overflights. Restricting all helicopter flights over the ICPP to a maximum of one per year reduces the helicopter in-flight rate to incredible for all areas of the ICPP.

The helicopter airport frequency in table 20 is bordering on incredible. The crash frequency can be reduced to incredible by restricting the number of flights to 211 per year. The airport assumption is that the flights around an airport are uniformly distributed in all directions. The risk, however, is greater in the direction the helicopter typically flies. Restricting takeoffs and landings to a direction away from the ICPP would reduce this crash frequency. Also, moving the helicopter pad farther away from the ICPP would reduce the crash frequency relative to the ICPP. The frequency for locating the helicopter pad further away from the ICPP is shown in table 21. By locating the helicopter pad between 6.4 and 8 km (4 and 5 mi), the frequency be reduced to an incredible level.

Table 21. Crash Frequencies Reduction Factors by Airport Distance

AIRPORT DISTANCE FROM ICPP IN KM (MI)	FATAL CRASHES PER KM ²	FATAL CRASHES PER MI ²	FREQUENCY REDUCTION FACTOR	FUEL STORAGE FREQUENCY/Y	REDUCED FREQUENCY/Y	FACILITY TOTALS FREQUENCY/Y	REDUCED FACILITY TOTALS FREQUENCY/Y
3.2-4.8 (2-3)	2.2E-8	5.6E-8	1.00	3.8E-6	3.8E-6	2.5E-6	2.5E-6
4.8-6.4 (3-4)	1.3E-8	3.4E-8	0.61	3.8E-6	2.3E-6	2.5E-6	1.5E-6
6.4-8 (4-5)	4.1E-9	1.1E-8	0.19	3.8E-6	7.2E-7	2.5E-6	4.7E-7

5. CONCLUSIONS

Based upon the results of this study, it can be concluded that any risk of aircraft crashing into ICPP facilities is small. The largest risk factor is because of the possibility of a PTI helicopter crashing while flying over the ICPP facilities ($5.9 \times 10^{-4}/y$) or crashing while taking off or landing ($3.8 \times 10^{-6}/y$). This danger can be greatly reduced if the PTI airport is moved 2 miles farther from the ICPP or the airport maneuvers are restricted to a direction away from the ICPP. Also, the potential for in-flight crashes of the PTI helicopter at the ICPP can be reduced to incredible by restricting overflights of the ICPP to one per year.

The FAA aircraft test flights crash frequency borders on incredible at $2 \times 10^{-6}/y$. Because FAA aircraft tests are conducted less than once every two years, the frequency averaged over several years is incredible.

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