UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

In the Matter of	)	
	)	
METROPOLITAN EDISON COMPANY, ET AL.	)	Docket No. 50-320
	)	
(Three Mile Island Nuclear Station,	)	
Unit 2)	)	

TESTIMONY OF

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EVALUATION OF AIRCRAFT CRASH

POTENTIAL FOR NUCLEAR POWER PLANTS

NOVEMBER 30, 1978

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1.0 Introduction

A considerable amount of testimony has previously been given in this proceeding regarding the likelihood of an aircraft crashing into the Three Mile Island Unit 2 facility. The Atomic Safety and Licensing Appeals Board decision (ALAB-486, dated July 19, 1978) points out there are a number of areas warranting additional discussion. This testimony is meant to explain the Staff's approach or methodology, its criteria, its model, and finally its calculations and conclusions. This testimony is subdivided into several separable parts addressed in subsequent sections of this testimony. These include:

- Background
- Data Base
- Calculation of P
- Results - Crash Frequency
- Conclusions

This will be discussed in general and also specifically with respect to Three Mile Island 2. This facility is located in Dauphin County, Pennsylvania, and is located about 2.7 miles from the Harrisburg International Airport. It is located off to the side of the extended centerline of the runway at an angle of approximately 34°.

2.0 Background

2.1 Acceptance Criteria

For a number of years the NRC Staff (and earlier the AEC Staff) has been utilizing a probabilistic approach for evaluating potential accidents from hazards or activities which occur in the vicinity of a nuclear plant. The general acceptance criteria for this type of an approach is found in NRC Standard Review Plan (SRP) 2.2.3. The approach used by the Sta is found in SRP 3.5.1.6. This approach is basically a "yardstick" or screening approach.

First, SRP 3.5.1.6 refers (see SRP Section II.1) to SRP 2.2.3 as guidance for the acceptance criteria.[1/]

1/ SRP 2.2.3 states, in fact:

> "The identification of design basis events resulting from the presence of hazardous materials or activities in the vicinity of the plant is acceptable if the design basis events include each postulated type of accident for which a realistic estimate of the probability of occurrence of potential exposures in excess of the 10 CFR Part 100 Guidelines exceeds the NRC Staff objective or approximately 10^{-7} per year."...
>
> "In view of the low probability events under consideration, the probability of occurrence of the initiating events leading to potential consequences in excess of 10 CFR Part 100 exposure guidelines should be estimated using assumptions that are as realistic as is practicable. In addition, because of the low probability events under consideration, valid statistical data are often not available to permit accurate quantitative calculation of probabilities. Accordingly, a conservative calculation showing that the probability of occurrence of potential exposures in excess of the 10 CFR Part 100 guidelines is approximately 10^{-6} per year is acceptable if when combined with reasonable qualitative arguments, the reaslistic probability can be shown to be lower."

It is my understanding that, with respect to the issue of appropriate probability criterion, the Appeal Board has accepted for the purposes of the Three Mile Island case, a criterion that "a facility need not be designed to withstand a crash the probability of which is less than approximately 10^{-7}" (ALAB-486, 8 NRC 9 at 28). I do not intend to reopen this question by quoting SRP 2.2.3. Rather, I wish simply to restate the criteria used by the Staff as succintly as possible, showing its two elements - realistic estimates and conservative estimates.

Second, SRP 3.5.1.6 was developed to be used as a guideline to assist the Staff in determining when aircraft hazards should be further evaluated. It was thus intended to be a "yardstick" for determining when further detailed evaluation was necessary.

Third, the general approach in SRP 3.5.1.6 (Section III.3) expresses, in equation-form, a method acceptable to the Staff for calculating the likelihood of an aircraft crash at a nuclear facility site located within five miles of an airport. This is the same basic equation form used in this analysis. It is discussed below.

Fourth, SRP 3.5.1.6 presents in tabular form, a set of crash densities for various types of fatal aircraft crashes (per square mile per aircraft movement). The SRP states that care should be exercised when choosing values for the parameters in the equation contained therein and notes that "the matter of interpreting the individual factors may vary on a case-by-case basis because of the specific conditions of each case or because of changes in aircraft accident statistics," or, in other words, while the table of crash densities in SRP 3.5.1.6 may be appropriate for determining "ballpark" values, detailed careful examination must be undertaken to ensure the applicability and appropriateness of those values for a specific application.

An estimate based on these "ballpark" values set forth in 3.5.1.6 is useful as a "screening" tool to determine those general cases in which potential aircrash impact warrants a more careful review. Outlined below are the elements of such a "more careful review".

2.2 Analytical Model

The general model used by the NRC Staff to calculate the likelihood of an aircraft crash into the Three Mile Island nuclear plant is as follows:

P =	C x	N x	A
(the likelihood per year that an aircraft will crash into the TMI plant)	(the crash density in the vicinity of the TMI plant - in no. of crashes per sq.mi. per MVT)	(the no. of aircraft flying over TMI that could crash into TMI)	(the target area of safety related TMI facilities)

Each of these terms will be described in detail later including the values assumed for the evaluation of the Three Mile Island plant. Since there may be various types of aircraft using an airport near a nuclear plant, and since the values of C, N and A may be different for these different types of aircraft, a value of P must be calculated for each major different type of aircraft. Therefore, this equation may take the form:

$$P_{total} = P_{\substack{\text{general}\\ \text{aviation}}} + P_{\substack{\text{small}\\ \text{air-carriers}}} + P_{\substack{\text{large}\\ \text{air-carriers}}} + P_{\text{military}}$$

$$= (C\times N\times A)_{\substack{\text{general}\\ \text{aviation}}} + (C\times N\times A)_{\substack{\text{sm}\\ \text{A\_C}}} + (C\times N\times A)_{\substack{\text{lg}\\ \text{A-C}}} + (C\times N\times A)_{\text{mil}}$$

2.2.1 The Term "C"

The value for "C", the crash density is derived from actual aircraft crash data that have occurred in the past. Crash data should be collected from appropriate sources as well as the total aircraft arrival and departure actions (movements) that generated the crash data. Since such data is for actual aircraft crashes, it automatically includes a variety of flying conditions and circumstances. For example, it includes the variety of flight paths used for arrivals and departures, for the many airports that generated this crash data, a variety of weather conditions, and a variety of terrain conditions near airports. In using this data it is necessary to assure that the airport of concern has no unusual features of terrain, etc., which require adjustment of the general data. A detailed discussion of this term is presented in Section 4.1.

2.2.2 The Term "N"

The Term "C" determined the likelihood of any one overflying aircraft crashing into a one square mile area surrounding a nuclear site. Since there are more than one overflying aircraft, the value of "C" must be multiplied by the number of overflying aircraft. The term "N" is used to denote the number of aircraft that fly near a nuclear facility such that there may be a risk of crash into the nuclear facility while, making a takeoff or landing approach at the airport of concern. This, for the relevant operations, is discussed in more detail in Section 4.2.

2.2.3 The Term "A"

The Term "A" represents the target area which a crashing plane must hit in order to present a hazard to the nuclear facility. This term is multiplied times "C" since "C" was calculated to be the number of crashes per movement into a one square mile target. Not all crashes into a one square mile area around a nuclear plant pose a hazard to it. Thus, a more precise target area must be determined. Such a target area is calculated by evaluating the detailed plant design and by assuming a angle of impact for crashing aircraft.

The value of "A" will vary for different sizes and types of aircraft since, for example, certain structures of the nuclear plant may not be vulnerable to the crash of a small aircraft but may be vulnerable to the crash of a larger aircraft, hence, the "target area" for larger aircraft would have to include such structures should they exist. This has the general effect of increasing the target area (i.e., the area of critical structures that a potentially damaging aircraft strike must hit to pose a hazard), for increasingly larger aircraft. Similarly, the target area is usually smaller for smaller aircraft. It is discussed in more detail in Section 4.3.

3.0 Data Base

In evaluationg the potential for a damaging aircraft crash at a nuclear facility near an airport, an appropriate data base must be sued. In the Three Mile Island proceeding this is discussed in the testimony of the Staff filed on November 30, 1978, (Read et. al.).

4.0 Calculation of P

The method of calculating the frequency of occurrence of an aircraft crash into the Three Mile Island facility or any airport with the same range of activities as those at Harrisburg, which in turn could pose a threat to the health and safety of the public, takes the following equation form, where P is the probability of the event occurring per year (more precisely P is the rate of occurrence):

$$P_{total} = P \text{ (scheduled air carriers)}$$
$$+P \text{ (non-scheduled air carriers)}$$

+P (training)

+P (commuters)

+P (military)

+P (general aviation)

This can in turn be written

$$P_{total} = (CxNxA)_{sch.\ A\text{-}C} + (CxNxA)_{non\text{-}sch\ A\text{-}C} + (CxNxA)_{training} + (CxNxA)_{commuters} + (CxNxA)_{military} + (CxNxA)_{g.a.}$$

As previously discussed in this proceeding, the Three Mile Island nuclear facility is designed to safely withstand the impact of a 200,000-pound aircraft at a speed of about 200 knots. It is therefore assumed that the facility can withstand the impact of aircraft weighing less than 200,000 pounds. Since all air Taxi Commuter and all General Aviation movements are with aircraft weighing less than 200,000 pounds, they can clearly be deleted as contributors to the overall likelihood of a damaging aircraft strike. This leaves an equation in the form:

$$P_{total} = (CxNxA)_{sch.\ A\text{-}C} + (CxNxA)_{non\text{-}sch.\ A\text{-}C} + (CxNxA)_{training} + (CxNxA)_{military}$$

4.1 Training Operations

For training activities at Harrisburg, it is not clear that training is so unlikely that it should be entirely disregarded (See Read et al. testimony). Due to an absence of data, the Staff have not developed a specific crash rate for training activities; but has concluded that it appears reasonable or conservative to use the non-scheduled off-runway rates for off-runway training accidents. Table 8, Note 3, Testimony of Read et al.

4.2 Military Operations

Operations with military aircraft for the past few years at the Harrisburg International Airport have been examined by the NRC Staff. Although there has been a significant change in the nature of the Airport in the last ten years, we do not anticipate any additional significant changes. During 1977 there was about 80-85 total operations of military aircraft at the Harrisburg International Airport that weighed over about 200,000 pounds. These movements consist of three principal types of aircraft - the C5A, C141 and the E4A.

As indicated in Dr. Read's testimony filed November 30, 1978, there have been no relevant aircraft crash events for heavy military aircraft. Therefore, for this specific component there is no specific basis upon which to calculate a crash rate precisely and therefore not a crash density distribution. However, in the absence of other data, we believe it is reasonable, for the types of operations for military aircraft that may be encountered at Harrisburg, to use the same crash density distribution as that for heavy aircraft for U.S. non-scheduled carriers.

Heavy Aircraft

As discussed above, Three Mile Island 1 and 2 have been designed to withstand the impact of a 200,000 lb. aircraft at approximately 200 knots. Consequently, the airplane crash of concern with respect to assessing a risk of serious damage to the plant are those associated with planes in excess of 200,000 lbs.[2/], or the so-called heavy aircraft.

As can be seen from Table 5, filed November 17, 1978, only 4 occurred off the runway. This is too small a number to derive a meaningful crash density distribution. Further, using the applicants' number of operations of heavy aircraft (Applicants' Table 13), of approximately 20 million (a number with which the Staff agrees) the crash rate for heavy aircraft would tend to be less than that for all U.S. Air Carrier Aircraft. We prefer to use the higher estimate derived from all U.S. carriers in deriving both the crash rate and a crash density distribution. Thus, our equation is now:

$$P_{\text{total}} = C_{\text{all scheduled carriers}} \times N_{\text{heavy scheduled}} \times A$$
$$+ C_{\text{all non-scheduled}} \times N_{\text{heavy non-scheduled and military}} \times A$$

2/ See Discussion below - for discussion of speed.

4.3 Crash Density C

As indicated in Section 2.3.1, "C" denotes the crash density which is derived from actual aircraft crash data. A different value of "C" must be derived for each different type of aircraft that uses the Harrisburg International Airport. From previous sections we have determined that only "scheduled air carriers" and "non-scheduled air carriers" need to be specifically evaluated for this purpose.

A determination of the value of "C" can take several forms. One can assume a uniform, or equal distribution, for all locations between 0 and 5 miles from a runway - but such an approach would be conservative in some areas and non-conservative in others. Similarly, the 0 to 5 mile region could be sub-divided into smaller area regions and the value of "C" could be assumed uniform, or equal, throughout each individual area. A more mathematically accurate formulation would be to use more elaborate mathematics techniques to calculate a specific value of "C" as it varies for various distances from the end of the runway (we call the distance "r") and at various angles from the extension of the centerline of the runway (call the angle, θ [theta]). This latter method can calculate a specific value of "C" at any specific location.

Using the data on crashes, number of aircraft operations set forth in the totals of Table 8 Read, et al. and summarized in Table 9 and the distribution information contained in Tables 9A and 9B, the Office of Applied Statistics has provided such a calculation for the point located 2.7 miles from the end of a runway, with a 34° angle to the extended centerline. This is discussed in the testimony of Drs. Moore and Abramson. The values derived are set forth in Table III of their testimony.

Because of variations in the density function, it has been calculated separately for landing accidents and for takeoff accidents.

4.4 Aircraft Movements, N

Table 20, Testimony of Read, et al. sets forth historical data for past operations of heavy aircraft at the Harrisburg International Airport. This information was examined to determine an appropriate value for the term N which is the number of operations from that Airport which could fly over or near the Three Mile Island facility, such that if they should crash, then they might effect the facility. From Table 20, Read et al., approximately 600 operations of heavy aircraft occurred in 1977.

The Harrisburg International Airport has one runway designated 13-31 - after 130° and 310°. This leads to two possible arrival (and departure) directions. The Three Mile Island facility is located south east of the Airport and is located off to the side of the extended centerline of the runway at an angle of approximately 34°.

Since aircraft generally land and takeoff flying "into the wind" at any given time, aircraft generally arrive from one end of the paved runway strip and generally depart from the other end. Hence, for 600 operations of heavy aircraft at the Harrisburg Airport, about 300 operations are over each end of the airport runway. Accordingly, about 300 operations occur at end of the runway nearest Three Mile Island. Because of prevailing wind directions at the airport, about 65% of these operations are landing operations and 35% are takeoff operations. Summarizing:

← 195 takeoffs   HIA   195 landings ←

→ 105 landings   105 takeoffs →

← Runway 31   TMI

Runway 13 →   X

Of the 300 aircraft movements that approach or depart in the general direction of Three Mile Island only a small fraction actually fly near the nuclear plant in such close proximity to pose a potential hazard to the nuclear facility. Because the principal flight paths of the airport tend to direct aircraft in the direction away from Three Mile Island, less than 1/2 of the total operations would fly in the quadrant in which the facility is located. In order to ensure that we conservatively bound our evaluation we assume that 1/2 of all operations that use the runway directed southeast, fl[illegible] the quadrant in which Three Mile Island is located.

In summary, the number of relevant heavy aircraft operations at the present time from the Harrisburg International Airport for our evaluation is:

Landings: $\frac{195}{2}$ = 98 operations

Takeoffs: $\frac{105}{2}$ = 53 operations

Since about 40% of the heavy aircraft movements are scheduled and since the remainder are non-scheduled (including training and military). Our assessment is broken down further to:

Operation at end of Runway Nearest Three Mile Island

Scheduled landings:	39
Takeoffs:	21
Non-Scheduled landings:	59
Takeoffs:	32

4.5 Target Area, A

Historically, the Staff has utilized a target area of 0.01 mi^2 per square mile per nuclear unit. This value was derived by considering various aircraft descent angles for both takeoff and landing accidents and considering a slidein area for aircraft crashing in front of the nuclear plant and sliding into the plant.

The Staff has performed a detailed evaluation of the Three Mile Island facility and has determined that the 0.01 mi^2 target area is conservative. Further, the Staff has evaluated the facility recognizing that it is designed to withstand the impact of a 200,000 pound aircraft and therefore has a certain amount of protection against aircraft strikes of larger aircraft.

Considering these various aspects, the Staff has determined that the use of a 0.01 mi^2 target area is acceptable. It has further determined that a target area of 0.0062 mi^2 for landing accidents and 0.0026 mi^2 for

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takeoff accidents is more appropriate and is still somewhat conservative. Details supporting these values are contained in Appendix A.

Recognizing these conservatisms the Staff's evaluation has been developed utilizing a target area equal for takeoff and landing accidents:

Landing Accidents: .0062 mi^2

Takeoff Accidents: .0026 mi^2

5.0 Results - Crash Frequency

In summary, the input information used by the Staff in its calculations for Three Mile Island evaluations are as summarized below:

Present Relevant Heavy Movements, N

	Total	Scheduled	Non-Scheduled
Landings	98	39	59
Takeoffs	53	21	32

Crash Target Area, A

For scheduled and non-scheduled activity, the target areas used are:

Landings: 0.0062 mi^2

Takeoffs: 0.0026 mi^2

Areal Crash Density, C

	Scheduled	Non-Scheduled
Landings:	2.3×10^{-9}	4.4×10^{-8}
Takeoffs	3.3×10^{-9}	2.1×10^{-8}

These values simply need to be put into our equation and computed to yield the value of the likelihood of a heavy aircraft from Harrisburg crashing into the Three Mile Island facility.

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$$P_{total} = [(CxNxA)_{landings} + (CxNxA)_{takeoffs}]_{scheduled}$$

$$+ [(CxNxA)_{landings} + (CxNxA)_{takeoffs}]_{non\text{-}scheduled}$$

Putting in the values yields:

$$P_{total} = [(2.3 \times 10^{-9})(39)(.0062) + (3.3 \times 10^{-9})(21)(.0026)]$$

$$+ [(4.4 \times 10^{-8})(59)(.0062) + (2.1 \times 10^{-8})(32)(.0026)]$$

$$\approx [0.056 \times 10^{-8} + .018 \times 10^{-8} + 1.57 \times 10^{-8} + 0.17 \times 10^{-8}]$$

$$P_{total} = 1.8 \times 10^{-8}/yr$$

As described earlier, this value is based on the assumption that there are approximately 600 movements of "heavy" aircraft at the Harrisburg Airport.

6.0 Conclusions

The Staff has evaluated the likelihood of a heavy aircraft attempting to either land or takeoff and crashing into the Three Mile Island nuclear facility. This evaluation was based on last year's (1977) record of operations which showed about 600 movements of such heavy aircraft (200,000 pounds).

We can calculate that the number of heavy operations can increase by a factor of about 5 to 6 and still have a crash probability that is no greater than about 1×10^{-7}/yr, i.e., the number of heavy operations at

Harrisburg could increase to about 6 x 600 = 3600 prior to exceeding the criterion of 10^{-7}.

This simple extrapolation must be cautiously assumed, however, since it must also be assumed that the breakdown of "heavy" scheduled and non-scheduled activity does not significantly change (it is presently about 40% scheduled and 60% non-scheduled plus other). This is particularly important since the crash density for non-scheduled activity is generally about an order of magnitude larger than for scheduled.

In addition, it should be noted that in accordance with our Standard Review Plan approach, an attempt has been made to calculate a realistic value for a damaging aircraft strike at the Three Mile Island plant. Although we have attempted to perform a realistic evaluation, we believe that our overall result is conservative for a number of reasons. A major conservatism for the evaluation was the assumption of the fraction of heavy aircraft movements that fly in the general direction of the nuclear plant. Whereas our evaluation assumed that 50% of the flights using the Three Mile Island end of the runway fly over the nuclear plant, the actual value will be much less since the flight path approach directs most aircraft in the opposite direction of the extended runway centerline.

It should be noted that although this evaluation was performed specifically for Three Mile Island Unit 2, the same evaluation is also applicable for Unit 1.

APPENDIX A

CALCULATION OF TARGET AREA FOR AIRCRAFT IMPACT AT THREE MILE ISLAND 2

The following buildings were considered as safety related:

Containment

Fuel Handlin_

Auxiliary Building

Service Building

Control Building

River Water Pump Building

Because of the structures capability to withstand the impact of aircraft of up to 200,000 lb it has been assumed that only head-on impacts by larger aircraft would result in significant damage.

For the Three Mile Island Unit No. 2 aircraft impact analysis, the Unit adjoins Unit No. 1 in the north, is protected by cooling towers in the south, is shielded by substation equipment on the east and is protected by the plant dike system and small buildings on the west side. Inasmuch as the transit of a large 200,000 to 300,000 lb aircraft through such structures will prevent the plane from maintaining the optimum or near-optimum head-on impact orientation required for penetration a slide-in area need not be included in the calculation of the target area.

Likewise, the calculation of target area can conservatively neglect, because of penetration capability reduction, glancing impact, aircraft wing impact, and separate engine impact. The capacity of plant

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structures to absorb such loadings is estimated to be well in excess of the loads imposed by such situations. Therefore, the analysis has not included wing extension shadow area and has reduced th ontainment shadow area from a ninety degree to a sixty degree sector.

In the calculation of the target areas it has been assumed that there is a uniform distribution of incoming planes from the North, South, West and East directions. However, only about 2/3 of the aircraft approaching from the East will reach the plant because of interference with the cooling towers. Similiarly, only about 1/3 of the aircraft coming from the South will be able to reach the plant.

Credit has been given for the shielding of portions of Unit 2 by some of the structures of Unit 1.

No credit has been given for shielding from other structures in the calculation of the target area for the River Water Pump Building. Aircraft have been assumed to approach equally from all directions.

RESULTS

The average plant target area decreases from 0.011 mi^2 at an angle of 5^0 to 0.0026 at 45^0.

The attached table sets forth various target areas for arrival and departure accidents. This evaluation clearly demonstrates that the use of a target area of 0.01 mi^2 is conservative. It also demonstrates that if a more realistic descent angle for arrival, incoming, aircraft of approximately 10^0 is chosen, the plant target area decreases to 0.0063 mi^2. Similiarly, if a more realistic angle of 45^0 is chosen for takeoff crashes, the takeoff target area decreases to 0.0025 mi^2. The staff believes that these values of 0.0063 and 0.0025 mi^2 are conservative because the utilization of such values assume that all crashes will occur with these descent angles whereas certainly some crashes will occur at steeper angles and hence result in smaller target areas.

Regardless of these conservatisms, the staff's initial evaluation assumes target areas of 0.01 mi^2 for all crashes.