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)	)	

NRC STAFF POSTHEARING MEMORANDUM REGARDING AIRCRAFT CRASH PROBABILITY ISSUE

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APRIL 30, 1980

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On July 19, 1978, the presiding Atomic Safety and Licensing Appeal Board (Appeal Board) issued its decision in this proceeding resolving all matters except for the radon issue and reopening the record with respect to the analysis of the probability of aircraft crashes. ALAB-486, 8 NRC 9 (1978). See also ALAB-480, 7 NRC 796 (1978). Specifically in regard to aircraft crashes, the Appeal Board concluded that, although

> "the record does enable us to find reasonable assurance of safety given present levels of aircraft traffic in the vicinity of the plant, . . . it contains sufficient inconsistencies and ambiguities relative to aircraft crash probabilities over the life of the plant that we must order a further hearing on that question." ALAB-486, 8 NRC at 13-14.

Further, the Appeal Board concluded that there were special considerations in this case which induced it to conduct the further hearings itself. In particular, the Appeal Board stated it had formed definite views respecting the "reach and ingredients" of the required new analysis and provided the parties with an outline of the scope of its intended inquiry. ALAB-486, 8 NRC at 44-46.

On September 15, 1978, the Commission, ruling on Intervenors' petition for review of ALAB-486, issued an Order denying review but at the same time identifying five areas related to the aircraft issue in which it believed the Appeal Board should request more detailed data and analysis in addition to that called for in ALAB-486. CLI-78-19, 8 NRC 295 (1978).[1/]

The reopened hearing was held on December 11 and 12, 1978 in Harrisburg, Pennsylvania. Participants included Metropolitan Edison Company, et al. (the Applicants), the NRC Staff (Staff), the Commonwealth of Pennsylvania and Intervenors York Committee for a Safe Environment and the Citizens for a Safe Environment (Intervenors), jointly represented by Dr. Chauncey Kepford. At this hearing, evidentiary presentations were made by the Applicants and Staff addressing each of the matters set forth in ALAB-486 and in the Commission's related Order. A further session of the hearing, originally scheduled to commence on April 4, 1979, was postponed due to the March 28, 1979 accident and was held on February 25, 1980. At this later session, supplemental testimony by the Staff and Applicants was presented to address the several concerns raised by the Appeal Board in ALAB-525, 9 NRC 111 (1979), regarding the respective statistical methodologies used in addition to testimony by four airline pilots subpoenaed by the Staff. Intervenors also presented a witness at the February 25, 1980 hearing.

1/ The requests for information by the Appeal Board and Commission, respectively, are set forth in Appendix I to this memorandum.

I.
INTRODUCTION

Unit No. 2 of the Three Mile Island Nuclear Station (TMI-2 or facility) is located within approximately three miles of the Harrisburg International Airport (HIA). As a result of the facility's relative proximity to HIA, a significant issue throughout this licensing proceeding has been whether the public is adequately protected against the hazards of a crash of an airplane into TMI-2. The facility's safety structures have been designed to withstand the aircraft impact and fire effects from the crash of a 200,000-pound plane traveling at 200 knots, the "design basis crash."[2/] An issue raised by the Intervenors before the Atomic Safety and Licensing Board (Licensing Board) in the operating license proceeding was whether the facility should be designed to withstand the crash of an airplane heavier than 200,000 pounds.[3/] The Applicants and Staff each computed the probability that an aircraft weighing more than 200,000 pounds might crash into the facility's safety structures and each found it to be such a low probability (less than 10^{-7}/yr[4/]) that it does not present a hazard to the public, and therefore the plant need not be

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2/ SER, Three Mile Island, Unit 1, dated July 11, 1973 at pp. 3-4, 3-5; incorporated by reference into SER for Unit 2 at p.2-8.

3/ CONTENTION 5. The containment structure and other buildings designed to withstand certain aircraft impact events are of inadequate strength to withstand the impact of airplanes which can reasonably be expected to frequent Harrisburg International Airport. Both the Boeing 747 and the Lockheed C-5A are reasonably expected to frequent Harrisburg International Airport and greatly exceed the kinetic energy set forth in the design consideration.

4/ Standard Review Plan (NUREG-75/087), §3.5.1.6 provides, in pertinent part, that "[t]he plant is considered adequately designed against aircraft hazards if the probability of aircraft accidents resulting in radiological consequences greater than 10 CFR Part 100 exposure guidelines is less than about 10^{-7} per year ..." (par. 11.1).

designed to withstand its effects. The Licensing Board accepted these analyses (6 NRC at 1197-1200).

To assure that these safety levels are maintained throughout the life of the plant, the Staff devised a technical specification requiring the Applicants to monitor the yearly number of movements of planes weighing more than 200,000 pounds and to take further protective measures if the heavy aircraft traffic become excessive. The Licensing Board approved the technical specification and adopted the Staff's figure of "2400 operations per year at HIA" as the point where such further measures would have to be taken. 6 NRC at 1198-99.

The Intervenors appealed from the Licensing Board's determinations. Upon review of the record on appeal, the Appeal Board ordered a further hearing.

The Appeal Board observed that the scope of the reopened hearing would be narrow. First, there is no serious claim that TMI-2 will not withstand the "design basis crash" for which it is designed. Second, there is no disagreement that the determination whether a plant needs to be designed to withstand the crash of a heavy aircraft may turn on the probability of occurrence of such a crash. Finally, for the purposes of this case, the Appeal Board has accepted the position 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 at 27, 28. Thus, the question posed in the reopened portion of this proceeding is whether the crash of an aircraft weighing in excess of 200,000 pounds traveling at 200 knots is an event of sufficiently low likelihood (less than 1×10^{-7}) that it does not present a hazard to the public, and therefore the plant need not be designed to withstand its effects.

It is the Staff's position that the record developed in this reopened proceeding clearly shows that the frequency crash rate of this event is less than 1×10^{-7}/yr. While methodological differences exist between the Staff's and Applicants' analyses as discussed below, each analysis was properly performed and each estimates a crash rate frequency of less than 1×10^{-7}/yr.

II.
THE ANALYTICAL MODEL USED TO CALCULATE THE LIKELIHOOD OF A HEAVY AIRCRAFT CRASHING INTO THE THREE MILE ISLAND, UNIT 2 NUCLEAR PLANT

In its review of TMI-2, the Staff used the guidance provided by SRP (Standard Review Plan) §3.5.1.6 including the methodology set forth therein in Section III.3, in equation form. It continued the use of the provisions of SRP §3.5.1.6 before the Appeal Board (see Testimony of Darrell G. Eisenhut, "Evaluation of Aircraft Crash Potential for Nuclear Power Plants," following Tr. 469, hereinafter cited as "Eisenhut"). For estimating the frequency of occurrence of an aircraft crash, P, the equation set forth in Section III.3 of SRP §3.5.1.6 should, in general, be written as:

$$P_{total} = (C \times N \times A)_{\text{scheduled air carriers}} + (C \times N \times A)_{\text{nonscheduled air carriers}} + (C \times N \times A)_{\text{training}} + (C \times N \times A)_{\text{commuter}} + (C \times N \times A)_{\text{military}} + (C \times N \times A)_{\text{general aviation}}$$

Eisenhut at 6 and 7.

For the reopened hearing, however, the data-base was independently compiled to provide an up-to-date basis for estimating C, the areal crash density in the vicinity of the TMI site, N, the number of aircraft flying over TMI that could crash into it, and A, the target area of safety-related structures at TMI. A discussion of the manner in which the specific values of C, N and A were determined for TMI follows.

A. Estimation of the Areal Crash Density (C)

1. Compilation of Data Base

The compilation of the data base to be used in estimating the Areal Crash Density ("C") in the model for estimating the frequency of aircraft crashes was extensively pursued by the Applicants and Staff using the resources of the Federal Aviation Administration (FAA), the Civil Aeronautics Board (CAB), the National Transportation Safety Board (NTSB), insurance companies, the Department of Defense and the Department of the Air Force (Prepared Testimony of John M. Vallance following Tr. 21, hereinafter cited as Vallance (Rev. 12/8/78) at Table 1, page 1; NRC Staff Testimony regarding U.S. Air Carriers and Military Accident and Traffic Data following Tr. 242, hereinafter cited as Read et al. at 2, 3). Initial consideration was given to aircraft accidents of all U.S. air carriers worldwide in the period 1956 to 1977 which includes 1514 events (Read et al. at 3 and 16).

First excluded from this universe of accidents by the Staff were all accidents of non-fixed wing aircraft, e.g. helicopters, and accidents which did not involve the destruction of the aircraft and/or an occupant fatality. This exclusion results in a total of 268 accidents considered relevant under the Staff's criteria (Read et al. at 3 and 16-17). The Applicants used somewhat different selection criteria resulting in a total of 251 events (Vallance at 3) (Rev. 12/8/78) being initially considered as relevant. The difference in result is due in part to Applicants inclusion of non-fixed wing aircraft and in part to the unavailability of data to the respective parties for certain of the events (see Read et al. at 5-7). Each, however, identified the event by data, where available, time, general location, phase of operation, type of aircraft, the extent of damage to the aircraft and injury to occupants, and the type of service in which the aircraft was being flown. Vallance (Rev. 12/8/78), Table 1; Read et al., Table 1). In addition, the Staff provided a brief comment on the nature of the accident.

Using the U.S. air carriers' worldwide information as a starting point, the Staff narrowed down the information to U.S. air carrier accidents occurring only within the contiguous United States (Read et al. at 8 and 17 and Table 2) yielding 197 accidents and then further to show only those accidents occurring during landing and takeoff (Read et al. at 8 and 17 and Table 3) which resulted in 103 events. Forty-two of these accidents occurred on the runway itself and are not considered relevant to a calculation of crash frequency at this facility (Read et al. at 17). The Staff then developed a table, Table 4, which shows for those events in Table 3, the range and bearing of the accident relative to the airport runway (see also Vallance (Rev. 12/8/78 at 4 and Table 3). In comparing the hit location set forth in Applicants' Table 3 and the range and bearing set forth in Staff's Table 4, a number of discrepancies appear. The Staff's effort to resolve those discrepancies through discussions with the Applicants and by indepth review of those complete NTSB accident files which could be obtained resulted in a number of changes to Table 4 which are shown in Table 4A; these have been incorporated in Table 4 Revised and Table 4 Revised 12/8/78. These differences and changes are a consequence of the description of range and bearing being provided generally only in narrative form, requiring, to some extent, subjective interpretation of information of various and sometimes unclear quality (Read et al. at 8-14). As a consequence, Table 4 Revised 12/8/78 included only 97 accidents including those 42 occurring on the runway. Table 5 displays those 13 accidents of the 97 which involved aircraft of 200,000 pounds (potential) or over.

The data on range and bearing have been compiled by the Staff to show the spatial distribution of the accidents in both tabular form (Read et al. at 14 and Tables 4 Revised A, B, C, D) and graphically (Read et al. at 15 and Figures 1, 1A, 1B, 1C, 1D). Since accidents occurring on the runway are not considered as having the potential for affecting off runway property, only those 55 events occurring off-runway are shown in the foregoing Tables and Figures.

In addition, to estimate the crash densities, the Staff used the data in Table 4 Revised for off runway crashes to develop Tables 9, 9A and 9B (see Read et al. at 16-18).

With respect to military aircraft of concern, the Staff corresponded with the Pennsylvania Air National Guard, Military Airlift Command and Department of the Air Force. Of the aircraft of concern, the C141, C5A and E4A (a military version of the Boeing 747), only a single accident was of potential interest. This involved the crash of a C5A during the airlift of Vietnamese orphans at the end of the Viet Nam conflict. Although this accident occurred during the landing phase, there was considerable pilot control over the aircraft. Since it occurred under conditions unlikely to exist at Harrisburg International Airport, the Staff does not believe it should be taken into account in projecting a crash rate for this proceeding (Read et al. at 19-20). The absence of sufficient data led the Staff to conclude that it would not be reasonable to develop a separate crash rate for military aircraft (see Read et al., Tables 6 and 7). Rather, the Staff considers it reasonable to use the crash rate for heavy nonscheduled U.S. civilian aircraft as representative of heavy military aircraft (Read et al. at 20).

It should be noted that activity of foreign air carriers in the contiguous U.S. has been excluded from consideration by both the Staff and Applicants (Tr. 36-38, 47-48). Indeed, with respect to operations at Harrisburg International Airport, only about half a dozen takeoffs and landings of foreign air carriers were observed in 1977 (Tr. 333-334).

Both the Applicants and Staff have examined the data to determine whether any trends are apparent (Read et al. at 21; Vallance (Rev. 12/8/78) at 7). The only statement which can reasonably be made concerning a trend is that scheduled air carrier service has become significantly safer over the past 22 years and nonscheduled service has become safer as well although to a less significant degree (See Read et al. at 21 and Table 8; Vallance (Rev. 12/8/78) at 7 and Table 6). While this much is readily apparent, it is not reasonable to quantify such improvements in safety for purposes of either limiting the data base to establish the current accident rate or to develop a rate for future projections. Thus, it is reasonable to use data for the entire 22-year period in computing an accident rate. It is recognized that the use of the full 22-year period results in a degree of conservatism (Tr. 475) in the estimated rates, possibly to the extent of overpredicting the accident rate by a factor of 2 to 3 (Tr. 477-478).

The Staff, using information from the CAB and NTSB, has developed a set of data showing scheduled and nonscheduled air carrier traffic for the period 1956-1977 (Read et al. at 22). This is reflected in Staff Table 8. Table 8 additionally sets forth the ratio of accidents for each category broken down into landings and takeoffs. Not included, however, are operations associated with training flights since, despite inquiry to the CAB, FAA, NTSB and airlines using Harrisburg International Airport, no data could be obtained nor could any reasonable basis for a reliable estimate be found. The Staff attempted to bound the effect of this exclusion by variously based estimates which result in a range of between 0.9 and 17 million training operations. Thus, the rate of accidents for training operations occurring off-runway was estimated to be between 10% and 130% of the off-runway rate for nonscheduled aircraft. Accordingly, it is considered reasonable by the Staff to use the nonscheduled off-runway rate as representative of the training rate (Read et al., Table 8, footnote 3; Eisenhut at 8).

From its Table 1, the Applicants similarly proceeded to narrow the accidents for consideration. Its Table 3 represents a table comparable to the Staff's Table 4 Revised 12/8/78, setting forth 97 accidents occurring during the landing or takeoff phases. Although the number of events is the same as the Staff's, the Applicants do include a number of different accidents and hit locations. As noted previously, such discrepancies appear to be attributable to an unavailability of information on some accidents to the respective parties and to their varied interpretation of unclear, qualitative information even in the full accident docket files (see Tr. 42, 49-50, 52-53). It should be noted that Applicants' Table 7 contains the same 13 events as reported in the Staff's Table 5 regarding those landing and takeoff accidents involving aircraft of 200,000 pounds. Additionally, of its 97 accidents, the Applicants also show 42 as occurring on runway (Vallance (Rev. 12/8/78), Table 5) and 55 as occurring off runway (Vallance (Rev. 12/8/78), Table 6). Applicants' military data is identical to that contained in Staff's Tables 6 and 7 and their respective attachments (see Vallance (Rev. 12/8/78), Tables 8-10). Unlike the Staff, however, the Applicants, in the absence of adequate data, have treated military aircraft as having the same accident rate as U.S. air carrier aircraft of 200,000 pounds or greater (Vallance (Revised 12/8/78 at 6).

Both Applicants and Staff have attempted to compile the speed of aircraft at the time of impact. The Applicants' efforts resulted in speeds for 70% of those events listed in its Table 3 (Vallance (Revised 12/8/78) at 6 and Table 17). The Staff's compilation is included in its Table 4A. Applicants' and Staff's data agree that, of the information obtainable, only one accident occurred in which the speed at time of impact was as high as about 200 knots.

Applicants' traffic data, as reflected in its Tables 11 and 13 differ from the number of operations reported by the Staff in its Table 8, the Applicants' figure being higher for scheduled operations for each year. One reason appears to be the Applicants' inclusion of operations attributable to Alaska and Hawaii (although the Table 11 title erroneously states that it is limited to the contiguous U.S.) (Tr. 60-6[illegible]

As with the Staff, however, the number of operations reported by the Applicants excludes training operations (Tr. 62, 63) which are believed to comprise only a small number (Tr. 63).

Regarding nonscheduled operations, the Applicants have adopted the Staff's values (Vallance (Rev. 12/8/78) at 7; Tr. 9-10, 22-24) and, therefore, they are identical.

Taking the above factors into account, the Applicants' calculated crash rates (Vallance (Rev. 12/8/78), Tables 14 Revised and 16 Revised) are somewhat understated since the denominator, the number of operations, includes Alaska, Hawaii and helicopter, while the numerator, the number of accidents does not.

Furthermore, regarding crash rates for heavy aircraft, the Applicants' number of operations is a derived value based on an average of 14% of operations being flown by heavy aircraft (Vallance (Rev. 12/8/78), Table 13 and 16 Revised). This assumes the same percentage of operations of heavy aircraft by scheduled and nonscheduled carriers (Tr. 65). However, the Applicants are uncertain of the contribution of supplemental carriers to heavy aircraft operations (Tr. 65-66). The effect of this uncertainty is to place in doubt the Applicants accident rates in Table 16 Revised.

The Applicants, further, have not included ferry accidents in the accident rate calculations in Table 16 Revised with respect to scheduled or nonscheduled operations, although it acknowledges that ferry operations are included in the definition of the term nonscheduled service (Tr. 74). The Applicants' failure to include accidents occurring during ferry operations thus understates the accident rate for nonscheduled operations.

In view of the passage of more than a year since the initial testimony was presented, the Staff, in order to assure that there was no significant change in the data-base used in its calculation, updated its traffic and accident data to include the additional year's data for 1978 (and revised certain of its data for 1976 and 1977 based on information which became available after the December 1978 hearing). While the inclusion of the new data would result in a slight increase in the Staff's estimated crash frequencies, the increase has no effect on the Staff's conclusions (see Affidavits of Jacques B.J. Read, February 4, 1980 and February 22, 1980, following Tr. 641; p.31 infra, n.13). For this reason, and since the Applicants used data only through 1977, this memorandum will focus exclusively on results based on data through 1977.

As discussed above, the values for "C" and "N" in the Staff's model were specifically calculated for this proceeding. Since, however, all commuter and GA (general aviation) movements are with aircraft weighing less than 200,000 pounds, they can be deleted, i.e., given the scope of consideration relevant in this proceeding, such movements would not be contributors to the overall likelihood of a damaging aircraft strike. This leaves the equation as:

$$P_{total} = (C \times N \times A)_{\text{scheduled air carriers}} + (C \times N \times A)_{\text{nonscheduled air carriers}}$$

$$+ (C \times N \times A)_{training}$$

$$+ (C \times N \times A)_{military}$$

(Eisenhut at 4-7).

Because of limitations on the availability of data regarding training operations, the Staff has used, as a reasonable surrogate, the nonscheduled off-runway crash rates for off-runway training accidents. Similarly, because there is no specific basis on which to estimate a crash rate for heavy military aircraft, the Staff considers it reasonable to use the same crash rates as for heavy nonscheduled air carriers (Eisenhut at 8).

Because the number of heavy aircraft off-runway crashes (Read et al., Table 5) is too small to derive a meaningful crash rate at TMI, the Staff utilized the estimate derived from all U.S. aircraft and argued that for deriving both the results overestimate the crash rate for heavy aircraft. Accordingly, the equation is expressed:

$$P_{total} = C_{all\ scheduled\ carriers} \times N_{heavy\ scheduled} \times A$$

$$+ C_{all\ nonscheduled} \times N_{heavy\ nonscheduled\ and} \times A\ military$$

(Eisenhut at 9).

The factors of this equation are discussed in detail below.

2. The Staff's Method of Estimating Areal Crash Density (C)

Using the data on crashes, the number of aircraft operations stated in the totals of Table 8 set out in the testimony of Read et al. and summarized in

Table 9 and the distribution information contained in Tables 9A and 9B, the Staff's statisticians, Drs. Moore and Abramson, used mathematical techniques described below to estimate the areal crash density (C) for a point located 2.7 miles from the end of a runway, with a 34° angle to the extended centerline.

The areal crash density at any point[5/] is the probability per square mile per relevant operation[6/] of a crash at the point. This can be expressed by the formula C (r, Θ) = P X D (r, Θ).[7/] Since the data was generally different for takeoffs and landings and for scheduled and nonscheduled flights, separate estimates were made for each of the following four events; a crash occurring during a (1) scheduled takeoff, (2) scheduled landing, (3) nonscheduled takeoff and (4) nonscheduled landing (Testimony of R. Moore and L. Abramson following Tr. 378, hereafter cited as Moore and Abramson (Rev. 12/11/78) at 1, 2).

Drs. Moore and Abramson first estimated P. The historical off-runway crash rates for all U.S. carrier aircraft for a 22-year period (1956-1977) was calculated separately for takeoffs and landings and for scheduled and nonscheduled operations. Using the numbers of operations and hits set out in

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5/ The point was stated in terms of its polar coordinates: r - the distance from the end of a runway and Θ - the angle from the extended centerline.

6/ A relevant operation was defined as an operation which has the potential of impacting the target point.

7/ P is the probability of an off-runway crash of a U.S. carrier aircraft engaged in a relevant operation and D, the conditional crash density, is the probability per square mile of a crash at (r, Θ) given an off-runway crash of a U.S. carrier aircraft engaged in a relevant operation.

Table 9 in Read et al. testimony, the following historical off-runway crash rates (P) were determined:

	Scheduled	Non-scheduled
Takeoffs	$.13 \times 10^{-6}$	$.85 \times 10^{-6}$
Landings	$.29 \times 10^{-6}$	5.5×10^{-6}

Moore and Abramson (Rev. 12/11/78) at 2.

Drs. Moore and Abramson then estimated the conditional crash density D(r, θ for each of the four operational categories. They used the data for the observed locations of off-runway crashes for all U.S. carrier aircraft for the period 1956-1977 as plotted in Figure 1 and tabulated in Table 9 of Read et al. However, before using this data, they tested whether the distance r and the angle θ were statistically independent and, based on the test results, assumed they were independent (Moore and Abramson (Rev. 12/11/78) at 3, 4). This allowed them to estimate D(r, θ) by multiplying estimates of the separate conditional crash densities for r and θ. These latter densities were estimated by assuming a uniform density in the vicinity of the point of interest and then estimating its value directly from the observed number of hits. Tables 9A (takeoff) and 9B (landings) of Read et al. show the data for all accidents distributed over intervals. Drs. Moore and Abramson then made an assumption of uniform density in the region of interest, i.e. where r = 2.7 miles and θ = 37° and chose an interval of 1.5 miles length and an angular width of 15 degrees surrounding it (Tr. 382). Since the angular density obtained from Table 9B of Read et al. consisted of data where all the angles were tabulated in one quadrant, Drs. Moore and Abramson divided the conditional crash density at θ for landings by 2 based on their assumption that, since planes tend to make a straight-in approach on landing, they have the same probability of crashing to the left as to the right. In Table 9B of Read et al., all angles are tabulated in one quadrant and therefore the conditional crash density of θ has been doubled. No division by 2 was done for takeoffs under the conservative assumption that planes always crashed in the quadrant over which they took off.[8/] The estimates of the conditional crash densities for takeoff and landings were calculated to be .0376 per square mile for takeoffs and .00704 per square mile for landings (Moore and Abramson (Rev. 12/11/78) at 6-8). Drs. Moore and Abramson made the further assumption that the conditional crash densities depend only on the type of operation, either takeoff or landing, and not on the type of flight (whether scheduled or nonscheduled) (Moore and Abramson (Rev. 12/11/78) at 2).

Finally, the areal crash density was estimated by multiplying the historical crash rates by the estimated conditional crash densities. The results were:

	Scheduled	Non-scheduled
Takeoffs	4.9×10^{-9}	3.2×10^{-8}
Landings	2.0×10^{-9}	3.9×10^{-8}

Moore and Abramson (Rev. 12/11/78) at 8.

8/ However, based on testimony of FAA experts, Staff witness Eisenhut stated that from a practical standpoint, the flight pattern on landings and takeoff approaches are essentially the same relative to a position close to the end of the runway such as the Three Mile Island site. Therefore, to make landings and takeoffs the same he divided the areal crash rates for takeoffs by a factor of 2 (Tr. 462).

3. <u>The Applicant's Method of Developing its Estimated Hit Frequency</u>

The Applicant's witness, John M. Vallance, testified that the estimated frequency of heavy aircraft using HIA crashing into the TMI-2 Unit was developed using two different techniques in processing the input data: 1) there is a single valued set of calculations and results, and 2) there is a probability distribution set of calculations and results (Supplemental Testimony of John M. Vallance following Tr. 646, hereafter cited as Vallance (1/9/79) at 2).

The first technique developed a single valued result for annual hit frequency using generally conventional techniques. Using this technique, Mr. Vallance estimated a hit frequency of 8.5×10^{-9} hits/year. This estimated hit frequency was developed as follows:

Scheduled Operations	Hit Frequency 10^{-9} Hits/year
Landings	0.5
Takeoffs	0.04
Nonscheduled Operations	
Landings	4.5
Takeoffs	3.5
Total	8.5

Vallance (1/9/79) at 3.

The second technique developed a probability distribution of hit frequency. It utilized Bayesian methodology to combine the historical data with subjective judgments about the model parameters to yield a posterior distribution of hit frequency. The mean of this distribution is 6.6×10^{-9}/year, developed as follows:

Scheduled Operations	Hit Frequency 10^{-9} Hits/year
Landings	0.5
Takeoffs	0.03
Nonscheduled Operations	
Landings	4.0
Takeoffs	2.1
Total	6.6

Vallance (1/9/79) at 4.

Thus, while the single-valued result and the posterior mean differed slightly from each other, Mr. Vallance testified that in his opinion they served to validate each other (Vallance (1/9/70) at 2).

4. Discussion of the Differences in the Results Estimated by the Staff and Applicant

From Vallance (1/9/79), the estimated crash frequency at TMI-2 is 8.5×10^{-9} per year. This value is about half of the Staff estimate of 1.6×10^{-8} per year, based on 1956-1977 data. There are many reasons for this discrepancy, involving both the data used and the methodology. These are summarized in Table I in the form of ratios of the Applicants estimates to the Staff estimates for each of five factors for which our estimates differ. The discrepancy ratios are calculated separately for landings and takeoffs and for scheduled and nonscheduled operations. For each fixed factor, e.g., target area, the discrepancy ratio expresses numerically the effect of the difference between Staff's and Applicants' analyses on the estimated crash frequency, provided the analyses were identical for all other factors; for the target area factor, the discrepancy ratios are the ratios of the assumed target areas. The discrepancy ratios are provided solely for the purpose of identifying in numerical terms the sources of the discrepancies between the Staff's and Applicants' analyses.

The discrepancy ratios vary from 0.30 for scheduled takeoffs to 2.63 for nonscheduled takeoffs. However, since the estimated crash rates for nonscheduled operations dominate both estimated crash frequencies, the driving ratios are 0.32 for nonscheduled landings and 1.32 for nonscheduled takeoffs. These ratios are weighted by the assumed annual numbers of operations by heavy aircraft on the relevant runways at Harrisburg International Airport to arrive at the ratio of 0.53 between the Applicants and Staff estimates of crash frequency.

A detailed examination of the differences between the NRC Staff and the Applicants for each of the five factors listed in Table I follows.

TABLE I
RATIOS OF APPLICANT TO STAFF ESTIMATES OF CRASH FREQUENCY FACTORS, BASED ON 1956-1977 DATA

	Ratio of Applicants to NRC Estimate			
	Landings		Takeoffs	
Factor	Scheduled	Nonscheduled	Scheduled	Nonscheduled
Accident and Operations Data	1.01	0.79	1.06	1.39
Bayesian Extrapolation	0.65	0.36	0.26	1.12
Crash Density Methodology	0.45	0.31	0.43	0.67
Target Area	1.81	1.81	1.27	1.27
Heavy Plane Accident Rate	2.00	2.00	2.00	2.00
TOTAL*	1.02	0.32	0.30	2.63
Source	Estimated Crash Frequency ($\times 10^{-9}$ per year)			
Vallance (1/9/79) Table 1	0.5	4.5	0.04	3.5
Staff**	0.49	14.2	0.14	1.33

*May differ from product of ratios because of rounding.

**Eisenhut at 15, Tr. 464, 465-468, 469A-471, 504.

Accident and Operations Data

This factor accounts for the effects of the somewhat different data bases used by the NRC Staff and the Applicant. The comparison is made in terms of the historical 22-year (1956-1977) off-runway crash rates, which are the basic crash rates used by the Staff. (Both the NRC Staff and the Applicants accident rates are based on destructive accidents within 5 miles from the end of the runway and do not take training, test or ferry operations or accidents into account.) The data is listed in Table II.

TABLE II
OFF-RUNWAY ACCIDENT RATES FOR 1956-1977

1956 - 1977	Landings		Takeoffs		Source
	S	NS	S	NS	
Off-Runway Accidents Operations (x 10^6)	26 88.6	11 2.54	12 88.6	3 2.54	Vallance (Rev. 12/8/78), Tables 6 and 11
Applicant Crash Rate (Per 10^6 Operations Per Year)	0.29	4.33	0.14	1.18	
Off-Runway Accidents Operations (x 10^6)	25 86.3	13 2.36	11 86.3	2 2.36	Read et al. Table 9
Staff Crash Rate (Per 10^6 Operations Per Year)	0.29	5.51	0.13	0.85	
Ratio of Applicant to Staff Rate*	1.01	0.79	1.06	1.39	

*May differ from ratios of rates in table due to rounding.

Bayesian Extrapolation

This factor deals with the differences due to the use of the full 22-year period by the Staff and the use of a Bayesian extrapolation model by the Applicants for the estimation of crash rates. The comparison is complicated by the Applicants' use of combined on- or off-runway crash rates at this stage of the analysis.[9/] In Table III, the Bayesian extrapolation effects are calculated by comparing the crash rates used by the Applicants[10/] with the 22-year combined on- or off-runway crash rates based on the Applicants' data ba e. The ratios from Table III are used in Table I as the effects of the Bayesian extrapolation. Under the assumption that the Table III ratios account for the Bayesian extrapolation effect if the Applicants had used off-runway rates exclusively, the first two factors in Table I account for the effects of the different da a bases and the Applicants' use of crash rates extrapolated to 1978.

TABLE III
EFFECT OF BAYESIAN EXTRAPOLATION

Crash Rate (Per 10^6 Operations	Landings		Takeoffs		Source
	S	NS	S	NS	
Mean Value of Bayesian Extrapolation	0.30	1.7	0.056	3.1	Vallance (1/9/79), at 7
On or Off-Runway (1956 - 1977)	0.46	4.7	0.21	2.8	Vallance (1/9/79), Table 6
Ratio*	0.65	0.36	0.26	1.12	

*May differ from ratios of rates in table due to rounding.

9/ The Staff uses only off-runway crashes throughout the analysis. The Applicants include on-runway crashes at the beginning of the analysis and adjusts for them in estimating the crash densities.

10/ From pages 6 and 7 of Vallance (1/9/79), these rates are the mean values of current (1978) accident rates, as extrapolated by the Bayesian model and methodology.

Crash Density Methodology

This factor deals with the different methodologies used to estimate the areal crash densities at TMI-2. By the different methodologies are meant the different approaches used to estimate the conditional areal crash densities at TMI-2, i.e., the densities of a hit at TMI-2 given that an off-runway crash on a relevant operation has occurred. The effects of the crash density methodologies are calculated in Table IV. First, the ratios of the areal crash densities are calculated. Since the Applicants' conditional crash densities are conditional on an on-or off-runway crash, equivalent conditional crash densities (conditional on an off-runway crash) must be calculated to compare with the Staff conditional crash densities. Since each areal crash density is the product of a crash rate and a conditional crash density, the equivalent Applicants' conditional crash densities can be calculated by dividing the Applicants' crash densities by the equivalent off-runway crash rates. But since it is only necessary to calculate the ratios of the Applicants' to the Staff's conditional crash densities, it suffices to divide the ratios of the crash densities by the ratios of the off-runway crash rates. These latter ratios, however, are given by the products of the ratios associated with the first two factors in Table I.

From Table IV, the Applicants' methodology yields conditional crash densities which vary between 31 and 67 percent of the Staff conditional crash densities. Since both the Staff and the Applicants assumed that r and θ were independent, the differences must stem from the differences in estimating the conditional crash densities for r and θ. One difference is the Staff's use of crashes only in the vicinity of r = 2.7 miles and $\theta = 34^{\circ}$ to estimate the conditional crash densities, while the Applicants assumed an exponental form for the densities.

TABLE IV
EFFECT OF CRASH DENSITY METHODOLOGY

	Landings		Takeoffs		
	S	NS	S	NS	Source
Crash Rate ($\times 10^{-6}$ Operations)	0.30	1.7	0.056	3.1	Vallance (1/9/79), "R" in Table 1
Conditional Areal Crash Density (per sq. mi.)	.0020	.0020	.0054	.0054	Vallance (1/9/79), "D" in Table 1
Applicants Areal Crash Density ($\times 10^{-9}$)	0.60	3.40	0.30	16.7	R x D
Staff Areal Crash Density ($\times 10^{-9}$)	2.0	39.	2.5*	16.*	Moore & Abramson (11/30/78, revised 12/8/78), Table III
Ratio of Applicants to Staff Areal Crash Densities	.29	.088	.12	1.04	
Ratio of Applicants to Staff Off-runway Crash Rates**	.65	.28	.28	1.56	Product of First Two Ratios in Table I
Ratio of Applicants to Staff Conditional Crash Densities (based on off-Runway Crashes)	0.45	0.31	0.43	0.67	Quotient of Two Ratios Above

*Incorborates division by 2 as discussed at Tr. 460-463.

**May differ from value calculated from tabular values due to rounding.

Still another difference stems from the treatment of on-runway crashes. While the Applicants do adjust the conditional crash densities for on-runway crashes, they make no distinction between scheduled and nonscheduled crashes in this adjustment. Since the Staff's off-runway crash rates are estimated separately for scheduled and nonscheduled operations, the calculated differences between the Applicants and Staff conditional crash densities are contaminated by the different treatments of on-runway crashes. This explains why the ratios in Table IV of the conditional crash densities are different for scheduled and nonscheduled operations. (Since both the Applicants and Staff conditional crash densities are the same for scheduled and nonscheduled operations, their ratios should also be the same.) However, this effect should average out so that one ratio is increased while the other is decreased. Accordingly, the gross differences indicated by Table IV should not be affected.

In sum, the Applicants' assumption of an exponental model is the major source of the differences between the Applicants and NRC Staff conditional crash densities.

Target Area

The NRC Staff assumed target areas of .0062 mi^2 for landings and .0026 mi^2 for takeoffs (Eisenhut (11/30/78), Appendix A) and the Applicant assumed target areas of .0112 mi^2 for landings and .0033 mi^2 for takeoffs (Vallance (1/9/79), Table 5).

Heavy Plane Accident Rate

The Staff assumed that the crash rate for heavy aircraft is one-half the crash rate for all aircraft and, accordingly, divided the estimated crash frequencies by 2 (Tr. 465-471). While the Applicants did make the same assumption in their original testimony (Vallance (Rev. 12/8/78) at 15), this assumption was later dropped (Vallance (1/9/79) at 7).

B. Development of Relevant Aircraft Movements (N)

The number of aircraft movements that could affect TMI-2, N, is taken from Table 20; for 1977, about 600 heavy operations are reported. Since aircraft generally land and take off into the wind, they would be expected to land at one end of the runway and take off from the other at any one time of the day; thus, about 300 heavy operations of the 600 would be expected at each end of the runway. Because of prevailing winds, however, about 65% of the 300 operations would be landings and 35% takeoffs, on the end of the runway nearest TMI-2 (Eisenhut at 11-12, Tr. 505). Further, breaking this down into scheduled and nonscheduled operations (including training and military), about 40% of the operations are scheduled and 60% nonscheduled, resulting in the following activity at the end of the runway nearest TMI-2:

Scheduled	landings:	78
	takeoffs:	42
Nonscheduled	landings:	118
	takeoffs:	64

(Eisenhut at 13).

C. Development of Target Area (A)

With respect to the final factor in the model, the Staff, which has generally utilized a target area ("A") of 0.01 per square mile (mi^2) per nuclear unit, unless a plant-specific value was calculated, has performed a detailed evaluation of the TMI facility and has concluded that such value is overly conservative. The Staff, based on its detailed evaluation, which included consideration of various descent angles for takeoff and landing accidents and a slide-in area, has concluded that more appropriate values would be 0.0062 mi^2 for landing accidents and 0.0026 mi^2 for takeoff accidents, which still retain a degree of conservatism (Eisenhut at 13-14, Tr. 482, 512-513).11/

D. Calculation of Probability

In summary form, then, the estimated crash rate at TMI was calculated using the following values:

Areal Crash Density, C

	Scheduled	NonScheduled
Landings:	2.0×10^{-9}	3.9×10^{-8}
Takeoffs:12/	2.5×10^{-9}	1.6×10^{-8}

11/ If a target area of .01 mi^2, is used in the evaluation,

$$P_{total} = [(2.0 \times 10^{-9})(78)(.01) + (2.5 \times 10^{-9})(42)(.01)] + [(3.9 \times 10^{-8})(118)(.01) + (1.6 \times 10^{-8})(64)(.01)] = 5.7 \times 10^{-8}/yr.$$

By footnote 1^ infra, P_{total} is divided by 2 to yield an estimated crash rate of 2.9×10^{-8}/yr as compared with the Staff estimate of 1.6×10^{-8}/yr. Tr. 508, 515, 519-520.

12/ The areal crash densities for takeoffs incorporate a division by 2 as discussed at Tr. 460-463.

Present Relevant Heavy Movements, N

	Total	Scheduled	Nonscheduled
Landings	195	78	118
Takeoffs	105	42	64

Crash Target Area, A

For scheduled and nonscheduled activity, the target areas used were:

Landings: $0.0062\ mi^2$

Takeoffs: $0.0026\ mi^2$

(Eisenhut at 14; Tr. 464).

The equation, appropriately broken down to reflect landing and takeoff data separately for each scheduled and nonscheduled (including training and military) operation is:

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

Substituting the above values yields:

$$P_{total} = [(2.0 \times 10^{-9})(78)(.0062) + (2.5 \times 10^{-9})(42)(.0026)]$$
$$+ [(3.9 \times 10^{-8})(118)(.0062) + (1.6 \times 10^{-8})(64)(.0026)]$$
$$= [0.097 \times 10^{-8} + 0.027 \times 10^{-8} + 2.85 \times 10^{-8} + 0.027 \times 10^{-8}]$$
$$= 3.2 \times 10^{-8}/yr$$

To account for heavy aircraft, this value was divided by 2 to yield an estimated crash frequency of 1.6×10^{-8}/yr.[13/]

(Eisenhut at 15, Tr. 464, 465-468, 469A-471, 504).

In light of the foregoing, the number of heavy operations can increase by a factor of about 6 and still yield an estimated crash frequency that is no greater than about 1×10^{-7}. ~.; i.e., the number of heavy operations could increase from the 1977 level of about 600 operations to about 3600 before exceeding the 10^{-7} criterion (Eisenhut at 15-16). This level of increase is not expected at HIA (see Read et al. at 28-30, 43).[14/] A word of caution, however: this conclusion assumes that the breakdown of scheduled (40%) and nonscheduled (60% including training and military) flights does not change

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13/ The factor of 2 represents a judgment value by the Staff to reflect the effect on the distribution of crashes attributable to the flight paths of heavy aircraft. This flight path would be weighted toward the runway centerline extended more so than is the case for the historical data, which includes smaller aircraft which can make sharper turns closer to the airports at which they land or take off from (Tr. 469A-471, 498-499, 504). As a result, their crash distributions appear more off the centerline extended than would be the case for heavy aircraft.

As discussed at page 14, supra, the calculation was updated to include 1978 data and revised 1976 and 1977 data. The effect of this would be to increase the estimated crash frequency to 1.75×10^{-8}/yr. Note that this value differs from that set forth in Dr. Read's Affidavit of February 22, 1980, 1.88×10^{-8}/yr., since Dr. Read did not reduce the "C" value for takeoffs (scheduled and nonscheduled) by a factor of 2 as should have been done (see Tr.460-464).

14/ The record indicates that TWA, the only airline previously providing scheduled service with heavy aircraft at HIA, has discontinued the use of such aircraft (Read et al. Attachment A; Tr. 599-600; Read Affidavit of 2/4/80 at 3 following Tr. 641).

significantly, since the crash densities for nonscheduled operations are about an order of magnitude larger than for scheduled operations (Id.).

The foregoing calculation is not dependent on the confidence limits discussed infra, in view of numerous conservatisms inherent in the Staff's approach. Such conservatisms include: a factor of about two in the data base because it includes aircraft which were destroyed and/or an occupant fatality occurred, even though some of the crashes were controlled events; another factor of about 1.5 attributable to the understatment of the total number of operations due to the omission of nonscheduled operations in some years; the use of 22-year crash data, which doesn't account for the decreasing crash rate such as is reflected in the Applicants' calculation resulting in a further conservatism by a factor of 2 to 3; the inclusion of military movements on the basis of nonscheduled crash rates resulting in a likely conservatism of something greater than 1 (although the value cannot be quantified precisely) since the data would show that the military crash rate is lower than that for nonscheduled operations; and, a factor of about 2, attributable to the use of crash rates that were derived for heavy plus light air carriers. A further, unquantifiable conservatism results from the use of an aerial crash density without inclusion of a smoothing function. Further, the Staff, in calculating the target area, A, did not perform a structural evaluation to determine what degree of protection was inherent in the structures; the Staff assumed that an aircraft of 200,000 pounds or more, at 200 knots or more, hitting the site would produce unacceptable results, i.e., releases greater than 10 CFR Part 100. Tr. 491, 493-496. This, too, results in some unquantified conservatism greater than a factor of 1. A final, unquantified conservatism results from the omission of a weighting factor to account for weather. The primary runway for landing under adverse weather conditions at Harrisburg International Airport is Runway 13 since it has the ILS. Thus, aircraft would be landing at that end of the runway, away from the TMI site. Even without taking credit for the last three items above, the total conservatism inherent in the Staff's calculation is about a factor of 12 to 18 (Tr. 477-479). Because of these conservatisms, confidence limits are not of significance in the Staff's analysis and, in fact, are not relied on (Tr. 476, 479-480).

E. License Conditions

Based on the foregoing, the Staff believes that the probability of the crash of an aircraft of greater than 200,000 pounds at a speed of 200 knots is well within the value of concern, 10^{-7} and, accordingly, no design and/or construction modifications to Category I structures at TMI-2 are necessary, consistent with the provisions of SRP §§2.2.3 and 3.5.1.6. Furthermore, Technical Specification 6.9.1.5.b., Annual Reports, which is part of the TMI-2 operating license requires:

b. The following information on aircraft movements at the Harrisburg International Airport:

1. The total number of aircraft movements (takeoffs and landings) at the Harrisburg International Airport for the previous twelve-month period.

2. The total number of movements of aircraft larger than 200,000 pounds, based on a current percentage estimate provided by the airport manager.

Given the low probability of occurrence of this event, the Staff considers the above Technical Specification to be generally adequate to assure that changes in flight operations that might cast doubt on the continuing validity of the calculated crash probability value will be discovered in a sufficiently timely manner to allow remedial action to be taken if necessary. However, in light of the significance of the nonscheduled component in the Staff's analyses (Eisenhut at 16), the Staff recommends that subpart 2 above be amended to read as follows:

> "2. The total number of movements of aircraft larger than 200,000 pounds (broken down into the scheduled and non-scheduled operations), based on a current percentage estimate provided by the airport manager" (underscored words added).

III.
UNCERTAINTY OF THE ESTIMATED CRASH FREQUENCY

A. The Staff's Uncertainty Analysis

The Staff calculated bounds for the exact confidence limits for the areal crash densities for each of the four operational categories, both for the 22-year (1956-1977) data base (Supplemental Testimony of R. Moore and L. Abramson in response to ALAB-525 following Tr. 641, hereafter cited as Moore and Abramson (3/16/79), Table IV) and for the 23-year (1956-1978) data base (Joint Affidavit of Roger H. Moore and Lee R. Abramson, dated 2/1/80, following Tr. 641, hereafter cited as Moore & Abramson (Joint Affidavit), Table IV). The approach used is described in the Appendix to Moore & Abramson (Rev. 12/11/78) and Moore & Abramson (3/16/79). This approach can be extended to calculate bounds for the exact confidence limit for the crash frequency.

First, the Staff calculated upper bounds on the exact confidence limits for the four areal crash densities based on the 22-year (1956-1977) data base, which have higher confidence levels than previously calculated. These are exhibited in Table V, with confidence levels of 99.7% for scheduled landings and takeoffs and 94.9% for nonscheduled landings and takeoffs. By the Bonferroni method, the bounds for scheduled operations result from the product of three 99.9% confidence limits (for the off-runway crash rate, for the conditional crash density for r, and for the conditional crash density for θ) and the bounds for nonscheduled operations result from the product of a 99.9% confidence limit for the off-runway crash rate and a 95% confidence limit for the conditional crash density.

TABLE V

UPPER BOUNDS ON EXACT CONFIDENCE LIMITS
FOR AREAL CRASH DENSITIES AT TMI-2
(Based on 1956-1977 Data)

SCHEDULED	Estimated Value*	Upper Bound	Confidence Level
Landings	2.0×10^{-9}	42×10^{-9}	99.7%
Takeoffs**	2.5×10^{-9}	106×10^{-9}	99.7%
NONSCHEDULED			
Landings	39×10^{-9}	269×10^{-9}	94.9%
Takeoffs**	16×10^{-9}	366×10^{-9}	94.9%

*Moore & Abramson (2/4/80), Table III.

**Incorporates division by 2 as discussed at Tr. 460-463.

Although the Bonferroni Method has been applied here only to the product of confidence limits, it applies equally well to the sum of confidence limits. Accordingly, the estimated values of the areal crash densities in the expression for P_{total} on page 30 supra, can be replaced by the upper bounds from Table V to yield an upper bound on the exact confidence limit for P_{total}, as follows:

$$[(42 \times 10^{-9})(78)(.0062) + (106 \times 10^{-9})(42)(.0026)]$$
$$+ [(269 \times 10^{-9})(118)(.0062) + (366 \times 10^{-9})(64)(.0026)]$$
$$= 2.9 \times 10^{-7}/\text{yr.}$$

Division by 2 to account for heavy aircraft yields an upper bound of 1.5×10^{-7}/yr. on the exact 89.2%[15/] confidence limit for the crash frequency. In

15/ This confidence level results from application of the Bonferroni calculation of confidence level to the confidence levels in Table V.

view of the conservatisms introduced by the repeated application of the Bonferroni method, it is reasonable to conclude that this value of 1.5×10^{-7} is in fact an upper bound on the exact 90% confidence limit for the crash frequency.

To derive a lower bound on the exact 90% confidence limit for the crash frequency, the approach described in Moore & Abramson (3/16/79) is used. The lower bound is calculated by replacing the estimated areal crash density for nonscheduled landings[16/] in P_{total} on page 30 supra by the lower bound on its exact 90% confidence limit as given by Table IV in Moore & Abramson (3/16/79). This yields

$$[(2.0 \times 10^{-9})(78)(.0062) + (2.5 \times 10^{-9})(42)(.0026)]$$
$$+ [(101 \times 10^{-9})(118)(.0062) + (16 \times 10^{-9})(64)(.0026)]$$
$$= 7.8 \times 10^{-8}/\text{yr.}$$

Division by 2 to account for heavy aircraft yields a lower bound of 3.9×10^{-8}/yr. on the exact 90% confidence limit for the crash frequency.

In summary, the 90% confidence limit on the crash frequency at TMI-2 lies between 3.9×10^{-8}/yr. and 1.5×10^{-7}/yr.

16/ Note that the other three components of P_{total} are left unchanged. It can be shown that replacing just one of the components of P_{total} by an exact $100(1-\alpha)$ % confidence limit for it (or by a lower bound on the exact confidence limit) results in a lower bound on the exact $100(1-\alpha)$ % confidence limit for P_{total}.

B. The Applicants' Uncertainty Analysis

The Applicants applied Bayes' Theorem to predict accident rates from historical data. First, the Applicants plotted the historical data showing annual crash rates. Inspecting the historical data curve, Applicants' witness, Dr. Kaplan, observed a clear downward trend in accident rates beginning in the early 1960's and made the assumption that such improvement would continue (Appendix A to Vallance (1/9/79) at A-1). He then reasoned that a direct linear extrapolation of the curve to 1978 would yield a crash rate very close to zero and a further extrapolation would become negative. Therefore, he made the further assumption that his extrapolation must reflect a leveling out of the curve. Where and how quickly the curve levels out is a matter of judgment. While he stated that no statistical technique or mechanical procedure could replace such judgment, he opined that it is possible to put forth a mathematical framework, Bayes' Theorem, which serves as a guide to judgment, and as a way of expressing the state of knowledge about the accident rate in light of all the information available. The manner in which Bayes' Theorem was applied in the present case is as follows:

(1) The Applicants regard the historical data curve as the result of sampling from an underlying population whose crash frequency varies with time according to the functional form

$$f(t) = a + b\ (b-a)e^{-\lambda(t-+_o)},$$

which reflects a gradual decrease and a leveling out at value a.

(2) In the form of the above equation, the Applicants fixed the year t_o and assigned a value to b. The Applicants then determined or "fit" the remaining two parameters, a and λ, using Bayes' Theorem. That is, the Applicants regarded the historical data as evidence. On the basis of this evidence, the Applicants derive by Bayes' Theorem a probability distribution on the space of a, λ pairs.

(3) From this probability distribution of a, λ pairs, the Applicants derive a probability distribution for the quantity of interest, that is, for

$$f(1978) = a + (b-a)e^{-\lambda (1978 - t_o)},$$

the accident rate in 1978.

By the above means, the Applicants developed an estimate of the aircraft accident rate, f, applicable to the plant in 1978. Since the Applicants do not know the value of f exactly, they express their uncertainty about f in the form of a probability distribution for f, the Bayesian posterior distribution.

C. Comparison of Uncertainty Analyses

The Staff's uncertainty analysis is not directly comparable to that of the Applicants', since confidence intervals and a Bayesian posterior have different interpretations. Nevertheless, a comparison of the results is useful in highlighting some of the differences in the approaches.

From page 37 supra, the 90% confidence limit on the crash frequency at TMI-2 lies between 3.9×10^{-8} and 1.5×10^{-7}. Since the estimated crash frequency is 1.6×10^{-8} per year, the 90% confidence limit lies between 2.4 and 9.4 times the estimated value of the crash frequency.

A comparable value from the Applicants' uncertainty analysis is the 90th percentile of the Bayesian posterior distribution of annual crash frequency. This value can be approximated from Table 2 of Vallance (1/9/79) by interpolation. As can be seen from Table VI, a good approximation to the probability that the hit frequency f is less than a x 10^{-9} is given by the function G(a) = 1 - 3 exp (- x/3) for x $\geq$ 6.4.

TABLE VI
APPROXIMATION TO BAYESIAN CUMULATIVE DISTRIBUTION FUNCTION FOR f

a	Cum. Prob. (Vallance (1/9/79) (Table 2)	G(a)
6.4	.63	.64
9.6	.86	.88
12.9	.95	.96
16.2	.982	.986
19.4	.995	.995
22.7	.[illegible]9	.999

Setting G(a) = .90 yields a value of 10.2 x 10^{-9} for the 90th percentile. This value can be compared with the estimated hit frequency of 8.5 x 10^{-9} (Vallance 11/9/79), page 3) or the mean value of 6.6 x 10^{-9} (Vallance (1/9/79), Table 2). The 90th percentile of hit frequency is 1.2 times the estimated value and 1.5 times the mean value. This compares with the range of 2.4 - 9.4 for the ratio of the 90% confidence limit to the Staff's estimated crash frequency.

The Applicants' uncertainty is considerably smaller than the Staff's uncertainty in the estimated crash frequency. In view of the Applicants' use of a Bayesian methodology, this result is not surprising. The Staff's uncertainty analysis is based on a minimum of assumptions while the Applicants assume a prior distribution for the crash frequency f which incorporates information about f which goes considerably further than the historical data.

Furthermore, since the Bayesian prior is an expression of the analyst's subjective judgment about f, the posterior depends on this subjective judgment as well as on the observed data. It is not clear from the Applicants' analysis just how sensitive the posterior is to the choice of prior.

Another factor in the use of a Bayesian approach stems from the fundamental requirement that the prior be chosen independently of the data. If the choice of the prior is influenced by the data, then the posterior will be overly weighted by the data and the uncertainty as expressed by the posterior will be understated. It is not clear from the record to what extent the Applicants' analysis suffers from this potential problem. For example, in Appendix A to Vallance (1/9/79), Dr. Kaplan uses four different priors for (a, λ), which seem to have been chosen to be consistent with the observed differences in the historical crash rates for the four categories. Also, in Appendix B to Vallance (1/9/79), Dr. Kaplan assumes the form $R(r) = a \exp(-r/\lambda)$ for the fraction of crashes occurring beyond radius r and assigns a discrete uniform prior to a and λ as given by Eqs. (16) and (17). It is not clear to what extent the data-based estimates of $a = .65$ and $\lambda = 1.7$ may have influenced the ranges of [0.4, 0.7] for a and [.75, 3.25] for λ, nor is it clear what effect a different prior might have had on the posterior.

In summary, the Staff's and the Applicants' uncertainty analyses are not directly comparable due to the different methodologies used. The Staff's classical statistical approach yields a larger uncertainty measure on the estimated crash frequency than does the Applicants' Bayesian approach. This difference stems primarily from the additional assumptions about aircraft accidents which the Bayesian approach is based on.

IV.
HARRISBURG INTERNATIONAL AIRPORT

A. Description and Use

Harrisburg International Airport (or HIA) is located one mile west of Middletown, Pennsylvania and approximately seven miles southeast of Harrisburg, Pennsylvania on the east bank of the Susquehanna River. The TMI site is approximately 2.5 nautical miles (NM) from the end of the nearest runway (see Staff Exhibits No. 1 and 2). The facts pertaining to the location, equipment, and use of the airport do not appear to be in dispute between the parties (see Prepared Testimony of Lowell R. Wright following Tr. 199 hereafter cited as Wright; Read et al., at 33-40). These facts are set forth below.

The airport was formerly the Olmsted Air Force Base and was transferred to the Commonwealth of Pennsylvania for civilian airport purposes on July 1, 1967 (Read et al. at 35). The airport serves Harrisburg and other central Pennsylvania localities. It receives daily commercial service through Allegheny and Trans World Airlines, as well as commuter carriers and accommodates a full range of charter, cargo and general aviation activity. The airport is the home base for private as well as military aircraft. The Pennsylvania Air National Guard aircraft maintained at the airport consist of C130s and C121s -- neither of which exceed 200,000 pounds. However, a private travel club owns and bases a DC-8 at Harrisburg International Airport.17/

17/ Pegasus International Travel Club has gone bankrupt; they have not flown this aircraft in the past several months and resumption of operation is questionable (Read Affidavit, 2/4/80 at 2, following Tr. 641).

This aircraft can exceed 200,000 pounds (Read et al. at 35). Traffic at HIA increased from a 1976 low of 82,653 operations to a 1977 count of 104,287 operations; the 1990 forecast is for about 167,000 total annual operations (Read et al. at 43). About 1% of all activity is estimated to be "heavy" operations (Id. at 42).

The airport has only one runway, aligned in a southeast-northwest direction which is approximately 10,000 feet long and 200 feet wide. This runway is capable of accommodating the largest airplanes in the civil aviation fleet. There are two approaches to this runway identified as Runway 31 and Runway 13 (Read et al. at 36).

The airport is average with respect to air navigation facilities. Runway 13 is equipped with an Instrument Landing System (ILS), including all components; i.e., localizer radio transmitter located at the southeast end of the runway and aligned along the runway centerline, middle radio marker located 0.5 nautical miles northwest of the end of the runway, outer radio marker and non-directional radio beacon located on the runway centerline extended 6.4 nautical miles northwest from the end of the runway, and a glide path transmitter signal aligned 126 degrees magnetic along the runway centerline extended through the middle and outer markers. Runway 13 is also equipped with an ILS approach light system and high intensity runway lights (Read et al. at 36-38).

The ILS localizer back course can be used for instrument approaches to Runway 31. No glide path is available for the back course. Radar approach control at Capital City Airport, about 5 miles northwest of Harrisburg International Airport, provides vectoring to radar fixes 8 and 5 nautical miles southeast of the runway centerline extended. A second ILS with full components is scheduled for operation in 1981 on Runway 31 (Read et al. at 36-38).

The Harrisburg area enroute air navigation radio facility is located 13 statute miles northwest of the airport. This is the Harrisburg VORTAC (HAR), a very high frequency omnidirectional radio tactical aid to navigation which gives both range and bearing to approaching aircraft. Under instrument flight, an aircraft will make a transition for an instrument approach, being directed by signals from HAR, Ravine (RAV), or Lancaster (LRP) VORTAC's, along with radar fixes from flight control at Capital City Airport which operates the airport surveillance radar (ASR) for the Harrisburg area. The ILS utilized at Harrisburg is designed to bring an aircraft to within 200 feet altitude and 1800 feet laterally of touchdown after which landing is completed by visual means (Read et al. at 36, 37). However, because of obstructions in the immediate vicinity (see Staff Exhibit No. 3), the established minimum weather conditions at the airport are a 300-feet ceiling and 3/4 mile visibility, at which point a pilot must see the runway environment to complete the landing.[18/]

18/ The ILS employed on Runway 13 will allow aircraft to land in worse weather conditions than that which would permit an aircraft to land on Runway 31 (Tr. 299). However, because of prevailing wind conditions, Runway 31 is used approximately 60 percent of the time. Testimony of Read et al., p. 44. This means that aircraft land on Runway 31 from the southeast from the direction of the TMI site and takeoff to the northwest - away from the TMI site.

Under normal conditions, the prevailing winds are from the west and west-northwest. During periods of low clouds and reduced visibility conditions, winds are normally from the east and southeast. Insofar as wind speed average, thunderstorm days, and reduced visibility days, Harrisburg is not unusual (see Table No. 3 of Wright's Testimony which shows weather information for 40 cities in the United States, including Harrisburg, Pennsylvania). The FAA has indicated that operations at Harrisburg are minimally affected by adverse weather. For instance, the airport has been completely shut down only one day each year for the past two years because of adverse weather conditions (Read et al. at 38).

In general, the topography of the area surrounding the airport is rolling to hilly. The airport is at approximately 300 feet MSL and the surrounding hills range from 500 to 1000 feet MSL. There are no unusual topographical features in the area that would be considered a hazard to operations at Harrisburg International Airport (Read et al. at 39; Tr. 541).

B. Traffic Control and Flight Patterns

Control Responsibilities

The control areas of Harrisburg International Airport and Capital City Airport overlap because of their closeness. Therefore, the operating procedures and the associated coordination responsibilites for the control of traffic in the area are well defined and set forth in a Letter of Agreement. Essentially, the established procedures state that aircraft approaching HIA will first establish contact with Harrisburg Approach Control at Capital City Tower which will advise the aircraft of the approach in use at HIA. Approach control is accomplished through the use of radar vectoring and direct voice communications with the aircraft (Read et al. at 40 and Attachment 9).

Aircraft destined for HIA are vectored to the approach for Runways 13 and 31 (Tr. 250). When the aircraft is ten miles or more from the airport, Harrisburg Approach Control will forward the following information to Olmsted Tower:

(1) Aircraft identification;

(2) Type of approach, if other than approach in use; and

(3) Type of operation, if other than a full stop landing, and issue missed approach procedures.

When the aircraft is five miles from HIA, Harrisburg Approach Control will transfer control of the aircraft to Olmsted Tower for a visual landing approach, or ILS or "back course" approach. The pilot is also instructed to contact HIA on the appropriate radio frequency for landing instructions. If the aircraft is on ASR Approach,[19] Capital City Tower will maintain control of the aircraft until the aircraft is one mile from the end of the runway at which point control is transferred to Olmsted Tower.

Air Traffic Patterns

The initial testimony regarding air traffic patterns at Harrisburg International Airport, on behalf of the Staff was given by Messrs. Coval and Beyers, of the

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[19] ASR Approach is a radar approach which gives information to a pilot regarding the aircraft's distance from the end of the runway and suggested altitudes based on that distance.

Federal Aviation Administration (FAA), chiefs of the Capital City Airport and Harrisburg International Airport control towers, respectively (Read et al. at 31, 32-33). Their testimony[20/] regarding air traffic patterns (Id. at 39-42, Tr. 249 et seq.), may be summarized as follows.

To avoid conflict with air traffic at Capital City Airport, the air traffic patterns for HIA restrict most flights to the northeast side of the extended runway centerline (Tr.258). These patterns designate a left turn pattern to Runway 13 and a right turn pattern to Runway 31. A pilot wishing to deviate from these patterns must obtain permission from Olmsted Tower.

These patterns do not apply to the heavy aircraft at issue here. Arriving heavy aircraft to Runway 31 are vectored by radar to a point on the runway centerline extended (at least 8 nautical miles out from the runway end) (Tr.250, 253) at an altitude of about 2500 feet. The rate of descent and airspeed decrease gradually to the airport boundary. The airspeed is approximately 160 to 180 knots at 8 nautical miles and is about 160 knots at 5 nautical miles out and 130 knots over the airport boundary. As to the altitude decrease, for the average rate to the 5 nautical mile fix to the point where the aircraft reaches its minimum descent height (at which point the pilot must be able to see the runway, or else must execute a missed approach), the average rate of descent (for an instrument approach) is 208

20/ Applicants' testimony on this matter is, essentially, in agreement with the Staff's (see Testimony of Wright following Tr. 199 at 8-10; see also, Tr. 249).

feet per nautical mile. On a visual approach, the rate would be about the same, but figured to a point where the aircraft crosses the airport boundary at an altitude of approximately 50 feet above ground (Wright at 10).

Large aircraft taking off, usually at between 120 and 140 knots, on Runway 13 (toward the TMI site) are required to climb and maintain runway heading until reaching the assigned altitude before executing a turn to its designation route. Depending on take-off weight and wind, the aircraft would normally reach 3,000 feet, the assigned altitude, at approximately three miles from the runway with a speed of approximately 240 knots (Id.). Accordingly, such a pattern on take-off would not place a large aircraft over the TMI site which is approximately 2 1/2 miles from the end of the runway and at an angle of 34 degrees from the extended runway centerline.

Based on this information, it is readily apparent that the operations at TMI and, in particular, the presence of the cooling towers do not present a hazard to aviation. While there is no data as to the actual number of planes that do overfly the TMI site on take-off or landing patterns, the FAA has indicated that a pilot on VFR could choose to overfly the site if conditions warranted (Tr. 264).[21/] It was emphasized, however, that even though it was physically possible to overfly the site on approach to Runway 31 in a heavy aircraft, a pilot of such an aircraft would not purposely fly over TMI (Tr.

21/ On IFR approaches, the aircraft would be vectored to the approach gate for Runway 31, which is at least 8 nautical miles from the end of the runway centerline extended (Tr. 250). Thus, it is clear that on instrument approaches, an aircraft would not overfly the TMI site.

264) or fly through the plume because he would lose visual reference to the runway (Tr. 275).

At the hearing on December 12, 1978, Intervenors' representative for the first time asserted that he had himself landed at HIA on an approach that took him directly over TMI-2, and that he had knowledge of others who similarly had landed at HIA (Tr. 262), contrary, he alleged, to the testimony of the FAA. Indeed, Intervenors' representative further asserted that he would show that "there is a routinely established flight path landing at Runway 31, which takes aircraft directly over TMI-2" (Tr. 283). The Appeal Board, in ruling upon Intervenors' motion to present witnesses and taking into consideration the Staff's offer to provide affidavits of appropriate airline flight personnel, directed that a further hearing be held to receive the testimony of such individuals and for the presentation of testimony by those individuals identified in Intervenors' motion (see ALAB-525, supra).

With respect to the Staff's presentation, four senior pilots were subpoenaed by the Staff: two from Trans World Airlines,[22/] a major operator of both scheduled and nonscheduled service at HIA; one from Transamerica Airlines[23/] (formerly Trans International Airlines), a major nonscheduled operator; and, one from Evergreen International Airlines,[24/] a smaller nonscheduled operator.

22/ Captains Clark Billie and Edward Beuerlein (Tr.526 et seq.).

23/ Captain David Lithgow (Id.).

24/ Captain Donald Ufford (Id.).

The testimony of these pilots was uniform[25/]; on making a VFR landing at and taking off from HIA, they would not fly over TMI-2, they would likely pass around the facility by about 1 1/2 miles on either type of operation,[26/] they would fly on the centerline extended about three to five miles before initiating any turn on takeoff and be on the centerline extended not less than three to five miles from Runway 31 when landing. These distances are determined by FAA approach charts from HIA (attached to Wright Testimony) and conforming company policy which, on takeoff, requires a pilot to fly on the centerline until reaching an altitude of about 1500 feet prior to initiating a turn and, on approaches, to intercept the centerline extended not less than about 2 1/2 miles from the runway. This testimony corroborates that presented by the FAA, namely, that although it was physically possible to overfly TMI-2, it would likely not be done. It further establishes that there are no unique features at HIA in terms of airport faciliites, the surrounding geography or the proximity to TMI that would present a particular hazard to operations at that airport (Tr. 541).

The testimony also confirms the FAA's description, above, of an ILS landing on Runway 31. In particular, Captain Billie testified that such approach begins at the eight-mile radar fix from which a descent is made to an altitude

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25/ See Tr. 526-639 generally. It is worth noting that Captain Billie's familiarity with HIA is based on his experiences training other pilots in Boeing 747 aircraft (Tr. 545-547) and Captain Lithgow's experiences with VFR approaches into HIA were as a military pilot of C-141s (Tr. 581); the C-141 is a heavy aircraft (Read *et al*. at 24).

26/ See generally Testimony of Clark Billie, Edward Beuerlein, David Lithgow and Donald Ufford, following Tr. 531, respective answers to questions 13-18.

of 1900 feet at the five mile fix on the runway centerline extended (see Staff Exhibit No. 4; Tr.534, 537), the descent continuing to an altitude of 860 feet until the runway is observed, the visual glideslope then identified and this continued to the landing (Tr.534-535). Captain Billie also corroborated the FAA's estimation of airspeeds, stating that for a takeoff in an aircraft such as a Boeing 747, the speed would be about 170 knots and on final landing approach about 145-155 knots (see Staff Exhibit No. 4, Tr.540-541).

On takeoff from Runway 13 (toward TMI), Captain Billie testified that he would fly on the centerline extended until reaching an altitude of about 1000 feet, a distance of about 2 miles from the airport, before initiating any turn off the centerline (Tr. 543).

Regarding a VFR approach, he stated he would normally intercept the centerline extended about two to three miles out; if less, it would be too close to make an approach (Tr.543).

With respect to the cooling towers, Captain Billie stated that they are good visual reference points but that he would not fly over them. To do so would be to risk turbulance or obstructed visibility (Tr.549-550). While the turbulance would not present a safety hazard, it would be noticed by passengers (Tr.552-553). Obstructed visibility is not permitted by FAA regulations if the plane is being flown VFR (Tr.549-550); thus a pilot could not make a VFR approach into HIA in compliance with the applicable regulations by flying over TMI if a visable plume existed.

As depicted on Staff Exhibit No. 4, Captains Beuerlein, Lithgow and Ufford confirmed Captain Billie's testimony regarding both landing and takeoff patterns and airspeed. Their testimony is essentially identical in other respects, to Captain Billie's, as well, and for that reason will not be restated herein.

The significance of the collective testimony of the pilots is threefold: first, it corroborates the testimony of Messrs. Coval and Beyers; second it gives substance to Mr. Eisenhut's judgment factor of two which he divides his P_{total} by (see p.31, supra, and Tr.481, 499) and; third refutes Intervenors' allegation that there is a routine flight path which overflies TMI-2.

At the February 25, 1980 hearing, Intervenors called, as their witness, Dr. Judith Johnsrud. The essence of Dr. Johnsrud's testimony is that on January 24, 1980, on US Air Flight No. 170 from Pittsburgh to Harrisburg, Pennsylvania, she flew into HIA in a DC-9 by directly overflying TMI-2, an observation confirmed, she alleged, by the pilot of that flight (Tr. 607-608). Although this flight took place about a month prior to the hearing, no written testimony on this matter was served on the Appeal Board or parties in advance of the hearing date. Thus, the Appeal Board and parties were deprived of an opportunity to fairly prepare examination of Intervenors' witness. However, inspite of this and the hearsay character of this testimony, it is worthy of note that Intervenors' witness did appear to consider this experience unusual, that, in fact, "Of the times . . . [she] had flown in from Pittsburgh or Chicago to Harrisburg: yes, the hook had been around the lower end of the island", seemingly not directly over the reactor (Tr. 625). In short, Intervenors' sole witness on this contention effectively refuted Intervenors' allegation that there was a routine flight path over the reactors (Tr. 266, 269, 283); even assuming, arguendo, that this flight did overfly TMI-2, the most that can be said is that it constitutes an isolated instance in an aircraft which itself is less than 200,000 pounds.

V.
CONCLUSION

Based on the foregoing, the Staff believes that the record demonstrates (1) that the probability analysis has been properly performed; (2) that at present traffic levels, the probability of a crash of an aircraft weighing in excess of 200,000 pounds traveling at 200 knots is substantially below 1×10^{-7}; (3) that the number of operations at Harrisburg International Airport by such aircraft could increase to about 3600 per year before approximating 1×10^{-7}; (4) that it is not expected that activity at Harrisburg International Airport will increase to such level within the lifetime of the plant; and, (5) that to assure that information concerning traffic activity and trends at Harrisburg International Airport is provided to the Staff, Technical Specification 6.9.1.5.b. be amended as set forth on page 34. Accordingly, the Staff urges that the Licensing Board's Initial Decision on this matter be affirmed.

Respectfully submitted,

Lawrence J. Chandler
Counsel for NRC Staff

Stuart A. Treby
Assistant Chief Hearing Counsel
for NRC Staff

Dated at Bethesda, Maryland
this 30th day of April, 1980

APPENDIX I

Appeal Board

"(1) There shall be provided a complete set of those data on aircraft crashes in the vicinity of airports in the United States which would be pertinent to the calculation of the probability of a crash of a heavy aircraft at the TMI-2 site. This compilation should cover the time period from the mid-1950's to the present. There should be an identification of the selection criteria used (e.g., fatal vs. destructive crashes), together with a justification for the choices made. In furnishing this evidence, the parties shall observe the following directions:

(a) The data should include the spatial distribution of crashes in the vicinity of runways, either graphically, similar to Figure 2.2-2 of the TMI-2 FSAR, or by listing appropriate crash coordinates.

(b) The data should be grouped in appropriate time periods, so that any time-dependent trends in rate or spatial distribution will be identifiable.

(c) The basic data set would presumably be for United States common carrier aircraft. However, to the extent possible, any differentiations which can be made along the following lines should be provided:

(i) Aircraft greater than 200,000 pounds vs. aircraft less than 200,000 pounds.

(ii) Aircraft speed at time of impact.

(iii) Scheduled vs. nonscheduled flights.

(d) Separate crash data for military C-5A's near airports should be provided.

(2) If there are trends evident in the data obtained above (e.g., crash rate different for heavy planes or in more recent years), these shall be addressed and, if possible, explained in the testimony.

(3) The data compilation shall be used to develop a model to compute the probability of a crash per operation and per unit area, at a site off the end of a runway. The model should reasonably reflect the spatial distribution of crashes displayed by the data and incorporate conservatively any trends for the future which these data portend. An attempt should be made to

assess the precision that might be expected for probability values determined using the model.

(4) Since the compilation will be based on crash data obtained for many airports, the Harrisburg International Airport should be considered in terms of its particular degree of hazard relative to other airports in the selected data base. The testimony should address, among other things, such factors as topography, magnitude of traffic, meteorological conditions, and the availability of electronic guidance equipment at the airport.

(5) The testimony should identify, preferably on a large-scale map upon which the TMI site and the Harrisburg airport are accurately depicted, the routine takeoff and landing flight patterns that heavy aircraft would use. Typical airspeeds at various points in the patterns should be indicated.

(6) The testimony should address the extent to which the cooling towers at the TMI site might influence flight patterns at the Harrisburg airport. There should be an assessment of the effect that the towers might have on computed crash rate values.

(7) The testimony should disclose the number of aircraft of weight greater than 200,000 pounds which have used the Harrisburg airport during each of the last 8 years. This traffic should be broken down, if possible, by aircraft type, scheduled or non-scheduled, and military or commercial. If possible, a breakdown of the operations according to the end of the runway at which they took place should be provided.

(8) Projections of the future heavy aircraft traffic at the Harrisburg airport should be made on the basis of the information developed in connection with item (7) above, as well as any additional reliable information.

(9) Using the model developed in response to item (3) above and a range of levels of heavy aircraft traffic consistent with the projections developed in connection with item (8) above, the testimony should address the probability per year of a crash of an aircraft at TMI-2, including an estimate of the precision of the assessment.

(10) Finally, the testimony should consider how the generic probabilities thus arrived at might be affected by those unique features of the Harrisburg airport-TMI site relationship which might not be expressly reflected in the computational model (e.g., the relative hazard of that airport, the effect of the cooling towers, etc.). This assessment should be cast in quantitative terms to the extent possible." ALAB-486, 8 NRC at 44-46.

Commission

"I. Crash Data. Crash data for operations in the U.S. during the last 5 years should be obtained by year and type of aircraft for those over 200,000 pounds, segregated according to whether military, scheduled, or nonscheduled. Data should include, for each crash: cause, location, type of ground control equipment in use (e.g., whether an instrument landing system was present), weather conditions, speed at impact, and type of operation (take-off, landing, touch-and-go). Sources of this information might include the National Transportation Safety Board, the Civil Aeronautics Board, the Federal Aviation Administration, the Department of Defense Office of Program Analysis and Evaluation, the U.S. Air Force Inspection and Safety Center at Norton Air Force Base, and insurance companies.

II. Flight Operations at Harrisburg International Airport. For operations during the past 5 years, to the extent possible, data should be obtained, on a year-by-year basis, on the actual aircraft type (e.g., C-5A, 707), for aircraft over 200,000 pounds; the operator (e.g., Air Force, scheduled, nonscheduled); the gross weight of each operation; the end of the runway used; and the type of operation (e.g., takeoff, landing, touch-and-go). The type of ground control equipment at the Harrisburg International Airport should be specified, including any changes approved but not accomplished, either upgrading or abandonment of equipment.

III. Future Traffic. For traffic at the Harrisburg airport during the next 5 years, forecasts should be obtained on a year-by-year basis from the airport, the U.S. Air Force, and the Federal Aviation Administration.

IV. Information on Landing and Takeoff Patterns at Harrisburg International Airport. A template should be prepared showing the takeoff and landing patterns, and indicating the location of the Three Mile Island site. Information should be obtained on: standard guidance (if any) given to aircraft; whether one area or one landing and takeoff pattern is usual (e.g., for noise control or because of prevailing wind conditions); whether, and if so, how often, the Three Mile Island site is overflown; and the feasibility of using landing and takeoff patterns which do not overfly the Three Mile Island site.

V. Analysis. An analysis and estimate should be made of the type of probability distribution appropriate in drawing conclusions on the basis of very limited data. The estimate should include an estimate of the uncertainty. It may be desirable to develop both an estimate of the probability of crash per operation for operations in the U.S., based on the data, and of the probability of hitting a given area in the event of a crash, based on aerodynamic analysis. The data outlined above should then be analyzed to give an estimate of the likelihood of crash by type of aircraft at Harrisburg International Airport. The analysis should also include an examination of the combinations of weight heavier than 200,000 pounds and lower speed which would lead to impact equivalent to that of the crash (200,000 pounds at 200 knots) that is the design basis for the Three Mile Island, Unit No. 2, facility." CLI-78-19, 8 NRC at 296-297.

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)	)	

CERTIFICATE OF SERVICE

I hereby certify that copies of "NRC STAFF POSTHEARING MEMORANDUM REGARDING AIRCRAFT CRASH PROBABILITY ISSUE" in the above-captioned proceeding have been served on the following by deposit in the United States mail, first class, or, as indicated by an asterisk, through deposit in the Nuclear Regulatory Commission's internal mail system, this 30th day of April, 1980:

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