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UNITED STATES
NUCLEAR REGULATORY COMMISSION

In the matter of:

METROPOLITIAN EDISON COMPANY, ET AL
(THREE MILE ISLAND, UNIT 2)
APPEAL BOARD HEARING ON
AIR CRASH PROBABILITY

Place: Harrisburg, Pennsylvania

Date: February 25, 1980 **Pages:** 521 - 728

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UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

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In the Matter of:

METROPOLITAN EDISON COMPANY, ET AL

(THREE MILE ISLAND, UNIT 2)

APPEAL BOARD HEARING ON

AIR CRASH PROBABILITY

---------------------------------------X

Docket No. 50-320

Hearing Rooms A & B
Harristown 2 Building
333 Market Street
Harrisburg, Pennsylvania

Monday, February 25, 1980

The above-entitled matter was discussed at this Appeal Board meeting which convened at 9:00 a.m., with Chairman Rosenthal, presiding.

BEFORE:

ALAN S. ROSENTHAL
JOHN H. BUCK
W. REED JOHNSON

On behalf of the Applicant:

GEORGE F. TROWBRIDGE, ESQ.

On behalf of the NRC Staff:

LAWRENCE J. CHANDLER, ESQ.
STUART A. TREBY, ESQ.

On behalf of the Intervenors:

DR. CHAUNCEY KEPFORD

On behalf of the Commonwealth of Pennsylvania:

KARIN CARTER

CONTENTS

tape 1

Reporter

jn-1

Harrisburg
2.

P R O C E E D I N G S

CHAIRMAN ROSENTHAL: This Appeal Board is taking additional evidence today on the question of the degree of probability that an aircraft weighing in excess of 200,000 pounds might crash into Unit 2 of the Three Mile Island facility in the course of landing at or taking off from the nearby Harrisburg International Airport.

In December 1978, we held a two-day hearing on this issue in Harrisburg. Subsequent to the conclusion of that hearing, the intervenors, Citizens for a Safe Environment, and York Committee for a Safe Environment asked that we reopen the record.

We granted that motion and scheduled a further hearing for April 4, 1979. In the wake of the accident which occurred at Unit 2 on March 28th, that hearing was indefinitely postponed. It later rescheduled for today and the opinion which was rendered on November 2, 1979, designated as ALAB-578.

We are receiving first this morning, testimony of witnesses for the NRC staff and the intervenors relating to the landing patterns employed by heavy aircraft approaching the Harrisburg Airport.

We will then hear additional testimony from witnesses for the applicant and the NRC staff who appeared at the [illegible] hearing and there presented statistical computations bearing upon the ultimate probability question.

By way of identification, the members of this Board are, on my right, Dr. John H. Buck, and on my left Dr. W. Reed Johnson.

I am Allen S. Rosenthal, the Chairman of the Board.

It might be noted that Dr. Buck has replaced Jerome E. Sharfman, who was a member of the Board at the time of the 1979 hearing, but, thereafter resigned from the Appeal panel to enter the private practice of law.

At this point, I will call upon the counsel or other representatives of the various parties to identify themselves formally for the record, and we'll start with the counsel for the applicant, Mr. Trowbridge.

MR. TROWBRIDGE: My name is George S. Trowbridge, I am a member of the Washington law firm of --

On my right, is Deborah Bernstein, an associate in our office. On my left is Mr. John Vallance who will be a witness in the proceedings.

CHAIRMAN ROSENTHAL: Thank you, Mr. Trowbridge.

For the intervenors, Dr. Kepford.

DR. KEPFORD: My name is Chauncey Kepford representative for the intervenors. On my left is Dr. Judith Johnsrud, co-director of the Environmental Coalition on Nuclear Power who will also be testifying.

CHAIRMAN ROSENTHAL: Thank you, Dr. Kepford.

For the Commission staff.

MR. CHANDLER: On behalf of staff, my name is Lawrence Chandler, with me is Mr. Stuart Treby. We are with the Office of the Executive Legal Director of the U.S. Nuclear Regulatory Commission.

CHAIRMAN ROSENTHAL: Thank you, Mr. Chandler.

For the Commonwealth of Pennsylvania.

MS. CARTER: My name is Karin Carter, Assistant Attorney General representing the Commonwealth of Pennsylvania.

CHAIRMAN ROSENTHAL: I might say, before we proceed that the appeal panel that this Appeal Board has with it this morning, on my far left, Ms. Linda Gilbert who is a legal intern assigned to the appeal panel.

Are there any preliminary matters that any of the parties wish to present?

MR. CHANDLER: Yes, Mr. Chairman.

This morning the staff provided the Board and each of the parties with two documents. One of these documents is a further affidavit from Dr. Reed revising somewhat [illegible] affidavit submitted on February 4, 1980, for the reasons set forth therein.

In addition, the staff provided to the Board and to the parties, copies of a memorandum from Dr. Reed to me discussing briefly the crash of a small General Aviation aircraft on the center line extended from Harrisburg Airport. We provide to the Board for its information.

CHAIRMAN ROSENTHAL: Now, do you propose putting one or the other or both of these documents into evidence?

MR. CHANDLER: Yes, Mr. Chairman, but I anticipate doing later will be to offer the affidavit of Jack Reed, and the the February fourth affidavit of Jack Reed, and ask that they be incorporated into the transcript as it's read. With respect to the memorandum from Dr. Reed to me discussing this carsh of a small aircraft, we are providing it to the Board and parties for their information.

We do not consider it to be relevant to the calculation of probability which we are here to discuss, but consistent with the staff practice, we believe it appropriate to bring it to the Board's and parties' attention. We will not offer it into evidence.

CHAIRMAN ROSENTHAL: Thank you, Mr. Chandler.

Are there any other preliminary matters?

All right.

As indicated a few minutes ago, we will take up first today the landing patterns issue and my contemplation is, unless there's some objection, that we will hear first from the commercial pilots who have been subpoenaed at the behest of the staff, and then from the intervenors' witness, Dr. Johnsrud. Is that agreeable?

(Affirmative response.)

CHAIRMAN ROSENTHAL: Mr. Chandler, you may proceed.

MR. CHANDLER: I would like to note for the record that the complete questionnaire submitted by each of the respective pilots has been submitted to the Board and parties. That of Captain Billie and Captain Ufford was submitted on February 4. The questionnaires of Captain Beuerlein and Lithgow was submitted by my letter of February 19th.

Mr. Chairman, at this time, I'd like to call to the stand and be sworn, Captain Clark Billie, Captain Edward Beuerlein, Captain Donald L. Ufford, and Captain David Lithgow.

CHAIRMAN ROSENTHAL: Okay.

If you gentlemen will remain standing -- would you get to the table for a moment and raise your right hand.

Whereupon,

CAPTAINS CLARK BILLIE, EDWARD BEUERLEIN,
DONALD L. UFFORD, AND DAVID LITHGOW

were called as witnesses, having been first duly sworn, were examined and testified as follows:

CHAIRMAN ROSENTHAL: Thank you, gentlemen, you may be seated.

Mr. Chandler, I hope that you'll get each of them to identify --

MR. CHANDLER: Yes.

CHAIRMAN ROSENTHAL: -- so that we can be clear as to who is who.

MR. CHANDLER: Yes, sir. That is certainly my intention.

If we can, Captain Beuerlein, would you please identify yourself, by whom you're employed, and if you would, please spell your name for the reporter.

CAPTAIN BEUERLEIN: My name is Edward Beuerlein, I've been employed by TWA for [illegible] years, and am currently flying, based in New York City.

MR. CHANDLER: Spell your name for the reporter, sir.

CAPTAIN BEUERLEIN: B-e-u-e-r-l-e-i-n.

MR. CHANDLER: And one further requestion, gentlemen, if you please, please use the microphone.

Captain Billie.

CAPTAIN BILLIE: Captain Mark Billie, B-i-l-l-i-e, with Transworld Airlines.

CAPTAIN UFFORD: Captain Donald L. Ufford, U-f-f-o-r-d with Evergreen International Airlines.

CAPTAIN LITHGOW: Captain David Lithgow, L-i-t-h-g-o-w, Transinternational Airlines.

MR. CHANDLER: Mr. Chairman, before going any further, I think it may be appropriate for me to explain to the Board and parties how these gentlemen come to appear here, and why the particular airlines have been selected. Each were selected by me, based on a very unscientific, random selection of air carriers utilizin -- having service at

Harrisburg International Airport.

Based on the staff's previously submitted testimony, it appeared that, to me, that Transworld Airlines represented a major U.S. air carrier which had both scheduled and nonschedule service, potentially using heavy aircraft to the Harrisburg Airport. For that reason, I asked that TWA be represented.

On the other hand, to -- I felt some perspective -- we selected Evergreen International Airline. That, again, kin my judgment, represented a somewhat smaller, nonscheduled carrier having service at Harrisburg Airport, and potentially using heavy aircraft.

The third airline, Transinternational Airlines, which is now known as TransAmerica Airlines, was selected because they are a larger nonscheduled carrier, having service at Harrisburg International Airport, potentially using large aircraft.

That is why I contacted the perspective airlines and these individuals were provided.

DIRECT EXAMINATION

BY MR. CHANDLER:

Q I would ask Captain [illegible], you have before you a three-page questionnaire containing 13 questions and answers?

A I do.

Q   Captain Beuerlein, did you complete the questionnaire?

A   Yes.

Q   Are there any additions or corrections you wish to have made in that questionnaire in responses?

A   [illegible]

Q   Is it true and correct to the best of your knowledge and belief?

A   Yes.

Q   And do you adopt the statements therein as your testimony in this proceeding?

A   Yes.

MR. CHANDLER: Thank you.

Mr. Chairman, I'll offer each of these -- I'll offer them collectively, so that they appear at the same place in the transcript.

CHAIRMAN ROSENTHAL: That would be helpful.

BY MR. CHANDLER:

Q   Captain Billie, do you have before you a three page questionnaire? Eighteen questions?

A   Yes.

Q   Did you prepare the responses contained therein?

A   Yes.

Q   And are there any corrections or additions you wish to have made in that?

A   No.

Q Is that document true to the best of your knowledge and belief?

A Yes, it is.

Q And do you adopt that as your testimony in this proceeding?

A Yes.

Q Captain Ufford, do you have before you a three-page document containing 10 questions?

A Yes, I do.

Q And did you prepare the responses contained therein?

A I did.

Q Are there any changes or additionas that you wish to have made in that?

A None.

Q Is that document true and correct to the best of your knowledge and belief?

A Yes, it is.

Q You adopt this as your testimony for this proceeding?

A Yes, I do.

Q Captain Lithgow, you have before you a three-page document containing 13 questions?

A I do.

Q And did you prepare the responses contained therein?

A Yes, I did.

Q Are there any corrections or additions you wish to have made in that document?

A None.

Q Is that document true and correct to the best of your knowledge and belief?

A Yes, it is.

Q And do you adopt this as your testimony in this proceeding?

A I do.

MR. CHANDLER: Mr. Chairman, I would ask that the completed questionnaires of Captains Edward Bauerlein, Clark Billie, Donald Ufford, and David Lithgow be incorporated in the transcript as if read.

CHAIRMAN ROSENTHAL: Any objections.

(No response.)

CHAIRMAN ROSENTHAL: It will be so incorporated in the record as if read.

MR. CHANDLER: Thank you. I'll supply the reporter with the required number.

Mr. Chairman, before making these pilots available for cross-examination, I would have a few additional questions, if I may?

CHAIRMAN ROSENTHAL: Yes.

BY MR. CHANDLER:

Q Captain Billie, on page two of the questionnaire, question No. [illegible], the question being: Please describe what you

1. Q. What is your name and by whom are you employed?

A. My name is Edward Beuerlein and I am employed by Trans World Airlines.

2. Q. In what capacity are you currently employed and how long have you been in that position?

A. I am currently a Captain and I have been so employed since August 1968.

3. Q. Briefly describe your prior professional (including military) experience and training.

A. I entered the USAF in June 1951 and served as a pilot in the USAF until October 1955. Upon release from the USAF, I was employed by TWA in December 1955.

4. Q. On what aircraft are you now and were you, in the past, rated?

A. Presently flying B-707 and previously flew Constellation Aircraft as Captain.

5. Q. Regarding your present position, could you please describe your duties.

A. Captain on B-707 flying scheduled flights within USA during winter months and international flights on B-707 during summer months.

6. Q. Have you ever piloted an aircraft into and out of Harrisburg International Airport (HIA)?

A. Yes.

7. Q. Have you done so since construction of the Three Mile Island Nuclear Station has been completed?

A. Yes.

For the following questions, please assume you are piloting an aircraft of 200,000 or greater, which, for purposes of this proceeding, include all models of the Boeing 707, 747, McDonnell Douglas DC-8, DC-10 and Lockheed L-1011.

8. Q. Please describe what you would consider to be an appropriate approach to Harrisburg International Airport?

A. Under instrument conditions either a radar vectored approach to RW 13 or RW 31. Under visual conditions; a radar vector to a visual approach to either runway.

9. Q. Are there any airport, company, or FAA regulations, rules, instructions, guidance, directives, or procedures that influence your prior answer?

A. Only weather conditions dictate type of approach.

10. Q. Do you know whether MDT has an ILS? (Harrisburg International-Olmsted Airline designator is MDT.)

A. Yes, Runway 13 and Runway 31.

11. Q. Would that influence your prior answer?

A. Yes, weather conditions at time of arrival determine minimum altitude for decent to landing using ILS.

12. Q. Assuming you were given VFR clearance, would that affect your prior answer?

A. Yes, weather conditions when good do not require ILS but use ILS for reference at all airports.

13. Would you, and under what circumstances, make an approach to the airport, flying over the TMI nuclear plant?

A. Not directly over but around the west, south, and east of the plant when making a visual approach to RW 31 from the west. The plant at night is a good reference point for RW 31.

14. Q. On those occasions when you have flown into HIA indicated in answer to question 7, have you flown over the TMI nuclear plant?

A. Not directly over the plant.

15. Q. When taking off from MDT, are there any airport, company, or FAA regulations, rules, instructions, guidance, directives, or procedures, that prescribe your flight path?

    A. Yes, departing RW 31 climb RW heading to 1500' before turning on course, and RW 13 climb RW heading to 1000' before turning on course.

16. Q. Taking your answer to Question 15 into consideration, are there circumstances under which you would overfly the TMI nuclear plant during a takeoff?

    A. No.

17. Q. On those occasions when you have flown from HIA indicated in your answer to Question 7, have you flown over the TMI nuclear plant?

    A. No.

18. Q. On takeoff and landing at HIA, please estimate how close you pass the TMI nuclear plant.

    A. On takeoff, about 1-1/2 miles using RW 13; on landing, about 1-1/2 miles using RW 31.

1. Q. What is your name and by whom are you employed?

A. My name is Clark Billie and I am employed by Trans World Airlines.

2. Q. In what capacity are you currently employed and how long have you been in that position?

A. I am currently Pilot and I have been so employed since 1964. Hired Sept. 1964 as Co-Pilot Boeing 727 - Convair-880 - upgraded to Captain 1968 - Became Captain Instructor 1976 until present (Jan. 1980).

3. Q. Briefly describe your prior professional (including military) experience and training.

A. USMC Fighter Pilot 3-1/2 years, TWA Co-Pilot Constellation, B-727, B-707, B-747 Convair-880, TWA Captain B-727, B-707, B-747, Instructor TWA 707, 747 (4 years).

4. Q. On what aircraft are you now and were you, in the past, rated?

A. B-727, B-707, B-720, B-747, Learjet (Airline Transport Rating).

5. Q. Regarding your present position, could you please describe your duties.

A. Pilot Instructor training and checking TWA pilots on the 3-747. Also training USAF and some Greek (Olympic Airways) pilots. This instructions is done both in a 747 simulator and/or aircraft.

6. Q. Have you ever piloted an aircraft into and out of Harrisburg International Airport (HIA)?

A. Yes. 707's and 747's.

7. Q. Have you done so since construction of the Three Mile Island Nuclear Station has been completed?

A. Yes.

For the following questions, please assume you are piloting an aircraft of 200,000 or greater, which, for purposes of this proceeding, include all models of the Boeing 707, 747, McDonnell Douglas DC-8, DC-10 and Lockheed L-1011.

8. Q. Please describe what you would consider to be an appropriate approach to Harrisburg International Airport?

   A. ASR to Runway 13 or 31, ILS to Runway 13 back course ILS (without glideslope) to Runway 31, and visual approaches to Runways 31 and 13.

9. Q. Are there any airport, company, or FAA regulations, rules, instructions, guidance, directives, or procedures that influence your prior answer?

   A. Yes, FAR's, Airplane Flight Handbook, Company Policy, and the Olmsted Tower SOP.

10. Q. Do you know whether HIA has an ILS?

   A. Yes.

11. Q. Would that influence your prior answer?

   A. Yes.

12. Q. Assuming you were given VFR clearance, would that affect your prior answer?

   A. No, visual approaches are common in the VFR and training environments.

13. Would you, and under what circumstances, make an approach to the airport, flying over the TMI nuclear plant?

   A. No.

14. Q. On those occasions when you have flown into HIA indicated in answer to question 7, have you flown over the TMI nuclear plant?

A. No .

15. Q. When taking off from HIA, are there any airport, company, or FAA regulations, rules, instructions, guidance, directives, or procedures, that prescribe your flight path?

A. Yes, FAR's, Airplane Flight Handbook, Company Policy, and the Olmsted Tower SOP.

16. Q. Taking your answer to Question 15 into consideration, are there circumstances under which you would overfly the TMI nuclear plant during a takeoff?

A. No .

17. Q. On those occasions when you have flown from HIA indicated in your answer to Question 7, have you flown over the TMI nuclear plant?

A. No .

18. Q. On takeoff and landing at HIA, please estimate how close you pass the TMI nuclear plant.

A. On takeoff, about 1-1/2 miles; on landing, about 1-1/2 miles.

1. Q. What is your name and by whom are you employed?

A. My name is Donald L. Ufford and I am employed by Evergreen International Airlines, Inc.

2. Q. In what capacity are you currently employed and how long have you been in that position?

A. I am currently System Chief Pilot and I have been so employed since February, 1978.

3. Q. Briefly describe your prior professional (including military) experience and training.

A. 1966-70 American Flyers Airlines - line pilot on L-188 aircraft
1971-72 McCulloch Int'l Airlines - line pilot on Boeing 707
1972-74 Modern Air, Inc. - line pilot on Convair 990
1974-76 Evergreen Int'l Airlines - line pilot L-188/DC-8
1976-78 Evergreen Int'l Airlines - Equipment Chief Pilot on DC-8/DC-9
1978-Present Evergreen Int'l Airlines - System Chief Pilot

4. Q. On what aircraft are you now and were you, in the past, rated?

A. DC-9, DC-8, L-188, CV-990, B-707

5. Q. Regarding your present position, could you please describe your duties.

A. (1) the selection of all flight deck personnel.
(2) discipline of all flight deck personnel, should it be required, to ensure compliance with regulations and with Company policy & procedures.
(3) direct supervision & utilization of flight deck crews.
(4) development of procedures for safe & economical operation.
(5) line qualification, initial operation experience, and proficiency of flight deck crews.
(6) the development & monitoring of standard procedures & the supervision of the flight crew training program.

6. Q. Have you ever piloted an aircraft into and out of Harrisburg International Airport (HIA)?

A. Yes.

7. Q. Have you done so since construction of the Three Mile Island Nuclear Station has been completed?

A. Yes.

For the following questions, please assume you are piloting an aircraft of 200,000 or greater, which, for purposes of this proceeding, include all models of the Boeing 707, 747, McDonnell Douglas DC-8, DC-10 and Lockheed L-1011.

8. Q. Please describe what you would consider to be an appropriate approach to Harrisburg International Airport?

A. Depending on existing weather conditions:

Runway 31	Runway 13
(1) visual approach	(1) visual approach
(2) localizer back course	(2) ILS
(3) radar (ASR)	(3) localizer approach
	(4) radar (ASR)

9. Q. Are there any airport, company, or FAA regulations, rules, instructions, guidance, directives, or procedures that influence your prior answer?

A. Yes. These are the only approved approaches for our company aircraft at this airport.

10. Q. Do you know whether HIA has an ILS?

A. Yes. It does for Runway 13 and a back course localizer for Runway 31.

11. Q. Would that influence your prior answer?

A. No.

12. Q. Assuming you were given VFR clearance, would that affect your prior answer?

A. No.

13. Would you, and under what circumstances, make an approach to the airport, flying over the TMI nuclear plant?

A. No.

14. Q. On those occasions when you have flown into HIA indicated in answer to question 7, have you flown over the TMI nuclear plant?

A. <u>Never</u>.

15. Q. When taking off from HIA, are there any airport, company, or FAA regulations, rules, instructions, guidance, directives, or procedures, that prescribe your flight path?

A. Company procedures are to climb on runway heading to 1500' AGL prior to turning on course. FAA requires runway heading to 1000' on Runway 13 departures and to 1500' on Runway 31 departures.

16. Q. Taking your answer to Question 15 into consideration, are there circumstances under which you would overfly the TMI nuclear plant during a takeoff?

A. <u>No</u>.

17. Q. On those occasions when you have flown from HIA indicated in your answer to Question 7, have you flown over the TMI nuclear plant?

A. <u>Never</u>.

18. Q. On takeoff and landing at HIA, please estimate how close you pass the TMI nuclear plant.

A. On takeoff, about 1-2 miles; on landing, about 1-2 miles.

1. Q. What is your name and by whom are you employed?

A. My name is David Lithgow and I am employed by Transamerica Airlines.

2. Q. In what capacity are you currently employed and how long have you been in that position?

A. I am currently a DC-8 Captain and I have been so employed since June 1978.

3. Q. Briefly describe your prior professional (including military) experience and training.

A. USAF 1964-1970; trained in and flew T-37, T-38, L-382, DH-4, and L-300. Worked as an instructor pilot in L-382 and L-300. Civilian experience: DC-8 F/O and Captain at Transamerica Airlines.

4. Q. On what aircraft are you now and were you, in the past, rated?

A. DC-8, DH-4, L-382, L-300.

5. Q. Regarding your present position, could you please describe your duties.

A. Final command responsibility for DC-8 operation under FAR Part 121 and ICAO regulations.

6. Q. Have you ever piloted an aircraft into and out of Harrisburg International Airport (HIA)?

A. Yes.

7. Q. Have you done so since construction of the Three Mile Island Nuclear Station has been completed?

A. I do not know when it was completed.

For the following questions, please assume you are piloting an aircraft of 200,000 or greater, which, for purposes of this proceeding, include all models of the Boeing 707, 747, McDonnell Douglas DC-8, DC-10 and Lockheed L-1011.

8. Q. Please describe what you would consider to be an appropriate approach to Harrisburg International Airport?

A. ILS RWY 13, LOC (Back-CRS) or ASR RWY 31.

9. Q. Are there any airport, company, or FAA regulations, rules, instructions, guidance, directives, or procedures that influence your prior answer?

A. Yes.

10. Q. Do you know whether HIA has an ILS?

A. Yes.

11. Q. Would that influence your prior answer?

A. Yes.

12. Q. Assuming you were given VFR clearance, would that affect your prior answer?

A. No.

13. Would you, and under what circumstances, make an approach to the airport, flying over the TMI nuclear plant?

A. No.

14. Q. On those occasions when you have flown into HIA indicated in answer to question 7, have you flown over the TMI nuclear plant?

A. No.

15. Q. When taking off from HIA, are there any airport, company, or FAA regulations, rules, instructions, guidance, directives, or procedures, that prescribe your flight path?

    A. Yes.

16. Q. Taking your answer to Question 15 into consideration, are there circumstances under which you would overfly the TMI nuclear plant during a takeoff?

    A. No.

17. Q. On those occasions when you have flown from HIA indicated in your answer to Question 7, have you flown over the TMI nuclear plant?

    A. No.

18. Q. On takeoff and landing at HIA, please estimate how close you pass the TMI nuclear plant.

    A. On takeoff, about 2 NM; on landing, about 1.5 NM.

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consider to be an appropriate approach to Harrisburg International Airport?

Your answer states, "ASR to Runway 13 or 31, ILS (without glideslope) to Runway 31, and visual approaches to Runways 31 and 13."

If I may ask, can you describe, perhaps geographically, what that approach would mean, and I would ask that you feel free to use the exhibits here.

MR. CHANDLER: I have, Mr. Chairman, provided copies of Staff Exhibit 1, 2, and 3, which were received in evidence in December 1978 here.

I will point out to the Board and parties that one modification has been made to what was previously Staff Exhibit 2, and that is, it has an overlay. An overlay has been placed over it indicating a center line extended for approximately five statute miles with the angle down to Three Mile Island, and the statute miles to that would be perpendicular from Three Mile Island up to the center line extended, and the approximate mileage there.

I think for purposes of perspective, it may be helpful to the Board and parties if I asked the individual pilots to describe using those charts and maps, what they would consider to be an approach to Harrisburg International Airport. In particular, utilizing Runway 31.

CHAIRMAN BECHHOEFER: All right, but I cross that

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the witnesses will identify specifically what they are referring to on the charts so that individuals who will have occasion subsequently to review their testimony will be able to determine precisely what portion of the map they're referring to.

MR. CHANDLER: Yes, I will ask that they in geographic terms describe where that approach might take them.

I will also make an attempt and ask that each pilot that they please pencil, try and mark an approach into Harrisburg Airport. I am trying to provide three different colors so that each one can be identified. It is my hope that if we are successful, I will then offer to have this photoduplicated and subsequently offered as an exhibit in the proceeding.

I am told by our photographic and graphics people that that process isn't always 100 percent possible because you use a grease pencil on acetate sheets, so I will ask that they each identify very clearly what they are describing.

CHAIRMAN ROSENTHAL: Very well, Mr. Chandler.

MR. CHANDLER: Thank you.

BY MR. CHANDLER:

Q Captain Billie, if you would perhaps approach --

MR. CHANDLER: For the record, I will ask that [illegible] use a blue grease pencil.

CHAIRMAN ROSENTHAL: I wish to make certain that

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counsel for the applicants and the representative of the intervenors can see the chart.

Mr. Trowbridge?

MR. TROWBRIDGE: Yes, I can see the chart.

CHAIRMAN ROSENTHAL: I assume that, Mr. Treby, you may have to move, if you wish to.

MR. TREBY: Yes.

MR. CHANDLER: I would point out that Captain Billie is making reference to Staff Exhibit 2, with the additional overlay.

THE WITNESS: The particular approach to Runway 31 most commonly used, the instrument approach, is the back course, ILS approach to Runway 31.

The approach begins at the eight-mile radar fix. Radar is required for the approach. From the eight-mile fix, descent is made to 1900 feet, so that at the five-mile fix which is approximately this position here. This is the final approach fix for the approach which would always be the beginning of the approach for at least -- this gate must be met for the approach. So at five miles, the pilot would be at 1900 feet, and begin his descent from that point to reach 860 feet prior to descending further. That is the minimum descent altitude, 860 feet, so he would be oncourse at five miles and follow this course to the runway, descending from 1900 feet at five miles to 860 feet until he sees the runway, identifies his visual glideslope and then continues and then continues his glideslope to the landing. That is the ILS approach 31.

CHAIRMAN ROSENTHAL: At what distance did you reach 860?

THE WITNESS: The distance would depend on the rate of descent from 1900 feet.

There's not a glideslope associated with this, so the pilot is free to leave the five-mile fix and descent 860 feet from that point. That is just about 1000 a minute, would put him somewhere in the vicinity between two and three miles when he reaches 860 feet, depending upon the winds, et cetera but it would be between two and three miles.

To continue then with the visual approach slope, there is a visual approach slope indicator or vasi (phonetic) indicator on the runway, at that point, he would pick it up visually and slide down the glideslope.

The other types of approaches that can be done at this runway would be the approach surveillance radar approach, also a published approach from Middletown Airport. It would be done much the same way, only radar would tell the pilot when to leave the specified altitude. Be done on radar without the guidance electronic guidance.

We also do visual approaches to this runway, and I think that's probably -- this line depicts the approach surveillance radar course, and it also depicts the ILS course. So I won't draw that line in. As well as that, you could do a visual approach, in other words in clear weather at a time when we're working just with the tower, you could be cleared to make a visual approach to the airport.

If you took off, for example on Runway 31, and then were going to come around and make a visual landing on 31, that's the pattern that I am going to draw this time.

Taking off on Runway 31, the tower requires you to turn, a right turn, north of the field, prior to the Turnpike Bridge out here. So, you would take off on 31, make a right turn to a generally northern heading, then further -- approximately three miles north of the runway, another right turn to take you downwind or paralleling the runway, flying at approximately three miles from the runway at 2000 feet, normal pattern altitude. Continue down to approximately three miles beyond the end of the runway, and again -- now this time turning perpendicular to the runway or the inbound course, beginning to descend from 2000 feet so as to intercept the final approach course between two and three miles sat approximately 1000 feet. This would be the normal visual pattern for that runway. At that point, picking up the visual approach slope indicator again, the vasi indicator, and flying a normal approach to the runway.

These are the normal landing patterns.

BY MR. CHANDLER:

Q Captain Billie, first of all, earlier you indicated that that line line represent ASR. Would you identify it so that the transcriopt will be clear? What you meant by "that line"?

A The inbound?

Q Yes.

A The line that is drawn on the map that depicts the statute miles and is on center line with the runway up to five statute miles, the inbound course line to the runway.

Q Captain Billie, in making a visual approach, is there any practice to land from the south and intercept the center line extended from a southerly direction, that would be left turn-ins?

A No.

In fact, the -- it would be quite unusual. It's not impossible, however, the tower's standard operating procedure, and, in fact, even these approaches on-- or circling approaches, which, again, we could also make an ILS approach, and I should have probably have point this out. An ILS approach could be made to Runway 13, the opposite direction, and there's a circle to land on Runway 31.

If this procedure were, in fact, done, the approach would be broken off at approximately this point, and circling approach then would follow the same course that the visual approach would fly. The course is specified on the charts.

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That circling approach must be made north of the airport. All of the approaches must be made north of the runway at this airport.

DR. JOHNSON: Is that a peculiarity of the Harrisburg International Airport? Or is that a standard procedure for all airports, that the circling maneuver take place to the north? However, according to my map, north is not up on the chart, since you have in front of you -- north is somewhat of a diagonal, off to the left upper side of that diagram. Is that your understanding.

THE WITNESS: This runway actually runs northwest, yes. I would say that this map is oriented, basically, east-west. And that this would be north of the -- you see the runway northwest.

The question is, is it peculiar to Harrisburg, and the answer is, it's not peculiar in the sense that it's not done in any other airport, but that procedure is peculiar to Harrisburg, the north approach.

DR. BUCK: So, does that happen to be because of the radar setup or --

THE WITNESS: It's mostly terrain. In this vicinity, you have high terrain, and, of course, you also have Capital City Airport down here. So, it's the terrain.

DR. JOHNSON: Well, you've taken us through the case where you take off from Harrisburg and then land back

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in Harrisburg. It does not seem to be particularly important.

How about a plane that's coming in from Pittsburgh or Chicago? Now, under visual flight rules, how might that plane enter the landing pattern at Harrisburg International Airport?

THE WITNESS: If I may, I will refer that question to Captain Beuerlein. My experience at Harrisburg has been basically in training, and I have not flown from Chicago or Pittsburgh. I come in from New York and then stay to pattern.

DR. JOHNSON: Well, coming in from New York, woul' you -- how would you get into the landing pattern?

THE WITNESS: It would be vector to this approach, flying in from the northeast, into this approach and right into the runway.

BY MR. CHANDLER:

Q Could you describe what you mean by "into this approach"?

A Okay.

Q Perhaps draw --

A Okay. It would be vectored -- I don't know the exact fix, but you would be coming in this direction be vectored to the final approach fix, five miles or the eight-mile radar fix. Then fly the course in. You would not come in from the south.

DR. JOHNSON: Yes, but this would be under visual flight rules since you would be vectored to that point?

THE WITNESS: No, that would be under instrument flight.

DR. JOHNSON: My question had reference to visual rule. If you came in from New York under visual rule, how might you do it?

THE WITNESS: Probably in exactly the same manner. We'd fly visually to that point to identify. We wouldn't fly visually without having tuned the station to know what it is because you might not see it for 20 miles. I would have this tuned until I --

DR. JOHNSON: Tuned to what, the ILS or the airport?

THE WITNESS: The ILS radio, the ILS frequency.

DR. JOHNSON: Thank you.

THE WITNESS: Yes, sir.

BY MR. CHANDLER:

Q Captain Billie, a couple of more questions.

Would it be possible for you, by the way, to indicate air speeds, relative air speeds, at various points on the lines you've drawn?

A Yes.

At lift-off, at takeoff, the air speed would be, depending upon the airplane. I am talking now about, perhaps, 747's. At lift-off, you would be obtaining speeds of approximately 170 knots, flying this pattern downwind, 2000 feet above and at 200 knots. Then when you commence to turn back across what we call the base leg or perpendicular to the runway, slowing from 200 knots to 180, 160, and then on final approach, maybe 145 to 155 knots, depending upon the weight of the airplane.

Q Thank you.

Also, do you -- in your opinion, are there any unique features attributable to Harrisburg Airport, in terms of its meteorology, geography, topograhy, electronic guidance equipment available? That type of consideration which might have some bearing on its degree of hazard relative to other airports that you are familiar with?

A I don't think to any extreme sense -- the topography, some of these high hills, the river, particular meteorology perhaps some fog in that area, but nothing that would be much different from many airports that we fly into. Their pretty much the same.

Q Now, you've indicated in your response to questions 9 and 15, and just briefly those questions request response as to whether there are any airport, company or FAA regulations, rules, instructions, guidance, directives, or procedures that influence with respect to pilot's answer regarding approaches and takeoffs in Harrisburg Airport. And you have indicated in response to question nine, "Yes, there are FAR's, Airplane Flight Handbook, Company Policy, and the Olmsted Tower SOP; have the same response to question 15.

Could you just indicate briefly what that kind of information might be. What it tells you to do?

A Okay.

We're bound first by the Federal Air Regulations because we fly into an airport.

These approach charts are, in fact, based on Federal air regulations and depict the approaches that we make which are the ones I have shown you here today.

We're further bound by company policy which requires us to fly these approaches even under visual conditions to tune and identify the ILS if there's a glideslope, to stay outside the glideslope. We're bound by the tower operating procedure, and when I say "we", in this case I'm speaking about training personnel. We have information from this tower, because we use it as a training field when we find the time, and we're also bound by that standard operating procedure which outlines what I've shown you here.

Those are basically -- we didn't get into the takeoff on this thing, but there are further restrictions involving takeoff, and those of the FAR rules.

Q Can you just describe, for example, what those might be on takeoff?

A Okay.

On takeoff on Runway 13, and I'm speaking about flying this direction. --

Q This direction being --

A Being southeast.

On takeoff, it's required and it's written on the charts here, that I employ the departure procedure on Runway 13, find runway heading to 1000 feet before turning on course. This would put us in the vicinity of two miles under normal conditions, so we must fly straight ahead to 1000 feet prior to turning on course, be it south, or north or whatever.

Q Thank you.

Now, that would explain that. Now, landing though -- can you just, in terms of statute miles, could you give us some approximation on where a VFR you would intercept the center line extended? Perhaps you've answered that, but just so it's clear.

A I think I have.

We turn, basically, it would be between two and three miles from the end of the runway. This could be extended, depending upon the traffic and other circumstances, but it would not be prior to that time. If you turn inside two miles, it would be too close to make an approach to the runway. So, from two miles, basically, normal two to three miles beyond the runway, we'd be turning base, be turning intercept the center line runway between two and three miles.

Q Now, in either an approach or a takeoff from

Harrisburg International Airport, could you explain to us, what effect, if any, the cooling towers at Three Mile Island may have on your flight path?

A I've never flown directly over the cooling towers. They are quite large, and are a good visual reference, and perhaps turning downwind when I turn to space flight, they might be used as a visual reference, that's the only time that I've had occasion to use them, as a reference point to turn into.

Q Thank you very much, Captain Billie.

MR. CHANDLER: I have no further questions of Captain Billie at this time, but I would ask that I proceed with the next witness and then --

CHAIRMAN ROSENTHAL: Well, the question is whether the applicatns and intervenor wish to question -- conduct cross-examination of each pilot individually upon the completion of his direct examination or would perfer to wait until all the pilots have testified. We can do it either way.

MR. TROWBRIDGE: My preference is to wait, Mr. Chairman.

CHAIRMAN ROSENTHAL: Doctor Kepford?

DR. KEPFORD: I think I'd rather go one at a time.

CHAIRMAN ROSENTHAL: One at a time -- all right, then -- Do you want the captain to remain at the chart, or can he resume his seat, Dr. Kepford?

DR. KEPFORD: If he would be more comfortable, he can sit down.

MR. CHANDLER: I can provide him with a chair here.

THE WITNESS: I'm fairly comfortable.

CROSS-EXAMINATION

BY MR. KEPFORD:

Q Captain Billie, you say you fly in and out of Harrisburg primarily on training flights?

A That's correct.

Q You've flown in and out in a revenue-producing flight?

A I never have.

Q As I recall in your question -- in your answers to the questions, you mentioned you had flown Boeing 747's?

A That's correct.

Q This year.

A Not 1980, I don't believe, I'd have to look, I'm not sure of that. Certainly last year.

Q 1979?

A Yes.

Q About how many times?

A You mean last year?

Q Yes.

A Three.

Q Thank you.

A I would have to confirm that by looking at my log book, but this would be about right.

DR. JOHNSON: Excuse me, Dr. Kepford, may I --

DR. KEPFORD: Sure.

DR. JOHNSON: The three flights refers to 1979, is that correct?

THE WITNESS: Yes, sir.

DR. JOHNSON: Thank you.

BY DR. KEPFORD:

Q The flight patterns you were talking about, do they pertain to training path flights?

A Yes, sir.

DR. KEPFORD: No further questions.

CHAIRMAN ROSENTHAL: Mrs. Carter?

MS. CARTER: No questions.

DR. JOHNSON: Captain Billie, what was the purpose of the training flight that you were engaged in at Harrisburg? Was it training relevant to landing at Harrisburg International Airport or was it training in general?

THE WITNESS: In general.

DR. JOHNSON: Is Harrisburg used as a training field by TWA routinely?

THE WITNESS: Yes.

Well, by routinely, you have to define what you mean by that. Three times is not very frequent. You will have to let me explain just briefly. We use another airport primarily. This is not our first choice.

DR. JOHNSON: But it is used?

THE WITNESS: Yes, right.

DR. JOHNSON: Are you a captain or a -- what does training mean? Is it requalification type training?

THE WITNESS: Initial qualification, requalification and proficiency training.

DR. JOHNSON: But in your case, it would be requalification and proficiency?

THE WITNESS: Not trainning for myself, I'm training other pilots.

DR. JOHNSON: I see. Excuse me. I thought --

You said three times a year, does this -- last year you referred to three times. Does this mean that you engaged in three training exercises which might have included a number of landings and takeoffs?

THE WITNESS: Yes, sir.

DR. JOHNSON: How many touch and go's might you in one training exercise?

THE WITNESS: We might do 20, maximum 25.

DR. JOHNSON: All following in the same pattern as you described on there?

THE WITNESS: Following these patterns, many of them, or I should say most of them are the visual patterns, some of them in the ILS or the back course ILS.

DR. JOHNSON: Thank you.

DR. BUCK: Captain Billie, what's the purpose of using Harrisburg on the three-times-a-year situation? You say you normally use other airports. Are they too crowded or what?

THE WITNESS: We have a priority to which airports we use and it's based on the proximity to New York. We prefer to use those. We use Atlantic City, primarily, many times. And then we have a priority of other airports and Atlantic City is one of them.

DR. BUCK: And what is the reason for coming to Harrisburg instead of going to the ones in high priority?

THE WITNESS: Well, Atlantic City -- the times that I was here, Atlantic City was unussable for one reason or another, the ILS was inoperative, the wind was --

DR. BUCK: Okay, thank you very much.

CHAIRMAN ROSENTHAL: Captain, to get clear on your answer to question nine, you on a training flight were to fly over the Three Mile Island facility, you understand that you would be in violation of precisely what, company policy?

THE WITNESS: No, sir, that's strictly in violation of --

CHAIRMAN ROSENTHAL: You would not be in violation of company policy? And what about Federal regulations?

THE WITNESS: No.

CHAIRMAN ROSENTHAL: So, you couldn't legally and without, as you understand, the requirements of the FAA and consistent with company policy, fly over the Three Mile Island facility, but what you're telling us is that you don't do it. That is the substance of your testimony?

THE WITNESS: Yes, sir, that's correct.

CHAIRMAN ROSENTHAL: Thank you.

MR. CHANDLER: If I may just expand on your question for a moment, Mr. Rosenthal, perhaps perhaps for clarity.

REDIRECT EXAMINATION

BY MR. CHANDLER:

Q Captain Billis, assuming the facility were operating and you were cleared for a BFR approach, would you be permitted to fly or would you be able to fly over the facility, assuming you had a visible flume?

A You would be able to do it. You would be legally able to do it. It would not a good procedure for us because of the possible turbulence that would come out of it.

Q You don't believe, in other words, that the flume might have struck in sight of airport?

A If it were actually a visible kind of station, it would not then visually fly through the clouds, I think, is a point. You would not be able to do that.

Q So, then if you were to make a VFR approach to Harrisburg Airport, and there were a visible plume from the towers of Unit 2, you legally could not, is that correct, fly over that? Through that?

A You see the strictest definition for visual flight rules, you must maintain a visibility of three miles, and flying through that, you probably --

MR. CHANDLER: Thank you. I have no further questions.

DR. JOHNSON: I would like you to expand a little bit on what you said about flying through the turbulence. Did I understand you correctly to say you would not fly over the tower normally, even though there was no visible condensation?

THE WITNESS: That's correct.

DR. JOHNSON: And what was the reason you gave for that?

THE WITNESS: The reason I gave is turbulence. If those towers were actually heated, I know nothing about the station, but if there is heat rising, it causes a turbulence at altitude. Normally, I would say that they do produce some heat.

Let me expand just briefly on that. If I were flying a visual pattern even from the ground, this would be a point at which I would turn around, normally, between like two and

2N-30

three miles, not over that. But for those two reasons, it would be too close and it wouldn't be good practice to just fly over that, turbulence.

DR. JOHNSON: What if the towers were operating and --

End 2N

DR. JOHNSON: What would be the effect on the aircraft of flying through that turbulence?

CAPTAIN BILLIE: It would be the same, I assume, if the heat were still there --

DR. JOHNSON: No, no. I mean in any event, what would be the -- would the passengers notice it as you flew through that turbulence?

CAPTAIN BILLIE: Yes.

DR. JOHNSON: Would it present any real hazard in terms of the pilot's ability to maneuver the aircraft into its final landing pattern; is it that much turbulence, or is it a minor degree of turbulence, in your opinion?

CAPTAIN BILLIE: It would be an opinion. I have not done it; I would suspect that it would not be a safety problem in handling the airplane.

MR. CHANDLER: I choose to remain silent; I think I normally would have objected to part of that question, because I think that question should have been phrased with the context of flying over Three Mile Island with the appropriate distances from the airport.

In other words, it's not only flying through the turbulence, but it is picking up the center line extended, given the distance from the airport at which that would take -- I think that's your question.

DR. JOHNSON: I was actually trying to get a pilot's opinion of what flying through the turbulence generated by a cooling tower is like. There was some discussion at our hearing a little over a year ago regarding this matter and no one at that hearing was a pilot and therefore, no one was able to give any testimony as to the effect of this turbulence.

However, the existence of the turbulence as a problem was postulated. If I asked an improper question, I appologize.

MR. CHANDLER: No, sir.

DR. BUCK: I think you are talking only about the turbulence when you are low enough to be in a landing or takeoff pattern, right? Is that what you are asking about, a turbulence only when you are at altitudes such that you could be in a landing or takeoff pattern. You are not worried about the airplane flying over at 10,000 feet for example; or are you?

DR. JOHNSON: No, not necessarily.

DR. BUCK: Captain Billie, I might ask you this question while you are up there. You said that you were only concerned about training flights, but there must be -- or should be, I guess -- some sort of a minimum turning radius in going into a landing pattern, shall we say, just a straight approach on a landing.

What would you consider, say in your landing and takeoff pattern that you have up to the north, what would you consider to be the closest approach to that long, horizontal line that comes down parallel to the river, you know, the one that's coming -- you are in your pattern around, now, going off the end of 13 and making a right-hand turn, coming down along the river and approaching your turn for the final approach, shall we say.

How close could that lon, parallel line be, the line that's parallel to the river and parallel to the landing line itself, how close could that be, in miles, to the actual runway and still make a safe turn?

CAPTAIN BILLIE: Three miles would be my --

DR. BUCK: About 3 miles. And, the same would be if you were coming in on a similar approach on the south side of the river, you would have to be about 3 miles southwest of the runway in order to make a safe turn?

CAPTAIN BILLIE: Yes, sir.

DR. BUCK: That's your thought?

CAPTAIN BILLIE: Yes, sir.

DR. BUCK: Okay, thank you very much.

And, would your minimum distance out from the end of the runway in which you could be on your straight line approach, I gathered you thought that would be about 3 miles at a minimum?

CAPTAIN BILLIE: Yes, sir; absolutely.

DR. BUCK: Okay, thank you.

CHAIRMAN ROSENTHAL: What specific aircraft are we talking about or does this apply to all aircraft?

CAPTAIN BILLIE: 747 and the 707.

CHAIRMAN ROSENTHAL: Okay, so your response to Dr. Buck's question was in the context of --

DR. BUCK: I was only talking about heavy aircraft; I'm not talking about --

CHAIRMAN ROSENTHAL: I mean, it was in the context, specifically, of those two type plance?

CAPTAIN BILLIE: Yes, sir.

CHAIRMAN ROSENTHAL: All right.

Is there any further questions of Captain Billie at this point? Dr. Kepford?

DR. KEPFORD: Captain Billie, if you were coming in from the south, as you mentioned earlier, and went past Three Mile Island, about what altitude would you be at that point?

CAPTAIN BILLIE: You mean, at approximately what altitude would I pass Three Mile Islan?

DR. KEPFORD: Yes.

CAPTAIN BILLIE: If I were going to turn in directly within the 5 miles, it would be between 1- and 2,000 feet.

DR. KEPFORD: Okay. Suppose you entered the landing pattern -- the center line extended about 3 miles out; about what would your altitude be?

CAPTAIN BILLIE: My intercept would be approximately 1,000 feet, based on a 3 degree glide slope from that runway.

DR. KEPFORD: Thank you.

CHAIRMAN ROSENTHAL: I take it then, Mr. Trowbridge, you still wish to defer your croxx-examination.

MR. TROWBRIDGE: Yes, Mr. Chairman; I would prefer to wait.

CHAIRMAN ROSENTHAL: All right. If there is no further questions of Captain Billie at this point, Captain, you can resume your seat.

CAPTAIN BILLIE: Thank you.

DIRECT EXAMINATION BY MR. CHANDLER:

Q Captain Beuerlein.

Also, with respect to your response to Question 8, and similarily, Question 9 and 15, as we went through right now with Captain Billie, could you, perhaps, describe for us using the map, what you would consider to be an appropriate approach into Harrisburg International Airport, and a takeoff as well?

Now, for the record, Mr. Chairman, Captain Billie indicated he essentially is involved in training operations.

I would ask if Captain Beuerlein would indicate what kind of -- what the purpose of the flights, if you will, that he is familiar with into Harrisburg Airport.

A I have flown scheduled flights into Harrisburg Airport, Middletown.

CHAIRMAN ROSENTHAL: From where?

CAPTAIN BEUERLEIN: From Chicago. Basically, our flight 707 comes from Chicago, non-stop to Harrisburg, Pennsylvania, landing at Middletown Airport.

BY MR. CHANDLER:

Q If I could give you the blue pencil.

A Using the U.S. Geological Survey Map also, I have come in for an ILS approach, landing to the southeast on runway 13, at -- I would say -- about 100 feet above minimum, which is 250 feet above the ground. So, I've come down to 350 feet before seeing the runway and land to the southeast.

Visual approaches; I have been vectored from a point approximately 5 miles to the west of Harrisburg VOR, visual omni (?) range, which is located off this particular map, but approximately 5½ miles to the west of Enola, which is on the west side of the river. And, I was cleared for a visual approach after stating that I could see the airport and continued the approach in a manner such as this, along the west side of the Susquehanna River, keeping in sight the airport at all times, and coming down to a point approximately three miles to the south of the runway at an elevation of about 2,000 feet.

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Q Two thousand feet above sea level? or the ground at that point?

A Mean sea level; indicated altitude -- I set it myself.

Q Right.

What is the elevation of the ground at the point you are indicating right now, southwest --

A It's approximately a thousand feet MSL.

Q That's the hill peaks --

A That's the hill right directly across from the airport.

MR. CHANDLER: If, if I may suggest, there is also an airport obstruction chart which may have some altitudes that either the Board or the witnesses may find useful. It's Staff Exhibit Number 3.

DR. BUCK: Mr. Chandler, I'm sorry; I'm having difficulty hearing you.

MR. CHANDLER: I'm sorry. I, I was indicating that if the Board and witnesses may find it useful to have reference to the airport obstruction chart, which is also available behind there, that has certain elevations that may be more readily identifiable.

THE WITNESS: The geographical area is in this position and states 960 feet. At a point abeam the end of the runway, I am turned on to this approach; but I use the Three Mile Island as a visual reference, especially at night. On these particular approaches, I've come in at night; and not only on the red lights on top of the stacks visible, but the string of white lights very, very good reference.

And using the Three Mile Island as a reference, I have turned on to an approach between two and three miles to the end of the runway. Using the ILS receiver of the aircraft as a reference for the approach to runway 31.

Now these are strictly VFR and visual reference with no relationship to radar or need of radar ground control.

DR. JOHNSON: Would you describe or characterize that approach as being a typical visual approach in which you would have to come around from the direction you're headed in and get back into the landing pattern or onto the runway extended for any airport?

THE WITNESS: Harrisburg is a, is a peculiar airport. The approach control is located in Capitol City. Capitol City previously was the airport servicing Harrisburg. In fact, I've landed there back in the days --

The approach control is located at this point. And when I was clear for an approach, for a visual approach, to runway 31 at Olmstead Middletown, I was cleared over to the tower. The tower, of course, is located in this airport complex.

So I was in constant communications now with Middletown. And this particular approach -- it's a standard left-turn approach. In fact, complicated as it might seem; but it's pretty standard for all airports, visual approach.

(Pause.)

DR. JOHNSON: Right.

If, if Three Mile Island Nuclear Power Plant was not there, would your approach coming from the south be any different? -- or coming from the west?

THE WITNESS: Be harder. Actually, of course, there's no lights in the river. The only lights you do have are the airport runway lights. When you get established onto the final approach, there is a visual approach slope indicator that lights, which aids in determining your glide path for landing.

There are lights along some of these other areas. This particular area on the west side of the river is unlighted. And so you have to be particularly wary of the elevation.

This area also is approximately 300 to 400 feet above the -- it's about 700 or 600 MSL in this area also. There are towers in this area that are well lighted, which are the -- highest being about 2,000 MSL.

But in this particular area there are no large areas of population as far as the lights at night. The Three Mile Island is excellent, an excellent area for visual turn.

BY MR. CHANDLER:

Q Captain Beuerlein, could you perhaps indicate your relative airspeeds at different points on that type of an approach?

A Well, prior to being cleared to original approach below 10,000 feet, it's 250 knots maximum indicated airspeed.

Flying this approach, we're slowing down to our flap extension speed, which is 220 knots.

Q At what, at what point?

A Approximately -- well, I'd say about two or three miles to the southeast of the VOR area, which is in this area here. Starting at 220 knots. And then tuning in the approach, slowing to about approximately 180 knots and then turning to final, slowing down to our final approach speed, which would be 10 knots above the minimum approach speed, which is in the area -- for the larger aircraft, it would be 125, 130 knots.

Q Could you indicate, if you would, where you approximated 180 knots?

A 180 knots would be on the downwind, parallel to the runway in the opposite direction.

Q And at the point that you turned around the Island over there?

A Around the island would be slowing to 140, then 120 in the final approach.

Q Thank you.

Captain Beuerlein, do you consider that there are any unique features about Harrisburg Airport in terms of either geography, topography, meteorology, what kind of guidance electroni equipment available, that may make or may affect the hazard relative, at Harrisburg relative to other airports you're familiar with?

A Well, it's the same electronic equipment as there are at other airports.

However, as I stated, the -- during periods of good weather, the excellent visibility that you receive from Three

Mile Island as a landmark for visual reference to the runway is excellent.

Q You've indicated approximately where you would intercept the centerline extended on a visual approach. In making an instrument approach, could you indicate approximately where you would intercept the centerline extended?

A Instrument approach would be at the eight-mile fix, as stated in our approach charts, which we carry with us on all flights. This is strictly radar vectored if you happen to have radar, ground-control radar.

Radar control would vector us to an eight-mile fix, which is off the map. And in order to continue inbound from the eight-mile fix, descending to a minimum fix altitude -- this is the final fix, the five-mile fix. And in the five-mile fix inbound, we would be descending to our minimum descent altitude, which would be 1,900 feet, five-mile fix, down to 860 feet, which is minimum descent altitude, until we visually receive the runway lights, the high-intensity runway lights of the airport.

And then we see the touchdown --

MR. CHANDLER: I have nothing further of Captain Beuerlein. He's available for cross-examination.

CHAIRMAN ROSENTHAL: Dr. Kepford?

CROSS-EXAMINATION BY DR. KEPFORD:

Q Captain Beuerlein, as you come in from Chicago and start your final turn to approach the runway centerline extended, and assuming you do it a number of times on a reasonably regular basis, what would be the kind of range of closest approaches or the range of actual approaches to the reactor itself? Would it be a mile? Would you be flying a mile from it? Two miles? Half a mile?

A About a mile and a half.

Q No closer?

A No really, no. Not myself in particular. I know of a, any known obstructions I steer away from.

(Pause.)

Q Have you ever flown a Boeing 70 -- 747 into Harrisburg International?

A No.

DR. KEPFORD: Thank you.

I have no further questions.

DR. JOHNSON: I'd like to ask a verifying question. When you said "a mile and a half" was the closest approach to the plant, was that referring to a visual flight rules landing?

THE WITNESS: Oh, yes. I'm referring, I'm referring to the pattern as depicted on the survey map. I'm coming around -- to this area. And also, as we turn onto our final approach, we're also in a bank.

And generally speaking, I avoid the known obstructions -- visual conditions.

Also, I avoid high-density areas for noise-abatement purposes.

And so I would make this approximately a mile and a half.

DR. JOHNSON: You would agree, would you not, in the way you have drawn it, it looks somewhat less than a mile and a half.

THE WITNESS: Looks closer, yes. I'm not an artist.

DR. JOHNSON: We didn't ask you to be. I just, I just wanted to make that clear.

THE WITNESS: Yes. When I say about "a mile and a half," using this as a reference the turn would be pro rata.

DR. JOHNSON: Would you also avoid, or do you have any opinion as to the wisdom of flying through the flume, a cooling tower, at this or any other power station?

THE WITNESS: If I saw a flume, I would very definitely not fly through it.

As stated by Captain Billie, in order to maintain a visual reference, do not fly through a cloud.

It's required, once you're cleared for a visual approach in this area, you must maintain visual reference to the airport; and flying through a cloud certainly doesn't --

DR. JOHNSON: Well, I was thinking more on the turbulence caused by the heated air rising.

Have you ever experienced that?

THE WITNESS: No. I've flown over nuclear power plants at high altitude, and there are no -- there is no suspected turbulence from that particular plant. There is turbulence, of course, in the mountains surrounding the area; and there are so many high ridges during the summertime especially. And also the heat rising from the land --

DR. JOHNSON: Right.

THE WITNESS: -- creates turbulent area.

So coming over the water area, I can't really pinpoint whether it was from the nuclear plant or from the water, or the trees from around the area.

DR. JOHNSON: Thank you, sir.

CHAIRMAN ROSENTHAL: Captain, I would like to ask you the same question that I asked Captain Billie:

To your knowledge, is there any company or FAA-imposed restrictions upon flying over the Three Mile Island site?

THE WITNESS: No, not directly over the site. There are no restrictions. There is a FAR rule that a thousand feet over nonmountainous terrain and 2,000 feet over mountainous terrain. Altitude for Part 121, Scheduled Aircraft.

CHAIRMAN ROSENTHAL: But that wouldn't preclude --

THE WITNESS: No.

CHAIRMAN ROSENTHAL: -- one from flying over the site.

THE WITNESS: If you were in this area, which is approximately the five-mile area, you're in the area of the control zone for that particular airport. And the governing factor for this area is the airport controller himself.

CHAIRMAN ROSENTHAL: Any further questions of the captain at this time?

MR. CHANDLER: Mr. Chairman, I would only ask if Captain Beuerlein would be good enough to put his name on the line that he drew.

CHAIRMAN ROSENTHAL: Yes.

MR. CHANDLER: At least in one point.

And with leave of the Board and the parties, I would ask that he also put Captain Billie's name down on the line that Captain Billie drew.

Thank you.

CHAIRMAN ROSENTHAL: All right, Captain, you may resume your seat.

(Pause.)

DIRECT EXAMINATION BY MR. CHANDLER:

Q Captain Ufford, could you describe for us very briefly what type of experience you have as a pilot at Harrisburg Airport, what kind of operations you have performed at the airport?

A Yes. I've operated out of Harrisburg over the past seven to eight years, about half of those operations in heavy aircraft over 200,000 pounds for destinations both domestic and international and the arrivals of the same type.

Q Passenger or cargo?

A All passenger.

Q Thank you.

Captain Ufford, if you would be good enough to join us at the map --

(Pause.)

And I have an evergreen grease pencil --

(Laughter.)

Oh, I'm sorry, I haven't. There you go.

Captain Ufford, if you would be good enough, would you please indicate what you would consider to be an appropriate approach, describing by drawing with the grease pencil on the USGS map; and to the extent possible indicating airspeed at, at different points on your approach.

CHAIRMAN ROSENTHAL: Let me ask this question:

Is this approach dependent upon where he's coming from?

MR. CHANDLER: Well, let me --

CHAIRMAN ROSENTHAL: If so, I'd like to know if he's going to identify an approach, where he is assuming that this flight had originated.

MR. CHANDLER: Can you, kan you --

THE WITNESS: I, I can do that.

MR. CHANDLER: If you would, then.

THE WITNESS: If you are approaching the Harrisburg

International Airport from the south or southeast, whether you're coming northbound from Florida or anything along the Eastern Seaboard, from Philadelphia you could -- anywheres from Philadelphia south, you'd be arriving and would be vectored at some point approaching midway on the land as depicted on this USGS map to the east of the Susquehanna River.

Our company policy is going to be -- our company policy requires that we be on the centerline extended and established on the approach at not less than a thousand feet above the ground, which would translate into three miles on the centerline extended -- at this point that we would anticipate being stable on centerline extended.

So coming from the Southeastern Seaboard, we would find ourselves approaching the airport at this point and intercepting centerline extended at the three-mile mark as depicted on the centerline extended on this map.

BY MR. CHANDLER:

Q Excuse me one second, Captain Ufford. I would like to, to point out that when I introduced this I indicated these are statute miles.

A That's correct.

Q Are you also making reference to statute or to nautical miles?

A It would be nautical miles, which would be 3.3 rather than 3 miles. It would be slightly outside of that.

If we were arriving from the Northeastern Seaboard, it would be a traffic pattern very similar to that, which may arrive, arrive from the upper righthand corner of the chart, again arriving at this same point on the centerline extended. This would be on gateway for a visual approach.

And so in that case we would come in this, this manner in maneuvering to reach this flight not less than a thousand feet. If we were arriving from Los Angeles or from the western coast of some -- or Chicago -- we would arrive very much as -- in one of these patterns that's already depicted. I, I think that the scale that we have here would put us a bit farther south.

This line may show, I think along like this, for a downwind south of the Susquehanna, turning right, again to intercept at a three mile on final, which would bring us in a pattern similar to this, coming north, intercepting the eastern shore of the Susquehanna somewhere to the east of Three Mile Island itself.

Coming from Buffalo, again we would be vectored to a downwind, which would be roughly three miles from the center of this map down, turning to the downwind, and then intercepting the other green line, as already drawn here, north and east of the airport.

That would be our, all the basic visual patterns that you would, how you'd maneuver to a line for a landing on runway 31 at Harrisburg.

Q If you were making an instrument approach, where would you intercept the runway centerline extended?

A Well, again, if we were landing on runway 31 at Harrisburg International -- requires radar. They will have you on the centerline extended 8 miles; they'll have you vectored to be established on the centerline extended, where you would descend at that point to 1,900 feet and radar would then identify you at the five-mile centerline extended point to continue your final descent to 860 feet MDA.

So you would be on centerline not farther out. You'd be on the centerline prior to reaching 8 miles on the centerline.

Q Could you indicate your approximate airspeeds at different points on the approaches you've indicated on the map?

A Yes. On the downwind or on these areas when you are flying south or north of the airport parallel with the runway but in the opposite direction of landing, you'd be running 180 knots, 180 knots in these areas and this area north of the airport as well.

(Pause.)

On the run when we're arriving from this way you'd take that same flying distance if you could relate from where I've marked this and extend these on these other lines, that flying distance from the airport or from landing, 180 knots would apply.

As you approach on the base leg of those areas that are drawn perpendicular to the landing heading, that area would be slowed to probably 165 knots in a heavy DC-8, the max landing weight 165 to 170 knots.

Then on the final approach, once you'd turned and were stable in that three miles at minima in on final approach would be at 140 to 155 knots, depending upon the weight of the aircraft.

Q So that we're clear for a moment, the type of aircraft we're talking about now is --

A I'm talking about a heavy DC-8.

Q Okay. And, and your approximate speed with your -- let's assume you're making an approach up from the south and you're within a couple of miles of the island, Three Mile Island --

A If you want to find -- that'd be around 155 knots if the max landing weight, 155; 160 would be an absolute max if you had strong gusty winds, you could carry a speed that fast.

But 150 would be a good average figure for normal landing weight.

Q And prior to intercepting the centerline?

A Prior to intercepting the centerline, you would be at 170, 180 at max out of this --

Q Could, could we, could we --

A At the bottom edge of the chart, at that distance out I would say 8 miles to 9 miles from touchdown.

Q Okay.

Captain Ufford, do you consider that there're any peculiar features of the area such -- in terms of geography, meteorology, topography, electronic guides available at the airport that affect the hazard of utilizing the Harrisburg Airport relative to other airports you're familiar with.

A No, I, I think it is -- all approaches and facilities have basic requirements that are set up that will give us a standard given amount in degree of safety.

And I, I find that the Harrisburg Airport is not unique in that; it's a very normal airport.

Q Do the cooling towers there have any bearing on your approaches and takeoffs?

A The only thing is that, as was earlier mentioned, that they are a very good visual clue if you are shooting a visual approach into the airport; that should the day be such that there is a, a flume that they are visible for some distance and if there is, they stand out during the day a bit better than the city or the airport itself -- from greater distances.

And at night the obstruction lights, of course, on them, again, give you a great visual reference.

But there's nothing negative as far as the approach by the cooling towers existing.

Q About how far from the towers, say, would you pass?

A I would say a mile and a half would be a very good distance. This mile and a half, roughly, that we are when you're abeam; that is about as near as you would be, as when you're on the centerline extended, abeam of the Three Mile Island is the nearest point that that would be to the island during a normal approach of any type.

Q Assuming there were a plume, a visible plume, would your answer be comparable to that given by Captains Billie and Beuerlein with respect to flying through that plume?

A Yes. I would not fly through a flume.

(Laughter.)

(Pause.)

Q On, on a takeoff now, how far down the centerline extended would you fly before initiating a turn from runway 13?

A If we were departing on runway 13?

Q Yes.

A If you, the FAR requires that, the procedure requires that you fly through 1,000 feet straight ahead on the centerline extended prior to turning on course.

Our company policy that we have established, which is not unique for Harrisburg but for all airports unless greater restrictions are implied, is that we will apply them straight ahead on the centerline extended for, to 1,500 feet prior to turning to proceed on course.

This will place us again at the same gateway that we must be at whether we, if we were landing on that runway. So it would place us roughly 3 miles on the centerline extended prior to initiating a turn to enter the en-route phase.

MR. CHANDLER: Thank you.

I have no further questions --

CHAIRMAN ROSENTHAL: Dr. Kepford?

CROSS-EXAMINATION BY DR. KEPFORD:

Q With regard to the rising plume, you would expect, you would expect turbulence if you were to fly through a rising plume?

A If someone flew through a rising flume, I would assume they would get turbulence, yes.

Q Suppose the plume had reached its maximum altitude and flattened out and was then moving horizontally, would you then expect turbulence? or the individual flying through it.

A I would would think that it would be decreased at that point, because there should be no vertical drafts once that it had leveled out with temperature stabilization.

CHAIRMAN ROSENTHAL: Captain, I take it that it would be a violation of company policy for a plane coming into Harrisburg to fly directly over the plant. Is that correct?

THE WITNESS: That is correct. And not because of the, of -- we have no policy about flying over nuclear power lines. But because of its location, it would be a violation of our company policy to find ourselves over it. That's correct.

CHAIRMAN ROSENTHAL: In the circumstances of this airport and the location of this plan. Now, as I understood it, you were not saying that there was a company policy that precluded flying over all nuclear power plants.

THE WITNESS: Your assumption is correct: that it would in violation of our company policy to fly over the Three Mile Island nuclear plant in an approach to the Harrisburg Airport.

DR. JOHNSON: How many times have you flown in to Harrisburg? Do you have an idea?

THE WITNESS: Total in my career or --?

DR. JOHNSON: Yes.

THE WITNESS: I, I'm not, I would guess maybe 65 or 70 times over the years.

DR. JOHNSON: Do you have an opinion as to what fraction of the time you are able to land under visual flight rules, as opposed to instrument flight rules?

THE WITNESS: I would not -- that information is available on statistics, and I -- it would probably be a lot more accurate than my guess. I would say that our procedures that we use, we always back up a visual approach with instrument, with instrumentation on board the, the aircraft.

THE WITNESS: I've flown 707's in here as well. It would be another company that I was flying with; 707 --

DR. BUCK: No C-5A's or anything --

THE WITNESS: No, sir.

CHAIRMAN ROSENTHAL: When, when you, in response to a question of Dr. Johnson, indicated roughly the number of flights that you have made into Harrisburg -- I think it was 65 or something of that order -- were you, was this figure meant to denote flights of heavy aircraft or --

THE WITNESS: Yes, I would say heavy DC-8 aircraft I have probably been in and out of Harrisburg Airport 30, 20 times, maybe 25 times, in heavy DC-8 aircraft.

CHAIRMAN ROSENTHAL: And the others were in lighter aircraft.

THE WITNESS: Either 707's or Lockheed Electras or something lighter.

CHAIRMAN ROSENTHAL: All right. If there are no further questions, you may resume your seat.

End Tape 2
rcp continues
on p. 582

And that normally the, I would say 60 percent of the time that, that you do some portion of an instrument approach. That doesn't mean that it's instrument weather, but that the same procedures or instrument-type procedures are used, I would say 60 to 70 percent of the time; and the other 30 percent they were probably visual approaches.

DR. JOHNSON: Well, is it true that you actually have to get clearance to use the visual approach until you are cleared by the tower or someone to go into visual?

THE WITNESS: That is correct. A visual approach is, is a maneuver you may be cleared for. The standard procedure is an instrument approach, and you may deny a visual. If they ask you for a visual, you may request and shoot an instrument approach if you request.

For reasons of economy, if we have the airport in sight and it's, the weather is good, and we're cleared for a visual; and it's, again, standard for, for all to accept the visual approach.

DR. JOHNSON: Thank you very much.

CHAIRMAN ROSENTHAL: Any further questions of this witness? -- at this time.

DR. BUCK: Captain, you mentioned the DC-8, the heavy DC-8, as the principal airplane that you fly. Do you fly any other heavy aircraft? Or have you flown any other heavy aircraft into --

DR. KEPFORD: When you say heavy DC 8's, is that in reference to a particular model DC 8?

CAPTAIN UFFORD: I say, that as a term only. All DC 8's are over 200,000.

DR. KEPFORD: There are some stretched-body DC 8's, are there are not?

CAPTAIN UFFORD: Yes, they are just heavier.

DR. KEPFORD: Right, thank you. No further questions.

DIRECT EXAMINATION BY MR. CHANDLER:

Q Captain Lithgow. Preliminarily, let me ask what your experience of Harrisburg is, what type of operations have you been involved with?

A The stretch of DC 8, the -63 and 61 models and the military C141 which is heavy category.

CHAIRMAN ROSENTHAL: Captain, I wish--I would appreciate it if you would speak up a little bit, the reporter is having some difficulty hearing you.

BY MR. CHANDLER:

A I have operated at the DC 8-61 and the DC 8-63 and the military C141 which is a heavy category.

Q With respect to the stretch DC 8's that was involved with the passenger-cargo activity?

A Passeneger activity.

Q So the record is clear, Captain Lithgow, Trans

International Airlines, has had a name change?

A That is correct. It is now Transamerica Airline.

Q Thank you.

Captain Lithgow, if you would be good enough as the other pilots, would you please indicate what you consider to be an appropriate approach--additional approach into the Harrisburg Airport, upon Runway 31?

CHAIRMAN ROSENTHAL: I would like to know where he is flying from.

BY MR. CHANDLER:

Q If you would also indicate that as well.

A Well, I suppose that I should preface my response with the comment that visual approaches are considered non-standard and are not recommended at Transamerica. So, it is unlikely that I would fly a visual approach in the first place.

CHAIRMAN ROSENTHAL: Well, have you even flown one?

CAPTAIN LITHGOW: Not in Harrisburg. We fly them but it is recommended that we always fly eastern approaches.

BY MR. CHANDLER:

Q Well, what reason does your company have such a rule; do you you what the basis for that policy in your company is?

A Yes. The Transamerica operation is a non-scheduled operation and we are generally not asked familiar with the airports which we land as scheduled there own air pilots are. Instrument procedures are more standardized and are therefore safer from our company standpoint than visual approached.

Q Thank you.

CHAIRMAN ROSENTHAL: Mr. Chandler, would you like to address the question of the relevance of the captain's testimony in light of his statement that he has never flown into Harrisbury and VFR?

MR. CHANDLER: Mr. Chairman, I am frankly pretty surprised to hear that response. I do not believe, though--let me ask Captain Lithdow.

BY MR. CHANDLER:

Q Have you flown into Harrisbury Airport?

A Yes.

MR. CHANDLER: Mr. Chairman, I suggest that--

MR. LITHGOW: I have flown in for VFR but not for Transamerica.

CHAIRMAN ROSENTHAL: Oh.

MR. CHANDLER: Oh.

MR. LITHGOW: It was a C141. I no longer fly for the Military.

CHAIRMAN ROSENTHAL: All right, but you have had--you have flown into Harrisbury under VFR conditions, how be that not your present employer.

CAPTAIN LITHGOW: That is correct.

BY MR. CHANDLER:

Q Would indicate on the--for an example of the approach, VFR approach?

A If for some reason I was referred by air traffic control to fly a visual approach, the company recommended procedure is to the stabilize and landing configuration a 1,000 feet above the ground. That would put us at 3.1 nautical miles or about 3.5 statute miles from the end of Runway 31, which would be this point here.

Q Your approach is from what side. For example, from what point of origin?

A Well, I would probably fly a left-hand traffic. In other words, fly south of Runway 13 on a left down wind, as we call it, making a left turn to a left base and a left turn to final.

Q Could you draw that in?

A Yes, I will. I might point out that in my mind I fly these approaches backwards in effect. This is the point that I want to be stable. At three and a half miles the radius turn is approximately one mile, so that would put me on base leg at approximately this point, four and a half statute miles.

The lateral displacement on down wind would also be about three miles with a one mile radius turn.

Tape 3 contd.
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Q Could you perhaps indicate your approximate air speeds at different points along there?

A I would enter the airport traffic area, which is the area of five statute miles around the airport at a maximum of 200 knots, that is an FAA restriction. On the downwind I would slow to approximately 180 knots, depending on aircraft weight. On the base leg would slow to probably a 165 knots, approximately. And stabilize on the final approach course, the speed would be approximately 150 knots.

Q Thank you. At an instrument approach, at approximately what point would you intercept the centerline extended?

A As has been pointed out in previous testimony, the appropriate instrument approach for runway 31 is the localized back course and radar vectoring is required. The final approach fix is at five miles. The FAA flight controllers handbook, which specifies the procedures which the controllers use requires that they intercept aircraft based on the angle of intercept generally at least one mile outside of the final approach fix. I would anticipate an intercept of one to three miles outside the final approach fix. So that would be somewhere between six and eight miles.

Q Thank you.

A From the end of the runway.

Q In making, say, a visual approach into Harrisburg, how do the cooling towers affect your flight path?

A They would not affect my flight path.

(Pause.)

Q And I would ask you the same question that's been asked of the, the other pilots, assuming that there were a visible flume. Would that have a bearing on your approach?

A Why, yes, of course, I would have to avoid that visual flume.

Q Are there any peculiar features that you know of at Harrisburg or in the vicinity -- meteorologically, attributable to topography, geography, or the availability of electronic guidance equipment at the airport -- that affect the hazard, relative hazard, at facility, as compared with other airports with which you are familiar?

A I would say that the approach facilities are certainly better than average. And the topography is, there is nothing particularly unusual about it.

Q On a takeoff from runway 13, about how far down the centerline extended would you fly prior to initiating a turn off the centerline?

A A minimum of 1,000 feet.

Q Which would place you about --

A Would, would put me probably, depending on the aircraft's weight, somewhere between 2½ to 3 miles minimum.

Q Down the centerline extended.

A Yes.

At approximately this point.

The radius of turn at that point, again, would be approximately one mile.

Q Are there any peculiar company policies that dictate approaches, a visual approach?

A The, the company-recommended altitude for intercepting or achieving a point stabilized on final is a thousand feet.

That is probably somewhat higher than other company minimum final approach altitudes.

Q But that is a general policy and not unique to Harrisburg Airport.

A That's correct. That's for all visual approaches.

MR. CHANDLER: Thank you.

I have no further questions of this witness, Mr. Chairman, at this time.

CHAIRMAN ROSENTHAL: Dr. Kepford?

(No audible response.)

DR. JOHNSON: I have a few.

How long did you fly in the military? I assume this was Air Force?

THE WITNESS: In the Air Force. Well, on active duty, for five years; and as a reservist, for another seven years.

DR. JOHNSON: And I understand that you flew into

Harrisburg while you were in the military service?

THE WITNESS: That's correct: as a reservist in the aircraft known as a C-141.

DR. JOHNSON: Were the regulations, military regulations and procedures regarding landing and takeoff in the military comparable to those of Transamerica Airline or the commercial airline?

Are there any distinctive differences that you can think of?

THE WITNESS: They were very similar.

DR. JOHNSON: So that a military aircraft under VFR would enter the flight path essentially the same thousand feet and 3-or-so miles out as the commercial --

THE WITNESS: The C-141 minimum was 800 feet. And that would, that would reduce the minimum displacement from the end of the runway from about 3½ miles statute to approximately 3 miles statute.

CHAIRMAN ROSENTHAL: What is the size of that plane?

THE WITNESS: The C-141?

CHAIRMAN ROSENTHAL: Yes.

THE WITNESS: It has a maximum gross weight for takeoff of 325,000 pounds, approximately the same as the 707.

DR. JOHNSON: What about the 5A aircraft? How would its minimum compare with the 141? Would it be a thousand feet? or 800 feet?

THE WITNESS: I would speculate that it would be similar to the 141. The Air Force tries to standardize the procedures as much as they can, among different types of airplanes.

DR. JOHNSON: And military aircraft would also on takeoff require a thousand feet before turning onto their course, off the runway bearing?

THE WITNESS: That's correct.

(Pause.)

DR. JOHNSON: I have no further questions.

DR. BUCK: Is your turn radius about the same, by the way? -- as the --

THE WITNESS: The turn radius is a function of speed, and the heavier the airplane the faster it has to fly, generally, and the greater the turn radius. At 180 knots the turn radius is almost exactly one mile. At slower speeds the turn radius is somewhat less; at higher speeds, much greater.

DR. BUCK: So the C-141 is operating on a different from the DC-8 as far as the turn radius.

THE WITNESS: The speeds of the 141 were somewhat lower, due to a different design of the wing; and the turn radius was somewhat smaller.

DR. BUCK: Okay. Thank you.

MR. CHANDLER: For the record, Captain Lithgow, are you rated on a C5-A? Or were you rated on a C5-A?

THE WITNESS: No.

CHAIRMAN ROSENTHAL: All right, Captain, you can resume your seat.

All right.

MR. CHANDLER: Mr. Chairman, the staff has no further questions of these witnesses at this time.

CHAIRMAN ROSENTHAL: All right. Well, I want, I want to get some idea as to the length of, likely length of the further questioning. It's getting close to the midmorning break time; and if you're probably talking about five to ten minutes of questions, I would --

MR. TROWBRIDGE: We will have no questions.

CHAIRMAN ROSENTHAL: You will have no questions.

Dr. Kepford, do you -- will you have further questions of --

DR. KEPFORD: No further questions.

CHAIRMAN ROSENTHAL: No further questions.

DR. BUCK: I have one question:

In the one-mile radius, what sort of banking angle are you at, at that point? I may not be using the right terminology for what I'm talking about --

BEUERLEIN: Are you referring to my turning radius?

DR. BUCK: Yes.

BEUERLEIN: From the downwind leg to the base leg? Maximum 30-degree bank.

DR. BUCK: Maximum 30-degree bank.

CAPTAIN BEUERLEIN: Yes.

DR. BUCK: That would be for the whole, say, 90-degree turn.

CAPTAIN BEUERLEIN: Yes.

DR. BUCK: Is that about the same for the other airplanes.

(No audible response.)

Okay. Thank you.

CHAIRMAN ROSENTHAL: Let the record indicate that the other pilots nodded affirmatively.

And any other questions of this panel?

(No audible response.)

Gentlemen, we appreciated your taking the time to be with us this morning and the very informative assistance that you have provided. And you may be excused.

And we'll take a --

DR. BUCK: Excuse me, but I have one question --

CHAIRMAN ROSENTHAL: Yes.

DR. BUCK: At this 30-degree bank and you're, say, a thousand feet off the, off the ground, sitting in a passenger seat, how close to directly underneath the airplane would you be able to see the ground?

CAPTAIN BEUERLEIN: Not directly underneath.

DR. BUCK: Not directly underneath, but how far --

CAPTAIN BEUERLEIN: Approximately a mile and a half to two miles.

DR. BUCK: Even in the bank.

CAPTAIN BEUERLEIN: It would look like -- for example, if you were in the Chicago holding pattern, there's quite a few people have noted that airplanes appear to be at the same altitude; but they have been about a thousand, two thousand feet from us.

And I don't know if you've ever been in a holding pattern around the Chicago area, there's quite a bit of traffic. People are all worried about putting --

It is because we are in a bank; and at night, especially, aircraft do look like they are at the same altitude.

DR. BUCK: Well, I am talking about objects on the ground.

CAPTAIN BEUERLEIN: Objects on the ground the same way. Say, at night, especially with no other reference -- perception, say in Harrisburg, is particularly bad to the west, with no lights. And the, the obstructions such as the terrain are not highlighted at night. And in a turn it would like you were definitely closer, even in a 30-degree bank, approximately a mile and a half to two miles away -- it would like a mile away from it.

DR. BUCK: Thank you.

Do the other pilots agree with that statement, by the way?

CAPTAIN BEUERLEIN: You can never see directly below.

DR. BUCK: I, I realize that. I was just trying to get a fix on the bank of the airplane and the lowest angle that a person could see on the airplane. You got the window cells and all that sort of thing there. I was just trying to get your opinion as to how close to the aircraft you could see.

And I get the guess here of a mile, a mile and a half.

Is that about right from the other pilots?

CAPTAIN LITHGOW: To make sure I understand the question: you mean if the airplane were in a 30-degree bank?

DR. BUCK: Yes. I'm talking about now: you're swinging around in your arc of, one-mile arc, and you're in a 30-degree bank or thereabouts.

And a person inside in the passenger seat, looking out, what would you estimate would be the nearest point in the ground that one would be able to see?

CAPTAIN UFFORD: On your question, too, I think it would be important: are you sitting in your passenger seat with your head centered on the seat and looking out the window? Or do you have your head lying against the window trying to look straight down?

DR. BUCK: Well, let's take the extreme case, where you're trying to push your head through the window.

(Laughter.)

CAPTAIN UFFORD: I, I feel that in a 30-degree bank, if you didn't have a wing under you to obstruct your vision, that I think there would be something less than, than a mile and a half to two miles. I would feel it closer to a mile, possibly, would be the very, very closest that you could see.

DR. BUCK: In your seat, of course, you would -- it would be further out.

CAPTAIN UFFORD: That's correct. And the higher the altitude the farther away --

DR. BUCK: I'm talking about a thousand-foot altitude.

CAPTAIN UFFORD: Thousand foot --

DR. BUCK: I'm talking about the landing pattern here basically, where you're maybe -- well, you'd be a little bit higher than a thousand feet, maybe into your turn you're at 7,000 to a thousand feet, say a thousand to 1,200 feet.

I'm talking about the extreme case here: you got your head up against the window and you're trying to see the ground. I'm trying to get a guess as to how close to the airplane you could see.

So I have a guess here of a mile to a mile and a half. And I have one to a mile.

Anybody else any other guesses?

CAPTAIN BEUERLEIN: A mile would be about a thousand feet. This is roughly figuring on a 30-degree bank.

DR. BUCK: Right. Okay.

CAPTAIN LITHGOW: I would say somewhat less than that.

DR. BUCK: Somewhat less than that.

Half mile?

(Pause.)

CAPTAIN LITHGOW: At the risk of muddying the water, I would say about a half mile. And it, and it is a guess; there's no -- I, I, we don't have any -- obviously any experience on looking out the window.

DR. BUCK: You don't, the trouble is you don't fly on the passenger seat.

(Laughter.)

CAPTAIN LITHGOW: Right. But my guess would be a half mile. And I, you'd have to work it out.

CAPTAIN BEUERLEIN: That information could be provided for you very accurately, in all probability, by the aircraft manufacturer. You know, if you asked him, "Look --" Or anyone could -- the trigonometry of that would not be difficult if you had the appropriate angles.

DR. BUCK: Well, you'd have to know -- the problem that I've had in looking at it is that these airplanes differ in the wall thicknesses -- and the inner window, how far in that is, compared to the outer window and all this sort of thing.

So I've been trying to guess --

CAPTAIN: Also if you're sitting in economy or first class.

(Laughter.)

CHAIRMAN ROSENTHAL: Let me ask -- are you finished?

DR. BUCK: Yes.

CHAIRMAN ROSENTHAL: Let me ask just one final question:

Testimony which you've given as to the landing patterns has been given in the context of heavy aircraft as we've been defining the term, weighing more than 200,000 pounds: would that essentially hold for smaller planes?

Or is this -- are these patterns specifically in terms of the heavy aircraft in maneuverability or other factors that might be applicable to the larger planes but not the smaller ones.

CAPTAIN BEUERLEIN: I couldn't answer that question. I'm not small-aircraft route qualified.

CHAIRMAN ROSENTHAL: Are any of you -- fly small planes?

CAPTAIN BILLIE: I do. Yes, I -- I think that it's basically wider. It's, it's because of the size of the airplane. In a, in a lighter plane, we're speaking of very light, now.

CHAIRMAN ROSENTHAL: Well, I'm --

CAPTAIN BILLIE: You're talking about a --

CHAIRMAN ROSENTHAL: DC-9? No, I'm not talking about a, a Cessna or Piper Cub. I'm talking about a commercial aircraft which is not over 200,000 pounds; it's smaller.

CAPTAIN BILLIE: No, no. I'd, I would say it's the same. The speeds are, are very comparable; and speed, speed would determine the size of the pattern.

CAPTAIN UFFORD: I fly the DC-9 regularly, as well as the DC-8. And my landing pattern in a DC-9 would not be different than it would in a DC-8. Same company procedures apply in the landing pattern and points of intercept with the centerline extended would be the same, whether it be a 100,000-pound DC-9 or a 250- or 300,000 DC-8.

CHAIRMAN ROSENTHAL: Well, gentlemen, thank you very much. We'll take --

DR. KEPFORD: Mr. Rosenthal.

CHAIRMAN ROSENTHAL: Yes.

DR. KEPFORD: I'd like to ask a question or two here. I'm really quite puzzled by the --

A plane flying level at a thousand feet, could not you see an object on the ground directly off to one side a mile away, if you're flying level at a thousand feet?

CAPTAIN: Who do you want to answer that?

DR. KEPFORD: All, please.

CAPTAIN UFFORD: Well, I think you could from the cockpit.

DR. KEPFORD: Could not a passenger see that?

CAPTAIN UFFORD: Well, I don't know. I'm not much of an authority on the passenger seat.

(Laughter.)

Depends on where the passenger is sitting, really. If you mean --

DR. KEPFORD: Well, let's say his vision is not obstructed by the wing.

CAPTAIN BEUERLEIN: Well, if the particular window is of sufficient viewing area, then he could see a mile down, yes. If your horizontal --

DR. KEPFORD: No, no, no. No.

No, let's -- flying flat --

CAPTAIN BEUERLEIN: Yes.

DR. KEPFORD: -- a thousand feet off the ground, could not he see an object on the ground a mile away?

CAPTAIN BEUERLEIN: Yes.

DR. KEPFORD: Now, how about half a mile?

CAPTAIN BEUERLEIN: I don't know. I don't believe so.

DR. KEPFORD: Now in a 30-degree bank, let's say a passenger sitting on the left side of the aircraft, adjacent to a window, and is willing to crane his neck, in a 30-degree bank, would that passenger not be able to see a point on the ground at much closer to being directly below the aircraft?

CAPTAIN BEUERLEIN: Much closer, yes; but not directly below.

DR. KEPFORD: But much closer than a mile or a mile and a half. Would it not be much more like a quarter of a mile?

CAPTAIN BEUERLEIN: I believe so, yes.

DR. KEPFORD: Any other --

CAPTAIN BILLIE: My conjecture would be that level at a thousand feet you would see about a mile; and in a 30-degree bank, about a half mile. And that's conjecture. But that would -

DR. KEPFORD: This, again, would not be a difficult problem to solve, given a little bit of trigonometry, would it?

CAPTAIN BILLIE: No.

(Pause.)

DR. KEPFORD: No further questions.

CHAIRMAN ROSENTHAL: Thank you. The --

MR. CHANDLER: Mr. Chairman, before excusing, I would just ask if Captain Lithgow initial or put his name on the black line; if not, if you'd be so good as to do that, so that we have it clear whose line is whose, in addition to color.

Thank you.

I would also ask, Mr. Chairman, that the Board formally excuse the appearance of Captain Daniel Clishman, Evergreen International Airlines. As the Board will recall, he was called in the alternative if Captain Ufford were unable to make it. Captain Ufford has appeared, and I would therefore --

CHAIRMAN ROSENTHAL. So he is so excused.

MR. CHANDLER: Thank you, sir.

CHAIRMAN ROSENTHAL: And the panel is excused with our thanks. And we'll --

I have now 13 minutes of 11:00, and we'll resume at 11:00 o'clock.

End Tape 3
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(Brief recess.)

MR. CHANDLER: If I could, I would like to recall to the stand for one or two brief moments Captain Beverlein. I think he has some information which may be relevant to our consideration.

CHAIRMAN ROSENTHAL: All right.

MR. CHANDLER: Captain Beverlein.

CHAIRMAN ROSENTHAL: I take it you just want Captain Beverlein, not --

MR. CHANDLER: Yes.

CHAIRMAN ROSENTHAL: Any of the other three panelists would.

You may proceed, Mr. Chandler.

MR. CHANDLER: Thank you.

Captain Beverlein, you indicated during your testimony earlier that you flew the Chicago-Harrisburg run for TWA. Is that correct?

CAPTAIN BEUERLEIN: Yes.

MR. CHANDLER: And in what kind of aircraft was that?

CAPTAIN BEUERLEIN: A Boeing 707.

MR. CHANDLER: When did you make your last flight?

CAPTAIN BEUERLEIN: My last flight was on March 21st of last year. And I remained overnight. The flight ended down from O'Hare to Harrisburg; it was Flight 74. And the flight outbound the following morning was flight 299 from Harrisburg to Chicago.

MR. CHANDLER: Why do you no longer make that flight?

CAPTAIN BEUERLEIN: The 707 has been replaced with a 727 flight, which I'm not qualified to operate.

MR. CHANDLER: So to your knowledge that service is no longer performed by a 707.

CAPTAIN BEUERLEIN: That's correct.

MR. CHANDLER: Thank you.

I have nothing further.

CHAIRMAN ROSENTHAL: Any cross-examination directed to this testimony?

DR. KEPFORD: Does that mean, then, that TWA -- are you saying that TWA never flies 707's?

CAPTAIN BEUERLEIN: No.

DR. KEPFORD: Into Harrisburg now?

CAPTAIN BEUERLEIN: As far as I know, the schedule is a 727 at the present time.

(Pause.)

DR. KEPFORD: Mr. Chairman, this is a matter that could be relatively easily checked, is it not?

CHAIRMAN ROSENTHAL: Yes, I have a schedule in my flight kit.

DR. KEPFORD: Does that show what equipment is used?

CHAIRMAN ROSENTHAL: The schedule I have is a passenger schedule which does not show the equipment.

MR. CHANDLER: I would point out, Mr. Chairman, that information is set forth in the staff's affadavit, the affadavit of Jack Reed, which I will be offering later.

DR. KEPFORD: No further questions.

CHAIRMAN ROSENTHAL: All right.

Thank you, Captain.

Yes.

DR. KEPFORD: Oh, Mr. Chairman, could I ask Captain Beuerlein if he'd look at a diagram momentarily.

CHAIRMAN ROSENTHAL: If he would what?

DR. KEPFORD: Look at a diagram momentarily.

CHAIRMAN ROSENTHAL: Yes.

(Pause.)

Have you shown the diagram, Dr. Kepford, to Mr. Chandler, Ms. Carter, and Mr. Trowbridge? -- so they'll have some idea. And maybe we could get a quick look at it as well.

DR. KEPFORD: I'll describe it, Mr. Chairman, is nothing more than a 30-60-90 right triangle, with the vertical leg --

One just like it.

(Pause.)

BY DR. KEPFORD:

Q Captain Beuerlein, for the record the diagram I've given you is a 30-60-90 right triangle, is it not?

A Yes.

Q It has a vertical leg of about, well, marked in units of 1,000, is that not correct?

A Yes.

Q The hypotenuse of the right triangle intersects the ground about how far from the vertical leg?

A 1,730.

Q This diagram is meant to represent -- well, could be used to represent, at least as far as the hypotenuse of the triangle goes, the vision of a passenger in an aircraft looking toward the ground, could it not?

MR. CHANDLER: Excuse me.

DR. KEPFORD: At an angle of 30 degrees down from the horizontal?

The hypotenuse --

MR. CHANDLER: Mr. Chairman, I'd like to object to that question. I think quite clearly it's just building on speculation and conjecture. I think as clearly indicated earlier in the testimony, not only of Captain Beuerlein,but of the other pilots as well, it was indicated that they really had no knowledge of what could be observed, that they would try and speculate responsively, I believe, to Dr. Buck's

5

question --

CHAIRMAN ROSENTHAL: Well, the, the Captain can indicate that if he doesn't have sufficient knowledge to respond to the question informatively.

CAPTAIN BEUERLEIN: I will stipulate to the mathematics involved if that'll save some time.

(Pause.)

DR. KEPFORD: Is it acceptable for -- where are we?

CHAIRMAN ROSENTHAL: Yes, I'm going to allow the question to stand.

Do you recall the question, Captain?

CAPTAIN BEUERLEIN: Would you remind repeating the question?

BY DR. KEPFORD:

Q The question was could, could the hypotenuse of that triangle be reasonable similar to what a passenger might see, looking out the window of an aircraft flying at a thousand feet, if he looked down at an angle of 30 degrees below the horizontal?

A On any equipment? or just 707's?

Q I'm assuming --

A There is a double layer of glass, which might have a light refraction to it.

Q Oh, are, let's -- yes, whatever equipment.

A The --

Q Assuming it's physically possible to do so.

A Physically possibly he'd see something down below.

Q Fine.

And, and horizontal distance along the ground would be 1,700-and-some feet?

A 1,730 is the figure that is written on the paper here.

Q Thank you.

If, now, that horizontal line -- well, assuming the plane were flying flat under those conditions, and assuming that it was physically possible under those conditions to see an object the 1,730 feet away, now if the plane banked to the left, to the 30-degree angle, would not an object quite a bit closer to t vertical distance down from the plane be visible?

A At a 30-degree bank there would be an object closer to the vertical distance of the airplane.

DR. KEPFORD: Thank you.

I have no further questions, Mr. Chairman. Would you like the diagram for the record?

CHAIRMAN ROSENTHAL: I think it's been adequately described.

Any further questions?

MR. CHANDLER: One very brief one, Mr. Charman.

Captain Bauerlein, is it your testimony that one, that a 30-degree bank turn is what's generally used? or is it somewhat less?

CAPTAIN BEUERLEIN: A 30-degree bank is the maximum. Anything over that is uncomfortable for the passengers and is not used.

MR. CHANDLER: Do I understand from that that generally a lesser bank is used?

CAPTAIN BEUERLEIN: Possibly anywhere from a 5-degree bank to a 30-degree bank.

MR. CHANDLER: Making specific reference to an approach into Harrisburg airport, on a visual approach as you've described it.

CAPTAIN BEUERLEIN: On a visual approach such I've described, approximately 20-degree bank to a 25-degree bank.

CHAIRMAN ROSENTHAL: All right, Captain, you may be excused.

Dr. Kepford will now entertain the testimony of your witness.

DR. KEPFORD: I'd ask Dr. Johnsrud to take the stand.

CHAIRMAN ROSENTHAL: All right, if she would --

(Pause.)

CHAIRMAN ROSENTHAL: Dr. Johnsrud, if you'd remain standing for a moment and raise your right hand.

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Whereupon,

JUDITH H. JOHNSRUD

was called as a witness, and being first duly sworn, was examined and testified as follows:

MR. KEPFORD: First off, Mr. Chairman, before we get into cross-examination, I would like to offer the Board and the parties an explanation as to why Dr. Johnsrud is testifying and why Mr. George Coombsmoon, Mr. Richard Hayden, and myself, Chauncey Kepford (phonetic spellings) are not testifying as we proposed on the order of a year ago.

The reason has to do with, quite simply, the accident at Three Mile Island. And to the best of my knowledge, none of the three individuals I mentioned -- Hayden, Boosmer (phonetic spelling), or myself, Kepford -- have flown into Harrisburg International since the accident.

Dr. Johnsrud did, a couple of months ago; and that is what she will describe. So in a nutshell, she is testifying because her testimony is more current and applicable.

MR. CHANDLER: Mr. Chairman, I, I'd like to note a general objection. I believe the Appeal Board's order ALF 370 indicated that the testimony of any witnesses was to be supplied by February 4th. And my records do not indicate the submission of any testimony by Dr. Johnsrud at that time -- or to day, for that matter.

(Pause.)

MR. CHANDLER: Having made that objection, Mr. Chairman, I'm willing to proceed.

Thank you, That saves the Board some time.

DIRECT EXAMINATION

BY DR. KEPFORD:

Q Dr. Johnsrud, could you describe your trip into Harrisburg International Airport?

A Yes. I have a very short statement:

On January 24th I returned from Pittsburgh to Harrisburg --

Q That's 1980.

A 1980, yes. January 24th, a month ago yesterday.

Q Would you pull the microphone a little closer to you, please.

THE WITNESS: Surely. Dr. Buck, is this better?

DR. BUCK: Pull the, the, your left-hand microphone up towards -- that's the one. That's it. Thank you.

THE WITNESS: On January 24th, 1980, I flew from Pittsburgh, Pennsylvania, to Harrisburg on U.S. Air flight 170 scheduled to leave Pittsburg at 110, delayed due to mechanical difficulties and apparently snow on the field as well, for approximately an hour and a half.

The flight coming into Harrisburg International Airport along a path akin to those that have been described and sketched on the U.S. Geological Survey Topographic sheet earlier today.

Having a certain familiarity with the topography and an expectation of seeing Three Mile Island, I was of course looking for it, sitting on the left side of the plane, such as to be able to view it. And to my amazement, saw the north end of the island, the bridge, but the reactor apparently was directly below me.

I was extremely surprised in view of my knowledge of the transcript of the previous hearings here. And therefore, as I deplaned, I asked the pilot if he had flown directly over Three Mile Island, Unit 2; and his response was "Yes, I thought I would give you all your daily dose of radiation," at which point I got off the plane, very much surprised, and inquired of a flight crew member, "This was a DC-9?"

And that in essence is what I have to say, this being a flight subsequent to the accident. U.S. Air, according to the pilot, as well as to my -- the best of my observation, directly over the reactor.

BY DR. KEPFORD:

Q When the pilot remarked to you that he thought he gave you your 'daily dose of radiation," is it possible that he might have been facetious or sarcastic?

A At the time I would have thought so. Subsequent information concerning continuing releases of krypton gas would cause me to wonder if he was serious.

MR. CHANDLER: Mr. Chairman, I object.

(Pause.)

MR. CHANDLER: I made an objection. This is not an opportunity to deliver speeches or to speculate on matters that Dr. Johnsrud may wish to deliver.

CHAIRMAN ROSENTHAL: Yes, I think that objection is well taken. Let's just confine ourselves to the, to the facts.

DR. KEPFORD: Mr. Chairman, does that mean the entire question and answer? -- have been objected to? Or some particular part? Or what?

CHAIRMAN ROSENTHAL: Well, I think --

MR. CHANDLER: Both, Mr. Chairman. The question calls for conjecture on the part of the witness as to the state of mind of the pilot when the statement was made. The response was not responsive in the sense that it involved a speech on matters extraneous to matters before this Board.

The objection goes to both.

CHAIRMAN ROSENTHAL: I think we'll allow to stand only the statement which Dr. Johnsrud made, that she asked the pilot the question she posed to the pilot, and the respons she'd gotten from him.

DR. KEPFORD: Thank you, Mr. Chairman.

CHAIRMAN ROSENTHAL: Any further questions?

17

DR. KEPFORD: I have no further questions.

CHAIRMAN ROSENTHAL: All right.

Mr. Chandler?

MR. CHANDLER: Mr. Chairman, I move to strike the testimony of Dr. Johnsrud on the grounds that it's irrelevant to any issue before this Board. Dr. Johnsrud indicated that her experience was on a DC-9 aircraft. And a DC-9 aircraft, as I believe the record indicates is not an aircraft of 200,000 pounds or greater.

Therefore, the testimony offered is not relevant to the issues before this Board.

CHAIRMAN ROSENTHAL: Well, that assumes, does it not, Mr. Chandler, that there is a difference in flight patterns that would be pursued by an aircraft weighing in excess of 200,000 pounds and one weighing less than that amount?

And you can refresh my recollection, but I don't recall anything in the testimony of the pilot witnesses this morning that indicated that. To the contrary, I thought in response to a question which I posed, one of the pilots indicated that it would make no difference, as he saw it at least, what the weight of the plane was.

Am I wrong about that?

MR. CHANDLER: I don't think I'd characterize it the same way. But I wouldn't disagree with what you said.

CHAIRMAN ROSENTHAL: Well, what is, why isn't the absence of an indication that heavy aircraft pursued different flight paths or are likely to pursue different landing approaches than other aircraft -- why isn't this testimony relevant?

MR. CHANDLER: Well, Mr. Chairman, I believe that one of the indications is also that this is on U.S. Air. We've heard testimony this morning from three different airlines -- Transworld, Transamerica, and Evergreen Internation. I believe that these pilots have indicated the practices and policies of that airline.

I don't what, I don't know whether the practices and policies, et cetera, of U.S. Air are comparable. To that extent I can't say that the testimony is to be discounted.

CHAIRMAN ROSENTHAL: Well, you chose pilots from three airlines, which was your privilege.

Now, the inquiry here isn't restricted to whether planes of those particular airlines might fly over Three Mile Island.

Let me ask this question; Dr. Johnsrud. Do you know offhand whether U.S. Air flies larger, large aircraft into Harrisburg?

THE WITNESS: I don't know the maximum size of the aircraft they fly in. No, sir. But it is, of course, a regularly scheduled major line in Pennsylvania, with flights

14

from many points in the State -- and numerous flights into Harrisburg.

MR. CHANDLER: I think, Mr. Chhirman, that if reference is made to Staff exhibits submitted in the past, certain tables would indicate what aircraft are used by U.S. Air, formerly Allegheny Airline. I think if reference is made, the Board will find that no heavy aircraft are used.

CHAIRMAN ROSENTHAL: Well, Mr. Chandler, I'm going to overrule your objection. We obviously will take into account in the evaluation of testimony of the witness that her flight was on a, an aircraft that weighed less than 200,000 pounds.

Do you have cross-examination?

MR. TROWBRIDGE: Mr. Chairman, I would like simply to note for the convenience of the Board that in the previous testimony of Lowell Wright in this proceeding, that of the Applicant, the testimony dated November 17, 1978, will be included a table of aircraft weights, Table 2-8, Where the DC-9 is listed as weighing empty 58,000 pounds and weighing at maximum 110,000 pounds.

CHAIRMAN ROSENTHAL: Well, I don't think anyone was disputing that the DC-9 was a plane weighing under 200,000 pounds.

MR. TROWBRIDGE: I'm simply getting with more precision how much --

CHAIRMAN ROSENTHAL: Mr. Chandler, do you have cross-examination?

MR. CHANDLER: Briefly, Mr. Chairman.

CROSS-EXAMINATION

BY MR. CHANDLER:

Q Dr. Johnsrud, you indicated you were seated on the left side, of the plane, I believe.

A So that I was, I was looking -- as the plane banked around, I was, I was looking toward the river, toward where Three Mile Island would be, and toward the Harrisburg Airport.

Q Would you be able to show us for a moment on the map where you would have observed the bridge.

(Pause.)

A The plane came in from the northwest and banked around thus.

CHAIRMAN ROSENTHAL: Well, "thus" --

THE WITNESS: Sorry.

CHAIRMAN ROSENTHAL: Can you -- "thus" will not turn up too well in the transcript.

(Laughter.)

THE WITNESS: Over the reactors and then around to the --

DR. BUCK: Exactly where is the bridge that you're talking about?

THE WITNESS: The bridge is at the north end of the

1b

island. As we came in, I could see the bridge.

CHAIRMAN ROSENTHAL: All of it?

THE WITNESS: Well, as a matter of fact, I was one of those passengers that was pressed against the glass to see as straight down as I could, expecting to see the reactors since I had in a few previous flights coming into Harrisburg been able to see the reactors, coming in on the flight line --

DR. BUCK: I asked if you could see all the bridge? or one end of the bridge? or --

THE WITNESS: What I'm saying is that my recollection is the far end of the bridge, and I'm, I'm not certain at that intermediate distance, but I was looking as straight down as I could, looking for the reactors, hoping to see or expecting to see --

(Pause.)

BY MR. CHANDLER:

Q Let me make reference to Staff Exhibit Number 1, which is an aerial photograph. Perhaps it may be possible to describe what you observed now.

Do you see the bridge on this map?

A Yes, the bridge is at the northwest end of the island, angling to the north-northeast toward the mainland on the east bank of the river.

(Pause.)

Q Can you describe the path the flight was taking at that point in time?

A No more precisely than I've done, Mr. Chandler. It was banking in from the west-northwest, around toward the east-northeast, to make the final approach, and presumably to the --

Q Where were you seated in the plane? relative to wing.

A I was seated, it was either the first or the second seat at the front of the passenger compartment. I had specifically requested, I always do, request a seat away from the wing, so that I will be able tohhave a maximum view up front.

Q You were forward.

A Yes, I was forward of the wing.

Q Can you describe the angle at which the plane was banking at the time?

A No, I was --

DR. KEPFORD: I object, Mr. Chairman.

CHAIRMAN ROSENTHAL: What's the basis of your objection?

DR. KEPFORD: Because a passenger would ha virtually no frame of reference for which to judge an angle.

CHAIRMAN ROSENTHAL: Well, if that's the case, the witness can so indicate. Nothing wrong with the question.

THE WITNESS: To repeat my answer, I would not want to make that judgment.

BY MR. CHANDLER:

Q Was the plane banked?

A Yes, the plane was banking.

Q Did you, were you able in your own feelings, were you able to perceive whether it felt as a steep bank? or a gentle bank?

A It was a bank that was steeper than a, I have been accustomed to in landing at that other airport.

Q And how did the plane then proceed after you saw the, the bridge?

Let us perhaps make reference to the other map.

(Pause.)

A Again, I cannot see, be absolutely precise as to the distance from the river. I was able to observe the houses from which I, I have been able to, I was able to identify on the basis of previous flights from the east into Harrisburg International; and I happen to know some residents there.

So I was able to identify the houses located along Route 441; and thus, we must have angled in and come in along the centerline, but did pass the houses to the north of the bridge or along 441.

Q You are contending, then, that the pilot flew over the island -- I presume you're saying, then, south of the north bridge?

A Yes.

Q And then do you recall whether the plane banked more steeply?

A I'm not sure about the bank from there on. To be perfectly, I was looking for the reactor, having expected to be able to see them, being somewhat familiar with this, this flight pattern.

MR. CHANDLER: Mr. Chairman, I have no further questions. I would just note that this is one of the problems of not having had an opportunity to have information such as Dr. Johnsrud has provided in advance.

CHAIRMAN ROSENTHAL: I, I appreciate that. And I'm going to have a few questions of my own to ask about this, some aspects of this.

Dr. Johnsrud, you can resume your seat.

Mr. Trowbridge?

MR. TROWBRIDGE: I'm going to have no questions for Dr. Johnsrud; but in view of her testimony and in view fact that we did not see it, and with the indulgence of the pilots whom I see are still here, one of whom --

I would be asked, would ask that they be allowed to resume the stand for a few questions.

CHAIRMAN ROSENTHAL: That will be done as soon as we finish with Dr. Johnsrud.

Ms. Carter?

MS. CARTER: No questions.

CHAIRMAN ROSENTHAL: Let me ask you this, Dr. Johnsrud:

You indicated that when the plane landed, you had a conversation with the pilot. Is that true?

THE WITNESS: Yes, sir.

CHAIRMAN ROSENTHAL: And what did you do? Did you go up to the cockpit? Or did you meet him after he had gotten off the plane, or what?

THE WITNESS: I met him at the, he was out of the cockpit but in the plane; and I spoke with him in the aisle.

CHAIRMAN ROSENTHAL: All right. Did you get his name?

THE WITNESS: No, I did not.

CHAIRMAN ROSENTHAL: Did you endeavor to get his name?

THE WITNESS: I have not done so. I had the flight number, and I presumed that that would be a sufficient identification.

CHAIRMAN ROSENTHAL: All right. Well, let me ask Dr. Hapford, this question:

I, when did you first learn of Dr. Johnsrud's experience? When did she communicate this to you, that she had taken this flight on January [illegible] and that she'd flown over the, the best she could determine she'd flown over the site and she'd had this conversation with the pilot?

DR. KEPFORD: Shortly after January 24th, Mr. Chairman.

I'd like to point out that sometime a year ago on, on the order of a year ago, we filed with the parties the planned testimonies of Mr. Sjoonsma, Hayden, and myself. And there is nothing essentially different in what Dr. Johnsrud has to say than what those three witnesses would have had to say.

And I'm really quite puzzled --

MR. TROWBRIDGE: Mr. Chairman, I recall no such distribution of testimony. I've asked Mr. Chandler if recalls.

MR. CHANDLER: No, sir, I do not.

CHAIRMAN ROSENTHAL: Well, that's entirely to one side. You have this occasion, you're offering the testimony of Dr. Johnsrud which, although there was no objection to this, that I've heard at least, did involve a heavy element of hearsay, to the extent that she was recounting what the pilot had said respecting his having flown over the site.

Now, Dr. Kepford, it would have seemed to me, knowing as you did that there were going to be commercial pilots from several airlines, the question that these pilots were going to address was flight patterns of commercial airlines, that given the information which had been imparted to you by Dr. Johnsrud, particularly involving statements allegedly made by the pilot, that you might have seen fit to have the pilot subpoenaed.

(Pause.)

CHAIRMAN ROSENTHAL: I would suppose that without at this point casting doubt on the accuracy of your witness's testimony that the pilot himself would have been the best evidence, as it were, as to the pattern that he had pursued in landing that particular plane and also would have been in a position to testify as to whether, assuming he had overflown the site, whether this was a customary procedure for U.S. Air when flying into Harrisburg and Pittsburgh; or whether this was an, an aberration.

And this brings of course to bear the value, as it were, of having testimony submitted in advance, because we had Dr. Johnsrud's testimony available to us in written form back in early February, even if you had not seen fit to subpoena that pilot, I daresay one of the other parties might have -- or we would have.

But it leaves us that, at a considerable disadvantage. And I'm frank to state I don't understand why in circumstances where your witness spoke to this pilot, the pilot represented to her that he had flown over the site -- endeavor was not made to subpoena the pilot.

Do youhave any response to that?

DR. KEPFORD: Sure. First off, in a filing dated

23

March 13th, 1979, handwritten, I served on the parties a document entitled "Summary of Testimonies of Intervenor's Witnesses Concerning Overflights of TMI-2," in which case I summarize what Mr. George Boomsma, Mr. Richard Hayden, and myself, Chauncey Kepford, would have had to say concerning overflights of Harrisburg International.

Now, with regard to Dr. Johnsrud's flight, I did not give much thought toward subpoena, toward requesting the issuance of a subpoena for that pilot; I was much more interested in trying to get as a witness for this proceeding a pilot who had indeed flown larger than design basis aircraft over the plant.

I would like to point out at this point both Dr. Johnsrud and I filed affadavits with this Board on December 27th, 1978, describing conversations with pilots who did indeed fly over the plant.

We have had further conversations, but we have not been able to produce a pilot who felt comfortable in testifying in this proceeding -- for the Intervenors -- even under subpoena.

CHAIRMAN ROSENTHAL: Comfortable about testifying in the proceeding -- is that the standard which applies to prospective witnesses, whether they would feel comfortable in the proceeding? -- if in point of fact, was the pilot who acknowledged that he had flown over the site, or pilots who'd flown a plane where you were fairly confident that you had a passenger who could make an informed judgment that that plane had flown over the site -- that pilot's subject to being subpoenaed.

And it doesn't make any difference whether the pilot is "comfortable about" it, as you put it, or not.

DR. KEPFORD: First off, with regard to that particular pilot of Dr. Johnsrud's flight, as I said, I didn't really think he would have that much more to say above and beyond what Dr. Johnsrud had to say.

Now, again, if we were the, the Intervenors were to go to the trouble to make this case, what we would have wanted for a witness would have been a pilot who had flown a larger-than-design-basis aircraft over the site.

I've had a number of conversations with such pilots, but none would, none wanted to testify, for fear of potential loss of jobs on behalf of the Intervenors.

CHAIRMAN ROSENTHAL: This was because their flying over the site was a violation, at least as they saw it, of their company policy?

DR. KEPFORD: No, absolutely. There were, they --

CHAIRMAN ROSENTHAL: Then why would they have been concerned about their jobs?

DR. KEPFORD: It had to do with testifying against potential clients of the airlines and so on.

7-5

CHAIRMAN ROSENTHAL: All right. Well, in any case, I think you've explained why you didn't do it; and --

DR. KEPFORD: I, I'd like -- excuse me, Mr. Chairman, could I add a little bit more?

CHAIRMAN ROSENTHAL: All right, if it's directly relevant to why you didn't undertake to have this particular pilot subpoenaed.

DR. KEPFORD: No.

CHAIRMAN ROSENTHAL: Well, that's all I really asked you about.

THE WITNESS: Mr. Chairman, might I add --

Dr. Kepford had been exceedingly busy with both the Three Mile Island Unit 1 and Unit 2 proceedings, in preparation. And during the remainder of January and early part of February, I was suffering the flu that everyone in Pennsylvania and the rest of the eastern United States seems to have suffered and was therefore not able to pursue contact with the pilot myself, on behalf of the Intervenors; and in the last week or so I guess I would take the responsibility for having felt that it was probably too late to be able to contact him and make the arrangements.

(Pause.)

THE WITNESS: But certainly in the immediate two weeks following that flight, I was in no shape to be [illegible], in touch with the pilot.

CHAIRMAN ROSENTHAL: I take it, Dr. Kepford, that this is not the pilot that you had indicated that you might seek a subpoena.

DR. KEPFORD: That's very definitely true. You are correct. Yes.

CHAIRMAN ROSENTHAL: It's a different pilot, because that pilot, as I understand, was a TWA pilot.

DR. KEPFORD: That's correct.

CHAIRMAN ROSENTHAL: And this is U.S. Air.

DR. KEPFORD: That's correct.

CHAIRMAN ROSENTHAL: All right.

Is there any further questions of Dr. -- Dr. Johnson.

End Tape 4
[illegible]

No, Dr. Johnson is going to ask.

DR. JOHNSON: Is that true?

THE WITNESS: Yes. I'd say within the past year, oh, somewhere between perhaps three and six. Maybe that's in the last year and a half; I'm not sure precise dates.

DR. JOHNSON: Was the flight path -- I gather the flight path that you are referring to on January the 24th was different from the normal flight path. You were expecting to to see the plant outside the side window, is that correct?

THE WITNESS: Well, I can't say concerning normal flight paths for all aircraft, no. But the few times that I had come in from Chicago or Pittsburgh I had been able to observe the reactor. But that was, as I say, only on the order of three or so -- from the west.

DR. JOHNSON: Well, I meant "normal" from your experience rather than from the totality of experience.

Did I understand you to indicate, however, that in your normal, or in your experience, the landing pattern of other flights had been somewhat the same as those which were described the pilots this morning?

THE WITNESS: Of the times that I had flown in from Pittsburgh or Chicago to Harrisburg: yes, the hook had been around the lower end of the island, such that I was able to see the reactors and cooling towers, which is why frankly I was so surprised at this one -- and I might add particularly, given the condition of the reactor since last March.

DR. JOHNSON: I have no further questions.

DR. BUCK: I just have a couple, Dr. Johnsrud.

When you saw the bridge, can you tell me at what angle it was to your flight? Parallel? At right angles?

(Pause.)

THE WITNESS: No. When I saw the bridge, we were into bank; we were banking.

DR. BUCK: Well, but when you looked out at this, was it roughly parallel to the flight at that moment? Or was it roughly at right angles to the flight? Or what angle was it at the particular point?

THE WITNESS: I, I really don't -- I don't think I can give you a response to that, Dr. Buck. I'm not quite sure I understand --

DR. BUCK: You have no recollection as to whether the bridge was slanting off this way, or this way, or any other way?

THE WITNESS: You mean, oh, I'm sorry. I, I guess I understand now what you're asking: was the bridge heading straight off to my line of sight, is that it? In which case, there was, and from my line of sight, the bridge was at something of an angle; but I could not specify precisely what --

DR. BUCK: It was something what?

THE WITNESS: There was something of an angle to the bridge; that is, I wasn't looking straight as if I were looking directly across the bridge.

DR. BUCK: In other words, you weren't at that point flying right along the length of the bridge.

THE WITNESS: Oh, no.

DR. BUCK: It was off to the side and slanting --

THE WITNESS: Slightly.

DR. BUCK: How long had the plane been in the bank before that, do you know? Or did it just tip into a bank at that particular point?

THE WITNESS: It was into the bank, but I, I can't tell you precisely how long, no.

DR. BUCK: How long had you been looking out the window at that point?

THE WITNESS: Oh, I'd been watching from, certainly from Carlisle and, in fact, all the way across -- I tend to fly, watching where I'm seeing or what I can see on the ground.

DR. BUCK: Well, you didn't have your head pressed against the window that whole time, did you?

THE WITNESS: Well, as a matter of fact, yes, I really did -- because I, I'm interested in what I can observe from the air and, of course, was particularly interested coming into Harrisburg.

DR. BUCK: What was the last recognizable point that you saw before you saw the bridges?

THE WITNESS: Well, when I saw the bridge --

DR. BUCK: Well, you'd been looking out the window before that, and I'm asking what was the last --

THE WITNESS: Yes, so I, I had -- yes, we had come along the, the west bank of the river; and I was able to see the river, Hill Island, essentially, the, the -- at that northern area.

DR. BUCK: You saw the island, both the islands?

THE WITNESS: Hill Island -- to the north.

DR. BUCK: Which island was that? Can you point it out to me?

THE WITNESS: It's the island to the north of Three Mile Island, in essentially the center of the river.

CHAIRMAN ROSENTHAL: Mr. Chandler, can you help us out by pointing out --

MR. CHANDLER: Hill Island?

CHAIRMAN ROSENTHAL: Yes.

DR. BUCK: Yes, where -- oh, that. You saw that, the whole of that island?

THE WITNESS: I don't, I, I really can't say that I saw the whole of the island. But I do recall seeing it, yes.

DR. BUCK: How did you recognize it?

THE WITNESS: From previous flights and from my familiarity with the area.

DR. BUCK: You could see the river on each side of the island?

(Pause.)

THE WITNESS: I really don't recall specifically the river on either side of the island, but I could, yes I could see the river and I could see the island, yes.

DR. BUCK: And that was at level flight, you could see all or most of the island, but not the river on the, on the west side.

THE WITNESS: I'm not sure whether that was, I, I think that was at level flight. I believe that was before we went into bank, but I would not be absolutely positive.

DR. BUCK: And relative to that island, when did the plane start the landing?

THE WITNESS: As I say, I'm not certain precisely. I believe it was while were at level, but I'm not certain precisely with respect to when we went into the bank. I was really looking for Three Mile Island and the reactors, primarily.

(Pause.)

DR. BUCK: So you have no recognizable point from that island until you saw the bridge.

(Pause.)

THE WITNESS: None other that sticks in my mind.

DR. BUCK: Okay. Thank you.

CHAIRMAN ROSENTHAL: Any further questions of this witness?

MR. CHANDLER: I will just have one.

CHAIRMAN ROSENTHAL: Mr. Chandler.

MR. CHANDLER: Did you see the cooling towers?

(Pause.)

DR. BUCK: What was that question, Mr. Chandler?

MR. CHANDLER: Did you see the cooling towers?

CHAIRMAN ROSENTHAL: The answer was "No."

MR. CHANDLER: Were the cooling towers perhaps off to the right side of the plane? Do you know?

THE WITNESS: Given where the pilot said we where, at where it appeared to me we were, the cooling towers should have been out of the view.

The northern ones and the southern ones.

MR. CHANDLER: Do you know what the distance is from the northern cooling tower of Unit 1, I presume, to the bridge?

THE WITNESS: No, I don't.

MR. CHANDLER: Did you indicate what your altitude was at the time you observed the bridge?

THE WITNESS: No. Nor did the pilot say.

MR. CHANDLER: I have no further questions.

CHAIRMAN ROSENTHAL: If there're no further questions, Dr. Johnsrud, you may be excused.

DR. KEPFORD: Mr. Chairman.

CHAIRMAN ROSENTHAL: Yes.

DR. KEPFORD: You mentioned something about hearsay, concerning Dr. Johnsrud's conversation with the pilot, as I recall.

CHAIRMAN ROSENTHAL: Yes.

DR. KEPFORD: Is that portion of her testimony being stricken?

CHAIRMAN ROSENTHAL: Well, I didn't hear a motion to strike it; and it will be therefore not stricken. However, I would have to tell you that, as with all hearsay, one must take into account the fact that the individual who allegedly made the statements in question is not present to be interrogated on them. And that obviously goes to the weight that can be attached to the captain's purported statements.

DR. KEPFORD: Might I call your attention to, in the Federal Rules of Evidence, Rule 8031, the "present sense impression" rule --

CHAIRMAN ROSENTHAL: Yes.

DR. KEPFORD: "A statement describing or explaining an event or a condition made while the declarant was perceiving the event or condition or immediately thereafter."

I believe that constitutes an exception to the hearsay rule; and hence, the pilot, what Dr. Johnsrud said of the pilot's conversation would be --

CHAIRMAN ROSENTHAL: Well, as I have indicated previously, the statement is not being stricken. All I said was that we have to take into account in evaluating it that the pilot is not present.

DR. KEPFORD: Thank you. Fine.

CHAIRMAN ROSENTHAL: All right.

Thank you, Doctor.

(Pause.)

CHAIRMAN ROSENTHAL: All right, now, Mr. Trowbridge, if I recall correctly, you wish to have one of the pilots -- or all the pilots -- recalled?

MR. TROWBRIDGE: I would like all the pilots --

CHAIRMAN ROSENTHAL: All right.

If the pilots are, pilot witnesses are still present, I would ask them to resume their seats at the --

(Pause.)

CHAIRMAN ROSENTHAL: All right, you may proceed, Mr. Trowbridge.

MR. TROWBRIDGE: Let me start with Captain Billie, since he was the first witness before.

And I note, Captain Billie, on your questionnaire that you have flown some smaller-than-2,000-pound, 200,000-pound --

Can you answer from your own experience or general knowledge as to whether there are reasons why you might expect a DC-9 to take a tighter turn into the airport, coming closer to the plant, than the larger aircraft, such as the 707's or 747's with which you are familiar?

CAPTAIN BILLIE: I think my experience basically in the lighter airplanes would be 727, and I would assume the same pattern, very similar pattern, would be flown. The speeds are not that uncomparable; the pattern would be very similar.

MR. TROWBRIDGE: Did you know about a DC-9?

CAPTAIN BILLIE: No, sir, I've never flown a DC-9.

MR. TROWBRIDGE: Are you aware that there are -- can you give any indication as to whether some of the lighter aircraft normally take a tighter turn into the, into, into this or other airports?

CAPTAIN BILLIE: My assumption is the pattern would be very similar, maybe somewhat tighter, but very similar. If I'm talking about three miles, that's the same way I would fly the pattern in a 727. And I would expect the DC-9 would be the same. I don't know that anyone here has flown the DC-9.

MR. TROWBRIDGE: Captain Ufford, you, you have experience with the DC-9, do you not?

CAPTAIN UFFORD: Yes, I fly it currently.

MR. TROWBRIDGE: Pardon me.

CAPTAIN UFFORD: Yes, I fly it currently, as well as the heavy DC-8.

MR. TROWBRIDGE: Can you comment on the, the question I asked as to whether one might reasonably expect that a DC-9 might take a tighter turn, I keep calling it, than say a 707?

CAPTAIN UFFORD: I can only speak from the experience I have, and I've flown this with, with Evergreen International.

Our procedures do not point out a difference in the pattern that should be flown, because of the fact that we operate heavy aircraft, for standardizing training and for transition on equipment. I couldn't, it would have to be an assumption on my part, the fact that Allegheny or U.S. Air does not operate any airplane in excess of 200,000 pounds.

There is a possibility they may have established a pattern as company policy that may be slightly tighter than -- but if you're saying, "Could you physically fly an airplane over the plant and still land --?" I think that is a possibility. I know of no procedure that would allow that, however,

MR. TROWBRIDGE: How could you compare the airspeed of the DC-9 with, say, a 707?

CAPTAIN UFFORD: The airspeeds are not that different. You would still be at, you would approach the downwind area there if you were coming in on that landing, as has been depicted. On the west bank of the Susquehana, you could be at, at 170 knots, in that area. And the final approach speed, once on the centerline, can vary from about 106 knots up to about 130. So it may be 25 miles per hour, or 20 knots roughly, slower than a, some of the lower speeds in a heavy aircraft, which would give you again a smaller radius of turn.

MR. TROWBRIDGE: Is that the consensus of all of the pilots? (Nonverbal affirmations.) Yes.

CAPTAIN LITHGOW: I have not flown the DC-9, but I have flown as a passenger many times, on Allegheny. And as a pilot, I would like to point out that it has been my experience that the Allegheny flights that I've been on generally tend to roll out on final at lower altitudes than are customary with the company I fly with.

MR. TROWBRIDGE: Could you, could you explain that a little bit more: they "roll out on" --?

CAPTAIN LITHGOW: It has been true of, in the testimony from the three different airlines represented here today that in each case the company policy has been that pilots will be established in the landing configuration a thousand feet above the ground, which puts them approximately three miles from the end of the runway.

It is my impression -- this is speculation on my part, but it's my impression -- that the Allegheny policy is not quite so restrictive. In other words, Allegheny pilots are permitted by company policy to be wings-level at a lower altitude as they roll out of the final turn.

At, if they, if their policy were to be level by 500 feet, why, they wouldn't be flying a tighter turn. They would be flying the same radius turn closer to the airport; and such a pattern could bring them closer to the Three Mile Island complex in this instance.

MR. TROWBRIDGE: Thank you.

I have no further questions.

CHAIRMAN ROSENTHAL: All right. Is there --
Dr. Kepford?

DR. KEPFORD: Yes, one general question or two:
Are there any rules, other than company procedure, for your various airlines that would prevent you from flying over the plant or, say, entering the runway at two miles, entering the runway extended, the centerline extended, two miles from the plant, assuming VFR?

CAPTAIN UFFORD: One rule -- when you say, "Are there rules other than company rules --"

DR. KEPFORD: Yes. In your particular case.

CAPTAIN UFFORD: It only requires one rule, for, you know, for you not to do that.

DR. KEPFORD: Okay. What I was thinking about was FAA. In, in your case, I believe, you testified it was company policy that you get on the centerline extended something like three or three and a half miles out.

CAPTAIN UFFORD: That's correct.

DR. KEPFORD: Okay. So in your case that's a limiting factor.

CAPTAIN UFFORD: Yes.

DR. KEPFORD: And you testified so, too, I believe, Captain Lithgow.

CAPTAIN LITHGOW: Well, I would like to point out that the, that the Federal Aviation regulation, regulations governing visual flight patterns do not specify minimums generally, because the design geometrics of different airplanes place different constraints on the operating procedures.

What, what happens is that the FAA evaluates and certifies the company operations procedures. Each company is required by law under 121 to produce an op, a company operations manual, which specifies the procedures. Once the FAA approves that company operations manual, that manual then takes on the force of law under part 121, so that, that the company manual is the FAA law.

DR. KEPFORD: Thank you.

Captain Beuerlein, is it TWA policy to, under VFR rules, to enter the runway extended at some minimum distance?

CAPTAIN BEUERLEIN: No minimum distance, no.

DR. KEPFORD: No minimum altitude?

CAPTAIN BEUERLEIN: Minimum altitude depends on the aircraft itself. The company policy is that the base leg should be flown 1,500 feet above the, the elevation which the, the elevation of the airport is 310 feet, approximately, so that the downwind leg would be flown at about 2,000 feet, 1,800 to 2,000 feet.

DR. KEPFORD: That's the one that's parallel to the runway.

CAPTAIN BEUERLEIN: That's the one that's in the southeast direction parallel to the runway, just to the

14

southwest of the airport.

DR. KEPFORD: When you enter your turn, your initial turn, at the end of the base --

CAPTAIN BEUERLEIN: Downwind.

DR. KEPFORD: When you're going downwind, parallel to the runway and you initiate your turn, do you stay in a constant bank until you are approximately approaching the centerline extended?

CAPTAIN BEUERLEIN: In this case, three miles from the side of the runway, which would be the downwind, it would be leveled -- at level wings -- on the base leg.

DR. KEPFORD: Okay. Are there are company procedures or policies which, in effect, have the weight of FAA rule that would prevent you from flying, let's say, a somewhat tighter pattern to within being a quarter of a mile to half a mile distance from TMI nuclear power plant?

(Pause.)

CAPTAIN BEUERLEIN: Well, in this case, the golf course which is located to the extended, runway extension at approximately the two-mile marker is 300 feet, I believe, above the field elevation, which would be more inclined to worry about that. Because I would be on the final approach, I would know where my approach would be; and that definitely would be in the way of my approach, so I would not go down any further than 500 feet above the ground approximately two to three miles from the runway extension line.

(Pause.)

DR. KEPFORD: I don't think I understood. Let's -- yours is the tightest pattern on that chart, is it not?

CAPTAIN BEUERLEIN: Artistically, yes.

(Laughter.)

DR. KEPFORD: Now, is there any procedure or company policy that would prevent you from tightening that a bit, such that your closest approach might be to, to the nuclear power plant might be on the order of one-quarter to one-half mile? Is there anything that would prevent you from flying that close?

CAPTAIN BEUERLEIN: No, there would nothing -- there's nothing in our FAR or company policy to prevent us from flying over the area. In other words, it's not a danger area or a restricted area.

CHAIRMAN ROSENTHAL: I thought, Dr. Kepford, that these questions were asked of the captain during his prior testimony, whether there was a company policy that precluded -- and I thought he answered at that time "no."

So I, I -- and this doesn't also seem to me to be cross-examination directed to what the captain was recalled to testify to.

DR. KEPFORD: Well, I'm essentially through.

CHAIRMAN ROSENTHAL: Any further questions of --

Any of the members of the panel?

SPEAKER: Nothing further.

CHAIRMAN ROSENTHAL: Ms. Carter.

MS. CARTER: Not, we have no questions.

CHAIRMAN ROSENTHAL: All right.

Once again the panel may be excused with our thanks.

(Pause.)

All right. My contemplation is that we'll take our luncheon recess around 12:30. And I think we can get started, therefore, with the testimony on the next phase.

Let me ask either Mr. Trowbidge or Mr. Treby, who I understand takes over for the staff at this point, whether there's been an agreement as to whether the applicant's witnesses, Mr. Vallance and Dr. Kaplan, or the staff witnesses, Moore and Abramson, will go first?

MR. CHANDLER: Mr. Chairman, Mr. Trowbridge and I have discussed it; and we determined that the applicant's witnesses will go first.

CHAIRMAN ROSENTHAL: All right, Mr. Trowbridge, you wish to call him?

SPEAKER: The last captain, please.

MR. CHANDLER: Mr. Chairman, I have not had the opportunity to discuss either with Mr. Treby or Mr. Trowbridge one matter that I did bring up this morning, that being with respect to the affadavit of Jack Reed, the second affadavit of

17

Jack Reed, and the joint affadavits of Doctors Moore and Abramson.

We had transmitted to the Board and parties by letter of February 4th the affadavit and attached analysis of Dr. Reed and a joint affadavit by Doctors Moore and Abramson regarding the staff's updating efforts.

At that time I indicated that I would offer those at this hearing.

Subsequently, it was learned that there was an error in Dr. Reed's affadavit, which was addressed -- is addressed -- in an affadavit of Dr. Reed, which was provided to the Board and parties this morning, although it was brought to the parties' attention on Friday, and the Board's as well.

I would at this time perhaps ask that these documents be received in evidence and that they be incorporated in the transcript as if read.

CHAIRMAN ROSENTHAL: Any objection?

DR. KEPFORD: No objection.

CHAIRMAN ROSENTHAL: So ordered.

MR. CHANDLER: I will provide the reporter with the requisite number of copies.

(Copies of the aforementioned documents follow:)

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))

AFFIDAVIT OF JACQUES B. J. READ

STATE OF MARYLAND)
COUNTY OF MONTGOMERY) SS

I, Jacques B. J. Read, being duly sworn, depose and state:

1. I am a Chemist-Nuclear Engineer, Accident Analysis Branch, Division of Site Safety and Environmental Analysis, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.
2. I have previously testified in this proceeding and my Statement of Professional Qualifications is incorporated in the transcript (following Tr. 232).
3. I have prepared the attached document entitled "Analysis of Addition of 1978 Air Traffic and Accident Rates and Revisions to 1976 and 1977 Estimates to 'NRC Staff Testimony Regarding U.S. Air Carrier and Military Accident and Traffic Data' and 'Evaluation of Aircraft Crash Potential for Nuclear Power Plants'", and, if called upon, I would testify as set forth therein.

Jacques B. J. Read

Subscribed and sworn to before
me this 4th day of February, 1980

Notary Public

My Commission expires: July 1, 1982

ANALYSIS OF ADDITION OF 1978 AIR TRAFFIC AND ACCIDENT RATES AND REVISIONS TO 1976 AND 1977 ESTIMATES TO "NRC STAFF TESTIMONY REGARDING U.S. AIR CARRIER AND MILITARY ACCIDENT AND TRAFFIC DATA" AND "EVALUATION OF AIRCRAFT CRASH POTENTIAL FOR NUCLEAR POWER PLANTS"

I.

Calendar year 1978 data has now been compiled by the Federal Aviation Administration (FAA), Civil Aeronautics Board (CAB), and National Transportation Safety Board (NTSB). Combined with information supplied by the Military Airlift Command (Attachment 1) and the Air Force Inspection and Safety Center (Attachment 2), these data are now sufficient to permit calendar year 1978 to be added to the tables of aircraft traffic and accidents previously submitted.

In addition, NRC and National Archives personnel have succeeded in recovering 1976 and 1977 air charter traffic information from the defective magnetic tapes, alluded to in my earlier testimony (following Tr. 242, at 26). Charter traffic for those years had been estimated, but is now in tables 19A, 19B and 20 as it was actually reported. The only notable difference between the previous estimates and actual traffic is that Capitol International Airlines had been estimated to average about one charter per month at Harrisburg International Airport (HIA), while in fact, during February 1977 they flew eight charters,[1] in October 1977 three charters, and in November of 1977 they flew four charters. The original estimates of heavy aircraft charter operations in Table 20 were four operations too high in 1976, but, due primarily to the three unusual months noted, thirty-four operations too low in 1977.

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[1] Each charter involves four operations.

Changes have occurred in the trends of air transport at Harrisburg International Airport:

1) Due to the "deregulation" of the air transport industry, a process begun in October, 1978, and still continuing, chartered passenger flights nationally have greatly diminished, and, during the first nine months of 1979, charter operations were about half of their volume in the corresponding 1978 period.

2) A significant fraction of the air cargo charters at Harrisburg International Airport were to deliver military hardware from the Cumberland Army Depot to the Iranian Royal Armed Forces. These flights terminated in early 1979.

3) The Pegasus International Travel Club, which owned the sole "heavy" aircraft stationed at Middletown, and which accounted for 38 yearly "heavy" operations, has gone bankrupt. The aircraft they owned has not flown during the past several months and resumption of operations from Harrisburg International Airport is questionable.

The largest single contributor to "heavy" aircraft traffic for the period of available recorded data continues to be Trans World Airlines flight 415, which leaves Harrisburg each morning for Chicago, and then proceeds on to San Francisco. Due to the time differential, there is no return flight, and the equipment is brought to HIA as flight 116 from Chicago. This equipment was usually a B707-100 prior to December 1974, and since has been either a 727 or one of a variety of B707 models. During 1978 and 1979, B707 models dominated, raising the number of "heavy" scheduled operations, as shown for 1978 in the revised Table 20. Since the actual equipment scheduled for use at HIA depends upon varying scheduling details of Trans World Airlines western U.S. route structure, the division between "heavy" and "light" scheduled flights have continued to change from year-to-year without apparent trend. As noted previously in Table 10 and Attachment A, flights 116 and 415 could weigh over 200,000 pounds, for example, if flown by a B707, 300-model series, with over 60,000 pounds of fuel and payload. Based on conversations with Trans World Airlines, I understand that TWA is in the process of retiring its Boeing 707 fleet, and expects to have completed this process sometime during 1981. Since the end of 1979, TWA flights 116 and 415 have been scheduled to be flown by Boeing 727-200 aircraft, and TWA forecasts the use of this equipment on these flights for the next several years. A review of several recent Official Airline Guides (North American Edition) confirms TWA's intention to serve these flights with Boeing 727 aircraft. "Heavy" aircraft operations at Harrisburg International Airport, therefore, are expected to decline from the relatively high value observed in 1978.

I have also reviewed available crash data for 1978 and, on this basis, have prepared Table 4 Addition, attached hereto. As indicated by Table 4 Addition, two crashes in 1978 involved heavy aircraft - a DC-10 in Los Angeles, California (crash no. 99) and a DC-8 in Portland, Oregon (crash no. 102). The former occurred on the runway during the takeoff phase and, therefore, is not considered relevant for inclusion in the crash rate calculation for the TMI site. The latter crash, having occurred beyond the five mile area of concern in this proceeding, similarly is not felt to be appropriately factored into the crash rate calculation for TMI.

Since I have been able to obtain operations data for 1978, I have updated Table 8 as shown in Table 8 Addition, attached hereto. This Table reflects the number of scheduled, non-scheduled and total operations in 1978, the number of landing and takeoff crashes in each categroy and the number of accidents per million of each type of operation. This information is also provided for the 23-year period 1956-1978.

Table 9 Revised, also attached, contains a summary of accidents and operations based on Table 4 as revised and updated through Table 4 Addition.

Table 11 Addition, attached, sets forth 1978 operations for Harrisburg International Airport, broken down into Air Carrier, Air Taxi, General Aviation and Military operation.

The activities of certified route air carriers at HIA for CY 1977 has been updated for CY 1978 in Table 16A, and Table 20 has been updated in Table 20 Revised to include the new information for 1976 and 1977 and the updated information for 1978.

TABLE 4 ADDITION

	Date	Location	Phase	Aircraft	Fatality	Type Oper.	Range & Bearing r mi	deg.
	1978							
98)	1/18	Pueblo, CO	T	DCH-6	F	Training	0	0
99)	3/1	Los Angeles, CA	T	DC-10	F	SP	0	0
100)	5/8	Pensacola, FL	L	B727	F	SP	3.0	3R
101)	9/25	San Diego, CA	L(1)	B727	F	NS(2)	3.1	23R
102)	12/28	Portland, OR	L(3)	DC-8	F	SP	5.0(4)	20R
							5.2	16L
							6.0	12L

FOOTNOTES:

(1) Officially labelled as "in-flight", aircraft was overflying the airport on its downwind leg when it collided with an aircraft climbing out from a cross-wind runway. Aircraft was headed __away__ from airport at time of collision.

(2) Pacific Southwest Airlines (PSA) was not CAB-certified at the time since its routes were within a single state. PSA was officially a "Commercial Operator of Large Aircraft". To be consistent with other earlier table entries, this crash is counted as "NS", although this flight was indeed scheduled. PSA has since been certified.

(3) Officially labelled as "inflight". This aircraft exhausted its fuel in a holding pattern while about 20 miles from its intended airport and glided closer.

(4) The aircraft is considered to have executed a forced landing in an open field. The cockpit voice recorder and radio communication transcript clearly indicate that a runway landing was recognized as impossible. The landing was largely successful in that 156 occupants were uninjured, and all fatalities and serious injuries occurred to occupants near the pont of penetration of a tree encountered late in the landing roll. The range and bearing of all runways near the final location of the landed aircraft are given. The nearest is the 4600 foot single runway of Troutdale airport, the farthest is the 11,000 foot runway at Portland International Airport which the aircraft would normally have used. The point of initial ground contact was approximately 1500 feet farther from all runways. This DC-8-61 weighed about 180,000 lbs at the time of the accident.

Based upon the above information, we do not consider this accident to be a crash within 5 miles of the intended runway.

TABLE 8 ADDITION

YEAR	TYPE	MILLIONS OF OPERATIONS	TABLE 4 REVISED ACCIDENTS LANDINGS	TABLE 4 REVISED ACCIDENTS TAKE OFFS	ACCIDENTS PER MILLION OF EACH TYPE OF OPERATION LANDINGS	ACCIDENTS PER MILLION OF EACH TYPE OF OPERATION TAKE OFFS
1978	S	9.03	1	1	.22	.22
	N	.21	1	0	9.5	0
	T	9.24	2	1	.43	.22
			23 YEAR TOTAL			
1956 through 1978	S	181.6	43	20	.47	.22

TABLE 9 REVISED

SUMMARY OF ACCIDENTS AND OPERATIONS FROM UPDATED TABLE 4 REVISED

	Off Runway	On Runway	Total	Operations(10^6)
Scheduled				
landing	26 1)	15 1)	41 1)	90.9
take off	11 1)	8 1)	19 1)	90.9
Non-scheduled				
landing	14 2)	2 3)	16 2)3)	2.47
take off	2 2)	5 3)	7 2)3)	2.47

1) Does not include 4 NA accidents, which are included in Table 8.

2) Does not include 2 take off and 2 landing accidents in training.

3) Does not include 5 take off and 5 landing accidents in training.

TABLE 11 ADDITION

	ITINERANT				LOCAL		TOTAL
	AC	AT	GA	MIL	GA	MIL	
1978	13846	16531	25512	4519	33064	8985	102,457

TABLE 16A

AIRPORT ACTIVITIES OF CERTIFIED ROUTE AIR CARRIERS AT HARRISBURG

CALENDER YEAR 1978

		DEPARTURES	
CARRIER	CARRIER	SCHEDULED	NON-SCHEDULED
Allegheny	CV580	8	0
	BAC-111-200	133	2
	DC-9-30	1480	10
	DC-9-50	1116	10
	MO-298	2082	0
	B727-100	339	15
Trans-World	DC-9-10	2	0
	B727-100	242	0
	B727-100C/QC	64	0
	B727-200	486	0
	B707-100B	227	0
	B707-300	6	1
	B707-300B	3	0
	B707-300C	3	0

Total Operations = 12458
B707 Operations = 480 (excluding ferry flights)

TABLE 19A

CHARTER DEPARTURES AND ARRIVALS AT HARRISBURG INTERNATIONAL AIRPORT, 1 APRIL THROUGH 31 DECEMBER, 1976

	NO. OF CHARTER STOPS		
AIRCRAFT	U.S. CERTIFIED ROUTE AIR CARRIERS	U.S. SUPPLEMENTAL AIR CARRIERS	TOTAL(1) U.S.
CV440	2	0	2
CV580	3	0	3
CV600	3	0	3
FH-227	10	0	10
L-188	0	13	13
BAC-1-11	5	0	5
B737-200	4	0	4
DC-9-30	21	0	21
DC-9-50	23	0	23
B727-100	20	0	20
Total "light"	91	13	104
B-707-300	40	0	40
B720	0	2	2
DC-8-30	0	9	9
DC-8-50	15	0	15
DC-8-61	4	10	14
DC-8-63	4	15	19
Total "heavy"	63	36	99

Note: (1) In addition a Canadian carrier, East Provincial Air, flew two round trips from Halifax, Nova Scotia, to Harrisburg to bring in and then out 58 passengers. The aircraft was of foreign manufacture, and is assumed "light." Hence, there were 212, i.e., (104 + 2) x 2, "light" operations and 198, i.e., 99 x 2, "heavy" operations during the nine month period.

TABLE 19B

CHARTER DEPARTURES AND ARRIVALS AT HARRISBURG INTERNATIONAL AIRPORT, 1 JANUARY THROUGH 31 DECEMBER, 1977

AIRCRAFT	NO. OF CHARTER STOPS U.S. CERTIFIED ROUTE AIR CARRIERS	U.S. SUPPLEMENTAL AIR CARRIERS	TOTAL(1) U.S.
CV440	9	0	9
CV580	4	0	4
CV600	14	0	14
FH227	2	0	2
L-188	0	2	2
BAC-1-11	6	0	6
B737-200	2	0	2
DC-9-[illegible]	1	0	1
DC-9-30	45	0	45
DC-9-50	10	0	10
B727-100	14	0	14
Total "light"	107	2	109
B707-300	32	0	32
DC-8-20	1	0	1
DC-8-30	0	18	18
DC-8-50	9	12	21
DC-8-61	9	30	39
DC-8-62	8	0	8
DC-8-63	5	14	19
L-1011	2	0	2
Total "heavy"	66	74	141

Note: (1) In addition, Canadian carriers flew four round trips from Toronto, and ALM Antillies Airlines flew two round trips from Aruba, Netherlands Antillies, none of these flights having enough passengers to require or suggest a "heavy" aircraft. Also, Japan Airlines made one stop with the cargo version of the DC-8-50. Hence, there were 230, i.e., (109 = 6) x 2, "light" operations and 284, i.e., (141 + 1) x 2, "heavy" operations.

TABLE 20 REVISED

OPERATIONS AT HARRISBURG INTERNATIONAL AIRPORT

	1978	1977	1976
AIR CARRIER REVENUE OPERATIONS			
Scheduled			
Heavy	482	206	190
Light	11978	10776	9876
Non-Scheduled			
H	232	284	266(1)
L	160	230	284
AIR CARRIER NON-REVENUE OPERATIONS			
H	58	58	58
L	936	1121	228
AIR TAXI-COMMUTER AIRLINES			
L	16531	17235	12382
MILITARY-ITINERANT			
H	38	82	166
L	4481	4368	3824
MILITARY-LOCAL			
L	8985	8542	7372
GENERAL AVIATION-ITINERANT			
L	25512	24138	22783
GENERAL AVIATION-LOCAL			
L	33064	37250	25224
TOTAL			
H	810	630	680
L	101,647	103,656	81,973
	102,457	104,286	82,653

TABLE 20(REVISED)(Cont.)

Note (1)

ESTIMATION OF TRAFFIC FOR JANUARY-MARCH, 1976

Numbers of Charters/Month	1977	1976
Jan.	20	N/A
Feb.	27	N/A
Mar.	16	N/A
Apr.	10	19
May	31	29
June	19	18
July	13	21
Aug.	23	13
Sept.	23	20
Oct.	27	28
Nov.	24	19
Dec.	17	25
Total, first quarter	63	N/A
Total, last three quarters	187	192

$$\frac{\text{First quarter}}{\text{last three quarters}} = 0.337$$

Therefore, assume for 1976 that full year traffic is 1.34 times traffic in last three quarters.

ATTACHMENT 1

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS MILITARY AIRLIFT COMMAND
SCOTT AIR FORCE BASE, ILLINOIS 62225

13 DEC 1979

Jacques B. [illegible]. Read, PhD
Accident Analysis Branch
Division of Site Survey and
 Environmental Analysis
Office of Nuclear Reactor Regulation
US Nuclear Regulatory Commission
Washington DC 20555

Dear Dr. Read

Enclosed are the data you requested in your letter of 4 December 1979 concerning MAC aircraft operations into Harrisburg International Airport PA. This updates the information we provided in the fall of 1978 for the preparation of testimony before the Atomic Safety and Licensing Appeal Board.

If we can be of further assistance, please let us know. My project officer is Major Williamson, HQ MAC/DOCSS, AUTOVON 638-3391.

Sincerely

Donald D

DONALD D. [illegible], Brig Gen, USAF
Assistant DCS/Operations

1 Atch
Harrisburg International
Airport Activity
Summary Update

E-4/C-5/C-141 AIRCRAFT

1 JAN 1978 - 30 SEP 1979

	FLYING HOURS		SORTIES		LANDINGS		DESTROYED AIRCRAFT		
	YEAR	1968-30 SEP 79 CUMULATIVE	YEAR	1968-30 SEP 79 CUMULATIVE	YEAR	1968-30 SEP 79 CUMULATIVE	NO	RATE*	REMARKS
E-4									
1978	2,109	5,590	479	1,380	1,388	5,320	0	0.0	
1979 (30 Sep)	1,407	6,997	335	1,715	1,026	6,346	0	0.0	
C-5									
1978	49,543	366,908	10,430	77,540	40,215	70,651	0	0.0	
1979 (30 Sep)	36,530	403,438	7,599	85,139	24,302	94,953	0	0.0	
C-141									
1978	282,594	4,713,892	81,205	1,269,176	170,983	2,223,416	0	0.0	
1979 (30 Sep)	220,380	4,934,272	64,545	1,333,721	136,760	2,360,176	1	0.5	Landing roll, nose gear collapsed, fire damage.

*Rates based on number of accidents per 100,000 flying hours.

ATTACHMENT 2

DEPARTMENT OF THE AIR FORCE
HEADQUARTERS AIR FORCE INSPECTION AND SAFETY CENTER
NORTON AIR FORCE BASE, CALIFORNIA 92409

DEPARTMENT OF DEFENSE · UNITED STATES OF AMERICA

REPLY TO ATTN OF: SERR

13 DEC 1979

SUBJECT: Request for Aircraft Mishap Information

TO: United States Nuclear Regulatory Commission
ATTN: Dr. Jacques B. J. Read
Accident Analysis Branch
Division of Site Safety and Environmental Analysis
Washington DC 20555

In response to your letter of 15 November 1979, the attached chart provides destroyed aircraft information for E-4, C-5, and C-141 aircraft.

Roger G. Crewse

ROGER G. CREWSE
Chief, Reports & Analysis Division
Directorate of Aerospace Safety

1 Atch
Chart

Strength through Vigilance

HARRISBURG INTERNATIONAL AIRPORT

ACTIVITY SUMMARY UPDATE

TYPE AIRCRAFT	OPERATOR	1978 (JAN-DEC)	1979 (JAN-OCT)
C-5A	Air Force	9	15
C-141	Air Force	9	45
B-707	AF Charter	1	0

II.

In the earlier testimony of D. G. Eisenhut, "Evaluation of Aircraft Crash Potential for Nuclear Power Plants" (following Tr. 469), the likelihood of a "heavy" aircraft crash was described as being estimated for each type of aircraft and airport activity by the product of three factors: the traffic density in the Three Mile Island quadrant (N), the areal crash density (C), and the effective plant area (A). The geometry of the plant and runway, and the prevailing winds have not changed, so that the effective plant area (A) and the distribution of the traffic by quadrant remain as described earlier. The inclusion of 1978 air carrier experience into the previous 22-year averages causes minor changes in the computed areal crash density (C) (See Eisenhut testimony at 14), as follows:

Areal Crash Density, C[2]

	Scheduled	Non-Scheduled
Landings	2.3×10^{-9}	4.5×10^{-8}
Take offs	4.6×10^{-9}	3.0×10^{-8}

The remaining factor, "Present Relevant Heavy Movements," N, varies from year-to-year, with a decreasing trend in the "nonscheduled" component, and a "scheduled" component which, at HIA, is totally determined by the operation of Trans World Airlines. The values of N, computed as before (see Eisenhut testimony at 14), for calendar year 1978 are:

---

[2] See "Analysis of the Effects of Updated Data on the Previously Submitted Testimony and Supplemental Testimony of R. Moore and L. Abramson" by R. Moore and L. Abramson.

1978 Relevant Heavy Movements

	Total	Scheduled	NonScheduled
Landings	131	78	53
Take offs	71	42	29

Combining these factors to estimate the total probability (see Eisenhut testimony at 15)

$$\begin{aligned} P_{total} &= [(2.3 \times 10^{-9})(78)(.0062) + (4.6 \times 10^{-9})(42)(.0026)] \\ &+ [(4.5 \times 10^{-8})(53)(.0062) + (3.0 \times 10^{-8})(29)(.0026)] \\ &= 1.1 \times 10^{-9} + 0.5 \times 10^{-9} + 1.48 \times 10^{-8} + .23 \times 10^{-8} \\ &= 1.87 \times 10^{-8}/\text{year} \end{aligned}$$

The term in the above equation corresponding to non-scheduled landings is dominant in determining the total, as it was also for the previous estimate. The 1978 data changes the previous estimate from 1.6×10^{-8} to 1.87×10^{-8}; this change is insignificant, indeed within the range of uncertainty inherent in the methodology. Therefore, our prior conclusions are not altered in any way.

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))

JOINT AFFIDAVIT OF ROGER H. MOORE AND LEE R. ABRAMSON

STATE OF MARYLAND) SS
COUNTY OF MONTGOMERY)

I, Roger H. Moore, being duly sworn, depose and state:

1. I am the Chief, Applied Statistics Branch, Office of Management and Program Analysis, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

2. I have previously testified in this proceeding and my Statement of Professional Qualifications is incorporated in the transcript (following Tr. 373).

I, Lee R. Abramson, being duly sworn, depose and state:

3. I am a statistical adviser, Applied Statistics Branch, Office of Management and Program Analysis, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

4. I have previously testified in this proceeding and my Statement of Professional Qualifications is incorporated in the transcript (following Tr. 374).

We the affiants Roger H. Moore and Lee R. Abramson, being duly sworn, depose and state:

5. We are jointly responsible for and participated in the preparation of the attached document entitled "Analysis of the Effects of Updated Data on the Previously Submitted Testimony and Supplemental Testimony of R. Moore and L. Abramson", and, if called upon, we would testify as set forth therein.

Roger H. Moore

Lee R. Abramson

Subscribed and sworn to before
me this 1ST day of February, 1980

Notary Public

My Commission expires: July 1, 1982.

ANALYSIS OF THE EFFECTS OF UPDATED DATA ON THE PREVIOUSLY SUBMITTED TESTIMONY AND SUPPLEMENTAL TESTIMONY OF R. MOORE AND L. ABRAMSON

Since the hearing on December 11-12, 1978, an additional year's worth of data (1978) has become available. We were provided with this updated data and requested to examine the effects of this additional data on our testimony as submitted November 30, 1978 and revised December 8, 1978 (to be denoted by "T") and on our supplemental testimony submitted March 16, 1979 (to be denoted by "ST").

With the addition of the 1978 data, Table I in "T" is updated as follows:

	SCHEDULED			NONSCHEDULED		
	OPERATIONS ($X10^6$)	HITS	RATE ($X10^{-6}$)	OPERATIONS ($X10^6$)	HITS	RATE ($X10^{-6}$)
TAKEOFFS	90.9	11	0.12	2.47	2	0.81
LANDINGS	90.9	26	0.29	2.47	14	5.67

Table I (updated). Off-runway destruct accidents for all U.S. carrier aircraft, 1956-1978.

Since there were no off-runway destruct takeoff accidents in 1978, our estimate of the conditional crash density for takeoffs as given in "T" does not change. From Table 4 Addition, the 1978 data increases the total number of takeoff accidents from 40 to 42 and the number of hits in the interval $2.0 \leq r < 3.5$ surrounding TMI from 8 to 10. The updated values for $g_L(r_o)$ and $h_L(\theta_o)$ are

$$g_L(r_o) = \frac{10}{42} \cdot \frac{1}{1.5} = .159 \text{ per mile}$$

$$h_L(\theta_o) = \frac{3}{42} \cdot \frac{180}{15\pi} \cdot \frac{1}{2} = .136 \text{ per radian} .$$

As on page 8 of "T", the updated estimate of the conditional crash density for landings is

$$D_L(r_o, \theta_o) = \frac{(.159)(.136)}{2.7} = .00801 \text{ per square mile} .$$

The estimate areal crash densities based on the 23-year period 1956-1978 is given by Table III (updated).

	SCHEDULED	NONSCHEDULED
TAKEOFFS	4.6×10^{-9}	30×10^{-9}
LANDINGS	2.3×10^{-9}	45×10^{-9}

Table III (updated). Estimated areal crash densities at TMI-2 for a U.S. carrier aircraft engaged in a relevant operation (probability per square mile).

The inclusion of the 1978 data results in a decrease of 6 percent[1/] in the estimated areal crash densities for takeoffs and an increase of 15 percent[2/] in the areal crash densities for landings. The magnitudes of these changes are not at all surprising, since they are well within the uncertainty bands on the estimates given in "T".

[1/] Scheduled takeoffs decrease from 4.9×10^{-9} to 4.6×10^{-9} and nonscheduled takeoffs from 32×10^{-9} to 30×10^{-9}.

[2/] Scheduled landings increase from 2.0×10^{-9} to 2.3×10^{-9} and nonscheduled landings from 39×10^{-9} to 45×10^{-9}.

Since the uncertainty results in "T" were replaced by the revised uncertainty analysis of "ST," we see no point to updating the confidence limits given in "T".

The inclusion of the 1978 data has very little effect on our supplemental testimony of March 16, 1979. Since there were no off-runway destruct takeoff accidents in 1978, the estimated crash densities for takeoffs from Figures 1 and 2 remain unchanged. The updated estimated crash densities for landings look very much like their counterparts in "ST" and are given in Figures 1 and 2 (updated). No change in the discussion is necessary.

In the uncertainty analysis, the bounds on the exact confidence limits change by a maximum of 16 percent[3] and are presented in Table IV (revised and updated). In this table, the two columns headed "Upper Bound (Table IV)" have been updated with the 1978 data.

BOUNDS ON EXACT CONFIDENCE LIMITS(x 10^{-9})

		70%	80%	85%	90%	
SCHEDULED	ESTIMATED RATE	Upper Bound (Table IV)	Upper Bound (revised)	Upper Bound (Table IV)	Lower Bound	Upper Bound (revised)
TAKEOFFS	4.6×10^{-9}	34.2	22.1	50.3	14.6	30.6
LANDINGS	2.3×10^{-9}	10.2	7.7	14.0	5.9	9.7
NONSCHEDULED						
TAKEOFFS	30×10^{-9}	401	261	640	98	390
LANDINGS	45×10^{-9}	224	168	312	117	215

Table IV (revised and updated). Estimated values and bounds on exact confidence limits for areal crash densities at TMI-2 for a U.S. carrier aircraft engaged in a relevant operation (probability per square mile)

---

[3] The bounds for takeoffs decrease by about 5 percent and the bounds for landings increase from 8 to 16 percent.

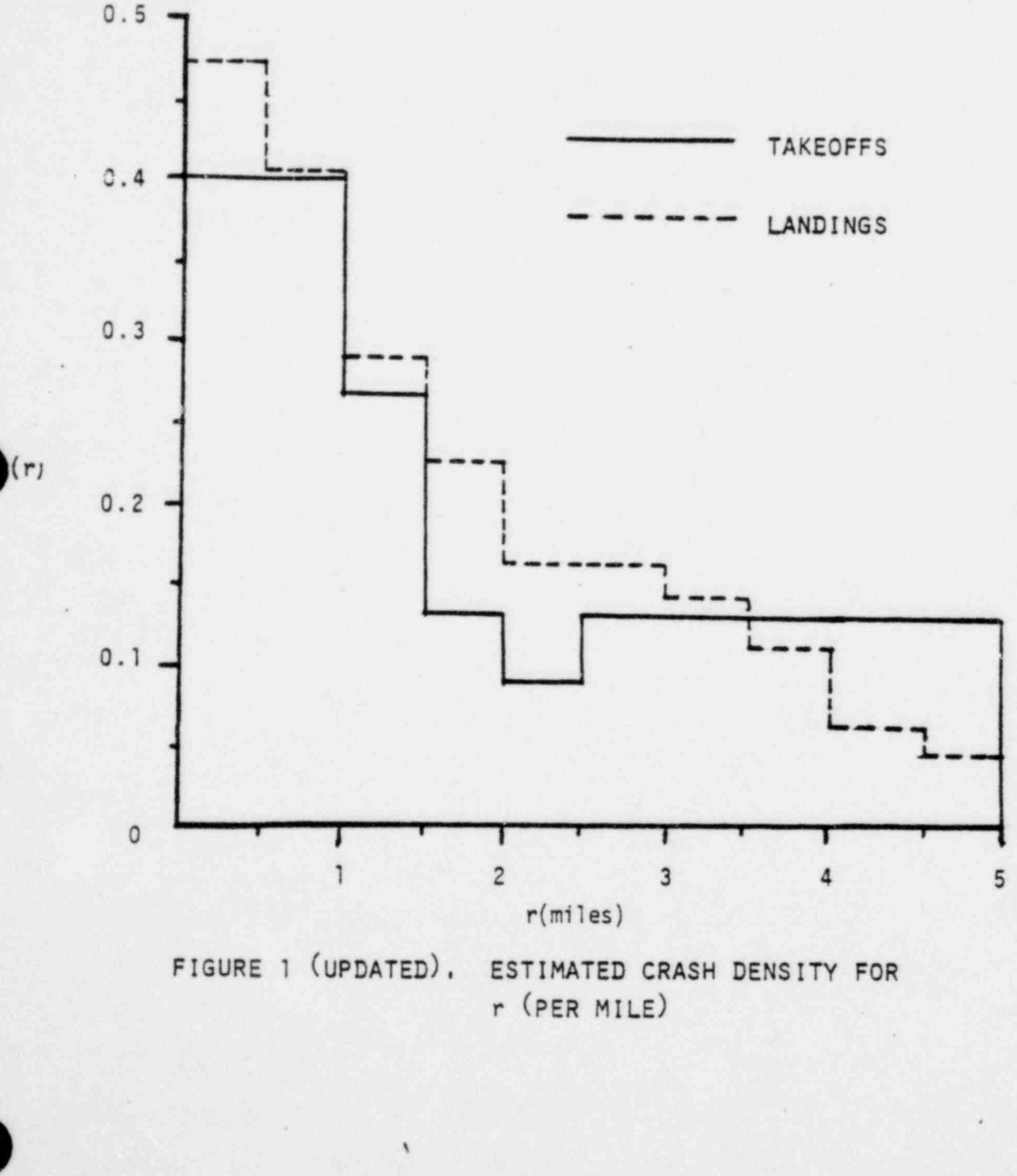

FIGURE 1 (UPDATED). ESTIMATED CRASH DENSITY FOR r (PER MILE)

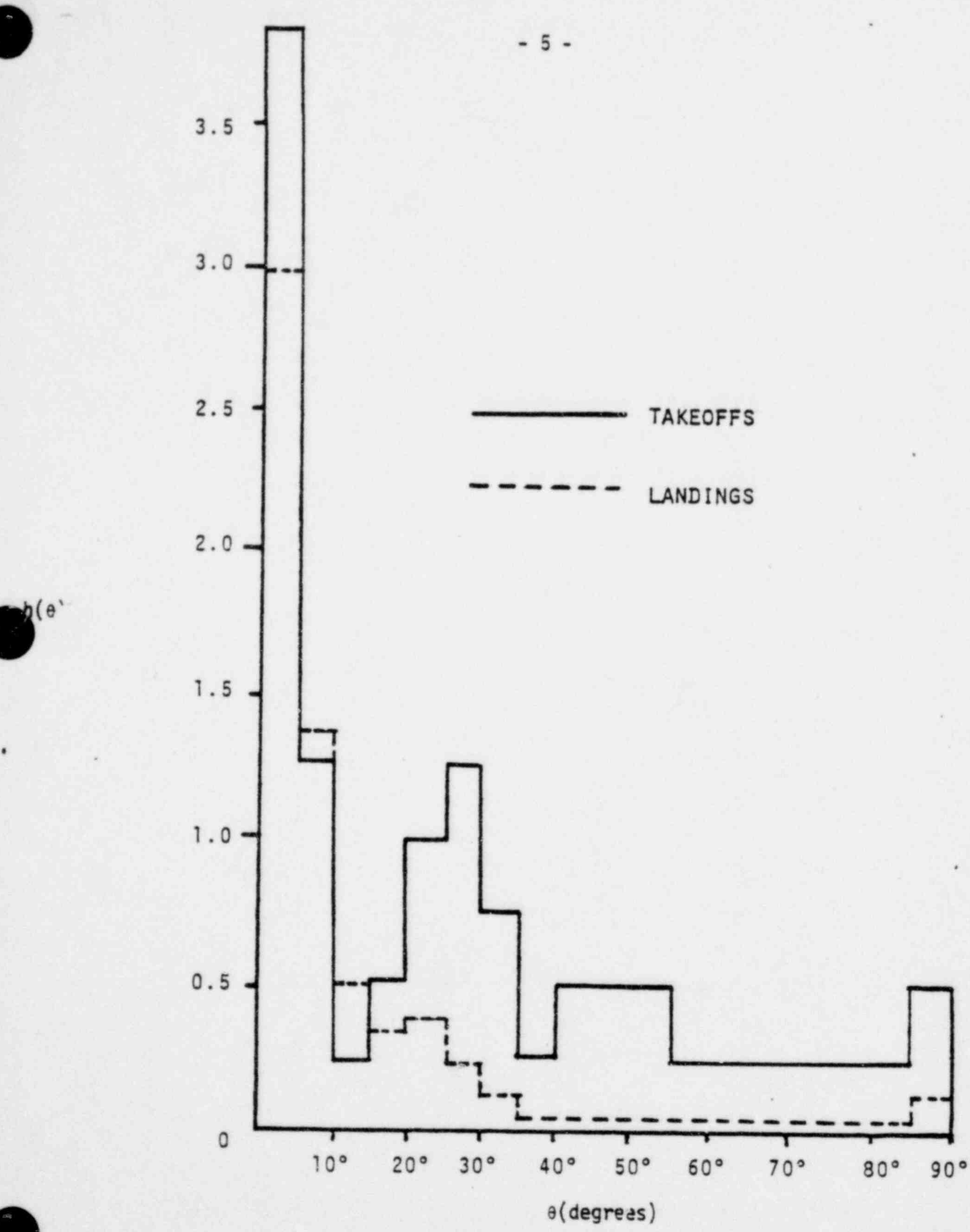

FIGURE 2 (UPDATED). ESTIMATED CRASH DENSITY FOR θ (PER RADIAN)

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)	)	

AFFIDAVIT OF JACQUES B. J. READ

STATE OF MARYLAND)
COUNTY OF MONTGOMERY)

I, Jacques B. J. Read, being duly sworn, depose and state:

1. I am a Chemist-Nuclear Engineer, Accident Analysis Branch, Division of Site Safety and Environmental Analysis, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

2. I have previously testified in this proceeding and my Statement of Professional Qualifications is incorporated in the transcript (following Tr. 232).

3. I prepared the document entitled "Analysis of Addition of 1978 Air Traffic and Accident Rates and Revisions to 1976 and 1977 Estimates to

'NRC Staff Testimony Regarding U.S. Air Carrier and Military Accident and Traffic Data' and 'Evaluation of Aircraft Crash Potential for Nuclear Power Plants'", filed in this proceeding on February 4, 1980.

Subsequent to submission of this document, it has come to my attention that there is an apparent error in the table of values entitled "1978 Relevant Heavy Movements," on page 6, with a corresponding error in the calculation of "P_{total}" which follows. The error results from my division of total landings and takeoffs, in the first column of the table, by two, which I had done based on the testimony of Darrell G. Eisenhut, as originally submitted, as discussed therein at page 12. At the hearing in this matter on December 12, 1978, however, Mr. Eisenhut made a number of revisions to his prefiled testimony, among them, the deletion of his testimony on page 12 which describes the propriety of dividing the relevant aircraft movements by two. The reasons for Mr. Eisenhut's revision are discussed in the transcript of the hearing on that date at Tr. 459-463. Mr. Eisenhut concluded that this division was inappropriate, resulting in his doubling of the numbers of movements (See Eisenhut testimony p. 13; Tr. 460). The foregoing revision to Mr. Eisenhut's testimony were not taken into account in my prior evaluation. Now taking this revision into account changes my table as follows:

1978 Relevant Heavy Movements

	Total	Scheduled	Nonscheduled
Landings	263	157	107
Takeoffs	142	84	57

The above numbers reflect rounding to whole aircraft. Also, it should be recognized that the breakdown of movements among scheduled and nonscheduled activity is not on the basis of the earlier assumption used - 40% scheduled, 60% nonscheduled (Eisenhut testimony at 13) - but rather is based on the breakdown of traffic as reported in Table 20 Revised. Table 20 Revised, submitted with my prior evaluation on February 4, 1980, shows that scheduled activity dominated in 1978, rather than nonscheduled as had been the case in earlier years and was stated in my prior evaluation.

Using the new values set forth above in the equation for "P_{total}", the result is as follows:

$$\begin{aligned}
P_{total} &= [(2.3 \times 10^{-9})(157)(.0062) + (4.6 \times 10^{-9})(84)(.0026)] \\
&\quad + [(4.5 \times 10^{-8})(107)(.0062) + (3.0 \times 10^{-8})(57)(.0026)] \\
&= 2.24 \times 10^{-9} + 1.00 \times 10^{-9} + 2.99 \times 10^{-8} + .445 \times 10^{-8} \\
&= \frac{3.76 \times 10^{-8} \text{ / year}}{2} \\
&= 1.88 \times 10^{-8} \text{ /year}
\end{aligned}$$

Note that the basis for the division by two in this equation is discussed by Mr. Eisenhut in his testimony on December 12, 1978 (Tr. 465-468, 469A-471).

The effect of the revisions discussed above is to change the value for "P_{total}" stated in my prior evaluation from 1.87 x 10^{-8}/year to 1.88 x 10^{-8}/year, which clearly is insignificant, even taking into consideration the estimate originally calculated by Mr. Eisenhut, 1.6 x 10^{-8}/year, and, thus, does not affect the Staff's prior conclusions.

Jacques B. J. Read
Jacques B. J. Read

Subscribed and sworn to before
me this 22nd day of February, 1980

Elizabeth Ann Tipton
Notary Public

My Commission expires: July 2, 1980

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)	)	

SUPPLEMENTAL TESTIMONY OF
R. MOORE AND L. ABRAMSON
IN RESPONSE TO ALAB-525

APPLIED STATISTICS BRANCH
OFFICE OF MANAGEMENT AND PROGRAM ANALYSIS
U.S. NUCLEAR REGULATORY COMMISSION

March 16, 1979

In ALAB-525 (February 1, 1979), the Board made several comments on the methodology of estimating the areal crash density at TMI-2 as presented in our testimony submitted at the December 12 hearing session in this proceeding (prefiled testimony following Tr. 378). The purpose of this addition is to respond to the Board comments.

Before responding to the specific comments, however, we feel that a short discussion of the rationale for our methodology would be helpful. Our choice of approach was motivated by the requirement to analyze the uncertainty associated with the point estimates. There are two sources of uncertainty - model uncertainty and statistical uncertainty. Model uncertainty stems from the particular choice of assumptions made about the underlying relations among the problem parameters and variables and the possibility that the assumptions might be in error. Statistical uncertainty stems from the random nature of the observations and the possibility that the observations might not be representative of the assumed model.

One way to handle model uncertainty is to choose the model assumptions such that any plausible departure from them would be in a conservative direction. This is the approach we adopted. Before adopting our particular model assumptions, we reviewed the applicant's approach involving the choice of a specific functional form for the conditional crash densities. This can be a useful approach, <u>provided</u> that the assumed functional form is correct, since it makes use of all the data to estimate the unknown parameters. However, if the assumed functional form is incorrect, then using it can lead to significant estimation errors. Instead of trying to use data distant from TMI-2 to estimate the probability of a hit at TMI-2, we based our estimates only on data in the vicinity of TMI-2. (By the assumption of model independence between r and θ, justified on pages 3-4 of our testimony, we treat r and θ separately.) Our estimates are then based on the mild assumption that the conditional crash densities for r and θ are approximately constant in the vicinity of TMI-2. If the conditional crash densities are not approximately constant, then it is plausible to assume that they would be concave decreasing (see Tables 9A and 9B, revised 12/8/78), so that a chord joining any two points on the curve would lie wholly above the curve. (The exponential form assumed by the applicant has this property.) In such a case, an estimate made with our methodology would be conservatively biased, i.e., it would tend to overestimate the density.

In addition to minimizing the model uncertainty, our methodology was also designed to estimate the statistical uncertainty in a straightforward manner. This we did by the method of confidence intervals, which require no extra assumptions in addition to those already made for the point estimate. In contrast, the applicant assumed a prior distribution and a likelihood function in order to apply a Bayesian analysis to estimate the uncertainty. Thus, our methodology requires fewer and weaker (i.e., assuming less) assumptions than does the applicant's methodology, both for the point estimates and the uncertainty analysis.

On page 12 of ALAB-525, the Board referred to the "very irregular angular probability distribution" produced by the staff's methodology and claimed that it fails to decrease regularly as the angle θ (measured from the runway centerline) increases. In addition, the Board noted that the staff model "appears to yield a zero probability for a crash within large segments of angle within the 0-5 mile range."

Our testimony was focused on the preselected location of TMI-2. For this use we felt that our methodology represented a conservative yet reasonable treatment of available data. Although our methodology was not specifically designed to apply to an arbitrary point in the (r, θ) plane it is certainly possible to do so, with modifications for "edge effects" and zero-valued estimates, as follows. To be consistent with the data available, we confine our attention to that portion of the (r, θ) plane defined by $0 \leq r \leq 5$ and $0 \leq \theta \leq 90°$. We omit consideration of angles greater than 90° because the data indicates that the density appears to be increasing in this region, and our methodology is designed for a decreasing density. Because of the apparent special situation for angles greater than 90°, it is our judgment that this case deserves special study before an appropriate estimator can be devised.

The approach described in our testimony was to base our estimates of the crash densities for r and θ at a point (r_0, θ_0) on the observed number of hits in an interval of width 1.5 miles roughly centered at r_0 and an interval of width 15° roughly centered at θ_0. This approach can be applied throughout the region of interest except where r_0 or θ_0 is near the edge of the region. Accordingly, the edge effect modification to our methodology is to base our estimates on the number of hits in the half-mile wide intervals [0, 0.5] for $0 < r_0 < 0.5$ and [4.5, 5.0] for $4.5 \leq r_0 \leq 5.0$, respectively, and on the 5° wide interval [0, 5°] for $0 < \theta_0 < 5°$. (Note that the 15° wide interval [80°, 95°] is used if $85° \leq \theta_0 \leq 90°$. Even though we do not estimate the density for $\theta_0 > 90°$, using the observed hits for $\theta_0 > 90°$ still leads to a conservative estimate of density for $85° \leq \theta_0 \leq 90°$.)

The second modification to our methodology is designed to obtain a non-zero estimate for the crash density at all points. There are several ways to do this. The one we use is to assume one additional hit at r_0 or θ_0 for those points for which the modified methodology described above would yield an estimate of zero for the crash density of either r or θ. The addition of this pseudo-hit raises both the numerator and denominator by one and yields a conservative non-zero estimate of the crash density.

The results of applying this modified methodology to the data in Tables 9A and 9B are shown in Figs. 1 and 2. Of the four estimated crash densities, three are essentially monotonically decreasing and the fourth (the crash density of θ for takeoffs) is somewhat irregular.[1] For TMI-2, $r_0 = 2.7$ miles and $\theta_0 = 34°$. From Figs. 1 and 2, $g_T(r_0) = .133$, $g_L(r_0) = .133$, $h_T(\theta_0) = .764$, $h_L(\theta_0) = .143$. Since the modifications discussed above were not needed at the TMI-2 location, these estimates are identical to those on page 7 of our testimony.

It is worth noting that the areas under the four estimated densities in Figs. 1 and 2 are all slightly greater than one. This is a reflection of the conservatisms introduced by the modifications for edge effects and zero-valued estimates. This phenomenon is not a matter for concern, since the purpose of our modified methodology is to obtain <u>point</u> estimates rather than estimates of the densities as a whole. If the latter were required, then an adjustment could be made so that the areas would be equal to one.

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[1] Due mainly to the absence of observed takeoff hits between 5° and 20°. This does not imply that the "true" density is zero between 5° and 20°. Because of the small total number of hits (15), a considerable degree of irregularity is to be expected in the estimated density.

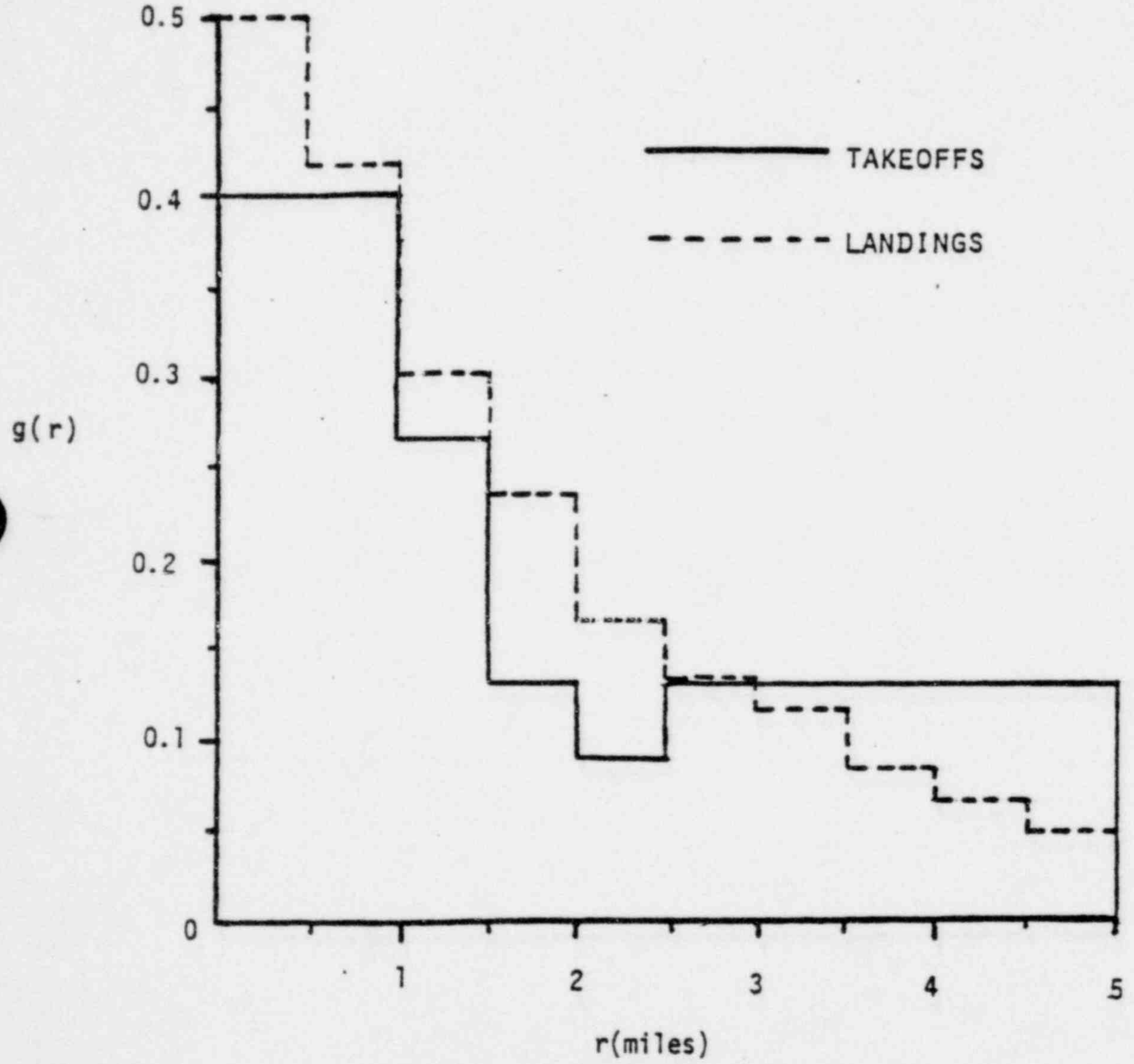

FIGURE 1. ESTIMATED CRASH DENSITY FOR r (PER MILE)

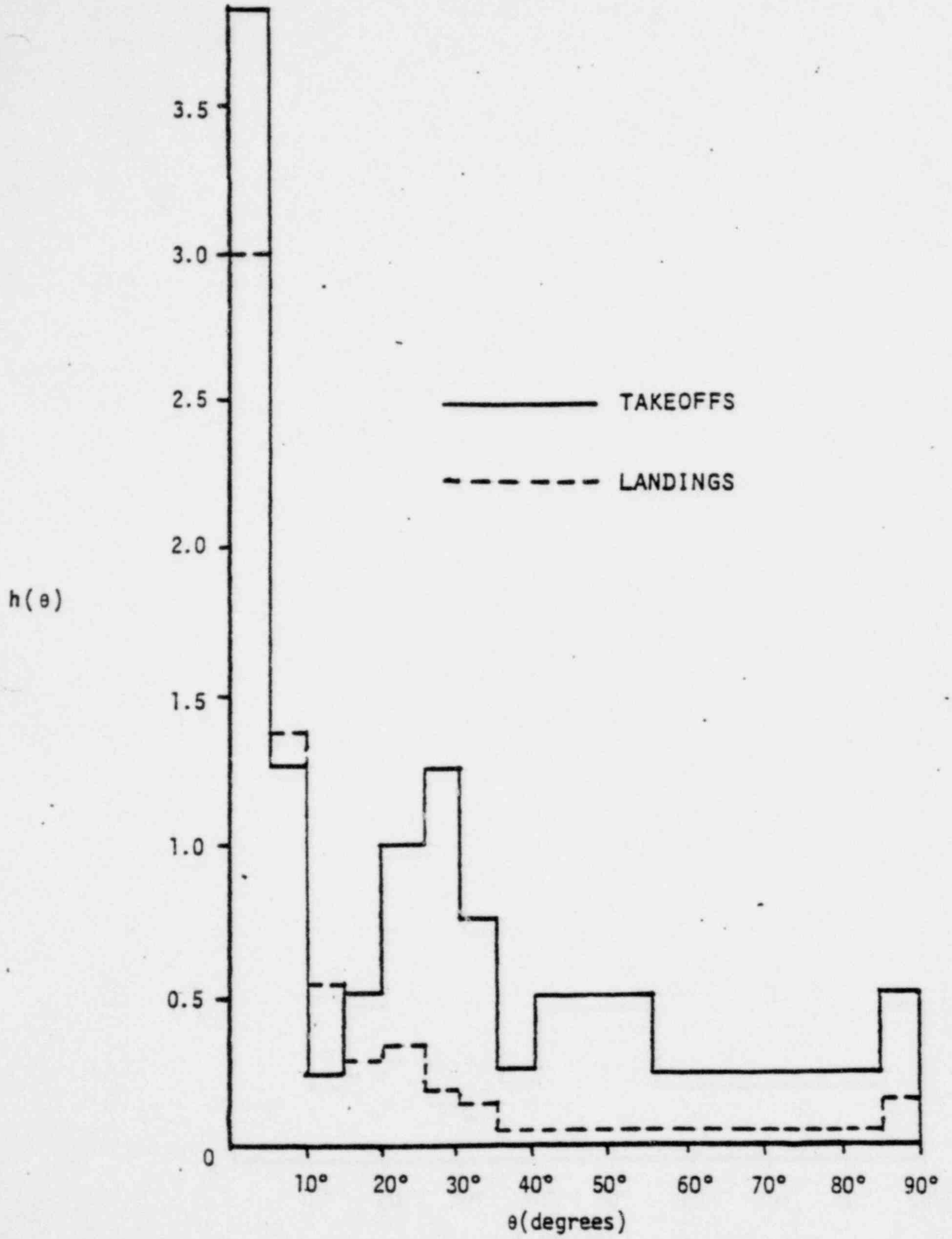

FIGURE 2. ESTIMATED CRASH DENSITY FOR θ (PER RADIAN)

ALAB-525 also discussed[2] our calculation of confidence limits for the areal crash densities and adduced reasons why our confidence limits might be overly conservative. While the observations made by ALAB-525 are well-taken, the approach we used appeared to us as the only feasible one at the time we developed our testimony. While, in principle, exact confidence limits can be determined from the model assumptions and the observed data, this would involve very extensive computations for the case at hand. As an alternative, we used the Bonferroni method of calculating bounds for the exact confidence limits. Since this method is a very general one, it yields bounds which might be overly conservative for any particular case.[3] Furthermore, the Bonferroni method yields only upper bounds on the exact confidence limits, so that no estimate of the degree of conservatism is possible. Despite these drawbacks, we were unaware of any other feasible approach, and so we used the conservative Bonferroni bounds as presented in Table IV of our testimony.

Upon reviewing our testimony, both written and oral, we have subsequently discovered that it is possible to calculate less conservative upper bounds on the exact confidence limits. Furthermore, it is possible to also calculate a <u>lower</u> bound for the exact 90% confidence limits. Since the upper and lower bounds for the 90% confidence limits generally differ by a factor of two, it

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[2] The description of confidence level given by footnote 9 on page 12 of ALAB-525 is misleading. An upper confidence limit L is the endpoint of a random interval (0, L). The confidence level is the probability that the interval (0, L) will cover the unknown parameter. Since the parameter is fixed, no probability is associated with it.

[3] Our bounds were obtained by multiplying three confidence limits, each with confidence (1 - g), and calling the product a bound on a confidence limit with confidence level (1 - 3g). As was pointed out by ALAB-525, there is an intrinsic conservatism in this calculation, regardless of the degree of independence or dependence among the three factors.

is our judgment that our revised procedure for calculating bounds on the exact confidence limits yields values which are not overly conservative and therefore no further refinements are felt to be worthwhile.

The revised bounds on the exact confidence limits are presented in Table IV (revised) for 80% and 90% confidence levels, together with the corresponding values from Table IV of our testimony. Because the Bonferroni method is applied to only two factors in our revised approach while it was applied to three factors in our original testimony, the 80% and 90% confidence level bounds in Table IV (revised) correspond to the 70% and 85% confidence level bounds in Table IV, respectively. (There are no revised bounds in Table IV (revised) corresponding to the 97% bounds in Table IV because there were no corresponding tables in the source paper we used for our revised approach.)

As compared with the bounds in Table IV, the revised bounds in Table IV (revised) show a double improvement. First, the confidence levels are increased and second, the upper bounds on the exact confidence limits are decreased. Furthermore, except for the relatively unimportant case of nonscheduled takeoffs[4/], the upper and lower bounds for the 90% level differ by about a factor of two.

[4/] From page 15 of the testimony of Darrell G. Eisenhut, nonscheduled takeoffs contribute less than 10% to P_{total}, the probability of a "heavy" aircraft impacting TMI-2.

BOUNDS ON EXACT CONFIDENCE LIMITS(x 10^{-9})

SCHEDULED	ESTIMATED RATE	70%	80%	85%	90%	
		Upper Bound (Table IV)	Upper Bound (revised)	Upper Bound (Table IV)	Lower Bound	Upper Bound (revised)
TAKEOFFS	4.9 x 10^{-9}	36	23	53	15.4	32.3
LANDINGS	2.0 x 10^{-9}	10	7	13	5.3	9.0
NONSCHEDULED						
TAKEOFFS	32 x 10^{-9}	420	273	670	103	409
LANDINGS	39 x 10^{-9}	210	148	290	101	196

Table IV (revised). Estimated values and bounds on exact confidence limits for areal crash densities at TMI-2 for a U. S. carrier aircraft engaged in a relevant operation (probability per square mile)

The source of this revision was the discovery that the estimates of the crash densities $g(r)$ and $h(\theta)$ (see page 7 of our testimony) are statistically independent for both takeoffs and landings. This fact allows us to calculate approximate[5/] 90% and 95% confidence limits for the conditional crash densities $D_T(r_o, \theta_o)$ and $D_L(r_o, \theta_o)$. (See "Confidence Intervals for the Product of Two Binomial Parameters", by Robert J. Buehler, Journal of the American Statistical Association, December 1957, 482-493.) The approximate confidence limits are then multiplied by the

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[5/] Based on the Poisson approximation to the binomial. As discussed on page 5 of the appendix to our testimony, this approximation yields conservative confidence limits.

approximate confidence limits for the off-runway crash rates to get conservative confidence limits for the areal crash densities using the Bonferroni method discussed on page 5 of the appendix. The lower bound for the 90% confidence limit is obtained by multiplying the approximate 90% confidence limits for the conditional crash densities by the estimated off-runway crash probabilities from Table I on page 2 of our testimony. If the values from Table I were equal to the true crash rates, this procedure would yield approximate 90% confidence limits for the areal crash densities, but since the values in Table I are only estimates of the true crash rates, this procedure yields lower bounds.

It should be noted that it is not all obvious that the estimated crash densities for r and θ are statistically independent. From Table 9A for takeoffs, the three hits in $2 \leq \theta < 3.5$ and the three hits in $25^\circ \leq \theta < 40^\circ$ have one hit in common and we believed that this common hit would induce a positive correlation between the estimates of the crash densities as calculated on page 7 of our testimony. The relevant data is summarized in the following table of takeoff hits.

Radial Distance (miles)	Angular Distribution			
	[0°, 25°)	[25°, 40°)	[40°, 100°]	
[0, 2.0)	5	1	3	9
[2.0, 3.5)	0	1	2	3
[3.5, 5.0]	2	1	0	3
	7	3	5	15

Our model assumes that each of the 15 takeoff hits impacts in one of the nine boxes of the table according to the following joint distribution, where p_i and q_j are probabilities such that $p_1 + p_2 + p_3 = q_1 + q_2 + q_3 = 1$.

Radial Distance (miles)	Angular Distribution			
	[0°, 25)	[25°, 40°)	[40°, 100°]	
[0, 2.0)	p_1q_1	p_1q_2	p_1q_3	p_1
[2.0, 3.5)	p_2q_1	p_2q_2	p_2q_3	p_2
[3.5, 5.0]	p_3q_1	p_3q_2	p_3q_3	p_3
	q_1	q_2	q_3	1

The assumption that the probability of a hit in any box is the product of the marginal probabilities is equivalent to the assumption on page 4 of our testimony that "r and θ for off-runway hits are distributed independently".

For the case at hand, the problem is to estimate p_2q_2, the probability that an off-runway crash will impact in the box including TMI-2[6/]. There are two ways to do the estimation. The first is to use the the ratio of the observed number of hits in the box including TMI-2 to the total number of off-runway hits. For this case, the estimate would be 1/15 = .067. The

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[6/] The conditional crash density $D(r_0, \theta_0)$ estimated in our testimony differs from p_2q_2 by a normalization factor which yields the probability of impact per square mile. This normalization factor is an exact quantity and it is omitted in this discussion for convenience and to allow us to focus most directly on the statistical issues. Its omission does not affect any of these statistical issues.

second method is to estimate p_2 and q_2 separately and then multiply. For this case, the estimate would be $\frac{3}{15} \cdot \frac{3}{15} = .04$. We use the second method because it has smaller variance than the first.

To consider the issue of independence, denote the estimates of p_2 and q_2 by $\hat{p}_2$ and $\hat{q}_2$, respectively. Even though we have <u>model</u> independence as expressed in the joint distribution table above, this does not necessarily imply that $\hat{p}_2$ and $\hat{q}_2$ are statistically independent. For this case

$$\hat{p}_2 = \frac{0 + 1 + 2}{15}$$

$$\hat{q}_2 = \frac{1 + 1 + 1}{15} ,$$

where we have decomposed $\hat{p}_2$ and $\hat{q}_2$ according to the observed data. In general,

$$\hat{p}_2 = \frac{n_{21} + n_{22} + n_{23}}{N}$$

$$\hat{q}_2 = \frac{n_{12} + n_{22} + n_{32}}{N} ,$$

where n_{ij} is the observed number of hits in row i and column j of the 3 x 3 data table and N is the total number of hits. It is the presence of n_{22} in both $\hat{p}_2$ and $\hat{q}_2$ that led us to believe that $\hat{p}_2$ and $\hat{q}_2$ are not statistically independent and, in fact, are positively correlated. However, because the total number of hits is fixed, n_{22} is <u>negatively</u> correlated with all of the other n_{ij} and, in particular, n_{22} is negatively correlated with

$(n_{21} + n_{23})$ and with $(n_{12} + n_{32})$. It turns out that this negative correlation exactly balances the positive correlation induced by the presence of n_{22} so that $\hat{p}_2$ and $\hat{q}_2$ are, in fact, statistically independent.

Since the estimated conditional crash density $D(r_0, \theta_0)$ is the product of two statistically independent quantities $\frac{g(r)}{r}$ and $h(\theta)$, we can use Buehler's tables to calculate approximate confidence limits for the conditional crash densities for takeoffs and landings. However, the estimated conditional crash densities are <u>not</u> independent of the estimated accident rate, since both depend on the same set of accidents and there is no mechanism to cancel out this dependence. (Numerical calculation indicates that the confidence limits for the accident rate and the conditional crash density are negatively correlated.) It is for this reason that we use the Bonferroni method to calculate bounds on the exact confidence limits for the areal crash densities.

CHAIRMAN ROSENTHAL: I don't whether I'm supposed be addressing you, Mr. Chandler, or Mr. Treby on this phase of it. But one of the questions that's arisen in our minds is whether Dr. Reed is going to be a witness. He was not on your witness list, and he seems to be the sponsor of, one way or another, of some of this testimony, a sponsor in point of, of reality even if not in point of form.

MR. CHANDLER: Dr. Reed is the affiant with respect to the updating information. It was not our intention to present Dr. Reed for purposes of the updating testimony in view of what we perceive to be the accuracy in the Board's estimation, oh, in ALAB 570, that the updating information would be, anticipate that little bearing on the overall presentation of the staff.

We are presenting this testimony, if you will, the affadavit of Dr. Reed, affadavits of Dr. Reed, and the joint affadavit of Doctors Moore and Abramson merely for the purpose of providing to the Board the results of our review and inclusion of one additional year's testimony -- excuse me -- data, the thrust of which is that it does not change significantly our prior position.

It is merely to assure the Board that in fact that there is no change of significance in the data that have been presented previously -- and to assure that the Board had before it the most current information available, consistent with numerous past Appeal Board decisions.

So it was not our intention to present either Dr. Reed for purposes of this update or, for that matter, Doctors Moore and Abramson with respect to their joint affadavit. Doctors Moore and Abramson will be presented subsequently regarding the, the model that they developed and their supplemental testimony that had been previously submitted last March.

CHAIRMAN ROSENTHAL: All right.

DR. JOHNSON: Mr. Chandler, I have one or two questions regarding some of the material that appears in the Reed affadavit. It relates -- well, it relates to the updated information that was used by the staff to prepare its revised estimate of hit probability.

It is conceivable that Doctors Moore and Abramson can answer the questions I have that would be appropriate.

However, to put it on the table, my question is to why the crash that occurred in San Diego of PSA was put down as a nonscheduled airline crash, as opposed to a scheduled airline crash. Now, Mr. Reed -- Dr. Reed -- deals with that in his affadavit. I have, I would like, I don't understand why the choice that was made; and I would like to ask questions about it.

MR. CHANDLER: I, I, I would, I, I certainly have no objection to, with that in mind, offering Dr. Reed.

I would point out that it's not only addressed in

20

his testimony but in some detail in the footnote, if that's what you had -- the footnote in one of the tables, if that's what you had reference to.

(Laughter.)

MR. CHANDLER: With that in mind, we will have Dr. Reed testify; and in, in view of the fact that the applicant's witnesses are on the stand, I would suggest we go forward this way; and I will call Dr. Reed later.

CHAIRMAN ROSENTHAL: Right.

Mr. Vallance and Dr. Kaplan, you were sworn in at the time of our hearing in December of '78; and you are, of course, remain under the oath that you took at that time. Whereupon,

JOHN M. VALLANCE and DR. STANLEY KAPLAN

were called as witnesses and, having been previously sworn, were examined and testified as follows:

DIRECT EXAMINATION

MR. TROWBRIDGE: Mr. Chairman, are we seeking to introduce two, two sets of prepared testimony.

The first is dated January 9, 1979, "Supplemental Testimony of John M. Vallance," which is attached as Appendix A. The testimony of Dr. Kaplan, entitled "Prediction of Accident Rates from Historical Data."

The Board may recall that these two pieces of testimony were originally provided to the Board, accompanied by affadavits at a time when we did not know we would have a further session of the Board; and it was thought at that time that, and understood at that time, that these would be accepted in the record without further testimony.

However, since we are here, I propose that we go ahead and put this into the transcript, so that --

Mr. Vallance, do you have the January 9 supplemental testimony, yours, in front of you?

MR. VALLANCE: Yes, I do.

MR. TROWBRIDGE: Does the supplemental testimony true -- is it true and correct, to the best of your knowledge and belief?

MR. VALLANCE: Yes, it is.

MR. TROWBRIDGE: Has it been affected by the passage of time? Can you -- do you adopt it as your testimony in this proceeding?

MR. VALLANCE: Yes, I do.

MR. TROWBRIDGE: Dr. Kaplan, do you have before you Appendix A of Mr. Vallance's testimony?

DR. KAPLAN: I do.

MR. TROWBRIDGE: Was this prepared by you and -- or under your supervision?

DR. KAPLAN: Yes.

MR. TROWBRIDGE: Is it true and correct to the best of your knowledge?

DR. KAPLAN: Yes.

MR. TROWBRIDGE: And is it, is the correctness of the testimony in any way affected by the passage of time?

DR. KAPLAN: No.

MR. TROWBRIDGE: Do you adopt it as your testimony in this proceeding?

DR. KAPLAN: I do.

MR. TROWBRIDGE: Mr. Chairman, I move that this testimony be accepted and incorporated as though read in the transcript. The reporter already has copies.

CHAIRMAN ROSENTHAL: Absent objection, it will be so done.

(Copies of the aforementioned documents follow:)

9 January 1979

UNITED STATES OF AMERICA
NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

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

SUPPLEMENTAL TESTIMONY OF JOHN M. VALLANCE

INTRODUCTION

This testimony provides data and information to augment the testimony previously furnished. At the hearing of December 11 and 12, 1978, the Applicant agreed to submit a set of calculations and results of estimated hit frequency, similar to those submitted at the hearing, but based on separate calculations for landing and takeoff accidents (in the testimony filed for the December 11 and 12 hearing, the calculations were based on combined takeoff and landing accident rates).

DISCUSSION

Results are developed herein for the hit frequency, based on the following four subdivisions:

1. Scheduled Operations - Landings
2. Scheduled Operations - Takeoffs
3. Non-Scheduled Operations - Landings
4. Non-Scheduled Operations - Takeoffs

In these calculations, the calculational procedure is identical to that previously used.

$$f = N A R D$$

There are four values of the number of operations, N: 1) Scheduled takeoffs on runway 13, 2) Non-scheduled takeoffs on runway 13, 3) Scheduled landings on runway 31, and 4) Non-scheduled landings on runway 31.

There are two values of the target area, A: 1) the area represented by the TMI-2 Unit for landings hits and 2) for takeoff hits.

There are four values of the accident rate, R: 1) for landings by scheduled aircraft, 2) takeoffs by scheduled aircraft, 3) landings by non-scheduled aircraft and 4) takeoffs by non-scheduled aircraft.

There are two values of the hit location probability density function, D: 1) for landing accidents and 2) for takeoff accidents.

The raw input data to the accident rate and hit location correlations are from Table 3 (Revised 12/8/78) and from Table 11 (Revised 12/8/78) of my previous testimony.

As in the previous testimony, results are calculated 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. The former develops a single valued result for annual hit frequency, using more-or-less conventional techniques. The latter develops the result in the form of a probability curve of hit frequency. It utilizes Bayesian methodology. The two sets of results differ slightly from each other, as might be expected, but serve to validate each other.

RESULTS

Single Valued Result Set

The estimated frequency of heavy aircraft using HIA crashing into the TMI-2 Unit, using the single valued calculational procedure is 8.5 x 10^{-9} hits/year. As explained in more detail below, this is based on 600 heavy aircraft operations per year at HIA, the target area used previously by Applicant at the time of the operating license proceedings, the projected current destruct accident rate for all sizes of scheduled and of non-scheduled air carrier operations and the hit location pattern exhibited by U.S. Air Carrier aircraft in destruct accidents during the past 22 years, 1956 - 1977.

The above estimated hit frequency is made up as follows:

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

The input to these results are summarized in Table 1.

Probability Distribution Results Set

The estimated hit frequency, wherein the raw input data were processed using Bayesian methodology to yield input data in the form of a probability distribution gives a mean hit frequency of 6.6 x 10^{-9}/year. This estimated hit frequency, expressed on a mean value basis, is made up as follows:

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

Table 2 summarizes the full detail of the probabilistic set of results, in terms of frequency versus probability of frequency.

Figure 1 displays these results in the form of a probability distribution of hit frequency. Both point and cumulative probability curves are shown. According to these results, there is a 0.1 probability of the hit frequency being less than 4×10^{-9}/year and a 0.9 probability of being less than 11×10^{-9}/year; the mean value being 6.6×10^{-9}/year.

Tables 3A, 3B, 3C and 3D show the detailed probability distribution of the individual categories making up the total.

CALCULATIONS

The calculation algorithm is of the form:

$$f = N\ A\ R\ D$$

As used herein, it is expanded in follows:

$$\begin{aligned} f = {} & [R(s,t) \times N(s,t) + R(ns,t) \times N(Ns,t)] \times D(t) \\ & \times A(t) \\ & + [R(s,l) \times N(s,l) + R(ns,l) \times N(ns,l)] + D(l) \\ & \times A(l) \end{aligned}$$

where

f = the annual frequency of aircraft crashes into TMI-2 (by heavy aircraft using HIA).

R(s,t), R(ns,t), R(s,l) and R(ns,l) = the applicable accident rate of scheduled takeoffs, nonscheduled takeoffs, scheduled landings and nonscheduled landings, respectively.

N(s,t) and N(ns,t) = the annual number of large scheduled and nonscheduled aircraft, respectively, taking off on the TMI end of the runway, i.e. using HIA runway 13.

N(s,l) and N(ns,l) = the annual number of large scheduled and nonscheduled aircraft, respectively, landing on the TMI end of the runway, i.e. using HIA runway 31.

D(t) and D(l) = the probability density (per square mile) that if a hit occurs within five miles, it will occur at the TMI-2 location, for takeoffs and landings, respectively.

A(t) and A(l) = the target area (in square miles) presented by TMI-2 for takeoff and landing accidents, respectively.

Input Data

Number of Operations:

Table 4 lists the number of operations of large aircraft at HIA used in making the calculations. These are the values used by the NRC staff at the December 11-12, 1978 hearing (Eisenhut direct).

Target Area:

Table 5 lists the target areas used. These values are from my testimony before the Licensing Board during the operating license hearings held in the Spring of 1977 (Vallance direct, pages 6 and 7). In that testimony, values of $A(t) = 0.0066$ mile^2

A(1) = 0.0225 mile^2 for the TMI Station were given. Thus, to put these on a "per unit" basis they must be divided by two. Also, in that testimony, the calculations were made on a composite (landing plus takeoff) basis that included weighting the landing and takeoff areas by the relative number of operations, yielding an equivalent area of 0.01 miles^2 per unit $((0.0225 \times 0.7 + 0.0066 \times 0.3)/2 = 0.009 \cong 0.01 \text{ mi}^2)$

Accident Rate:

Table 6 lists the historical destruct accident rates experienced by U.S. Air Carriers for accidents in the contiguous U.S. These are for all sizes of aircraft. Several sets of accident rates are given, and for several time periods into the past. The sets include: scheduled landings, scheduled takeoffs, non-scheduled landings, non-scheduled takeoffs. The time periods include 5, 10, 15, and 22 years into the past.

Tables 7 and 8 give the yearly and past cumulative accident rates for scheduled and for non-scheduled operations for the past 22 year period 1956-1977. The data are also subdivided into landing, takeoff and composite rates. The input data used in preparing Tables 7 and 8 are from Tables 3 and 11 (Rev 12/8/78) of my prior testimony.

In my December 11-12, 1978 testimony, I used the past five year average accident rate as the basis of the calculations as it appeared to reasonably represent the trend line. However, in subdividing the accident rate into more categories, it turns out that two of the four rates are zero during the past five years. Therefore, the accident rates developed in Appendix A using the Bayesian methodology are used for both the single valued result and the probability distribution result. These rates provide a reasonable extrapolation of the trends exhibited by each category during the past 22 year period, to a current 1978, accident rate. For the single valued result, the mean values of these rates are used, as follows:

	Destruct Accidents per Million Landings or per Million Takeoffs (Mean Values)
Scheduled	
Landings	0.30
Takeoffs	0.056
Non-Scheduled	
Landings	1.7
Takeoffs	3.1

It may be noted that the accident rate thereby derived for non-scheduled takeoffs (ns,t) is larger than the value for non-scheduled landings (ns,l); whereas for the entire 22 year data base period, the ns,l rate was appreciably larger than the ns,t rate. However, as may be observed in Figures A3 and A5 (Appendix A), the ns,l rate has been trending down whereas the ns,t rate has been decreasing only slightly.

Note that in these accident rate data, accidents for training, test and ferry operations are not counted. Also note that no credit has been taken for the accident rate of heavy aircraft being lower than the rate for all sizes of aircraft.

Hit Location:

Table 9 lists the algorithms derived to represent the location of a hit if one occurs within five miles of the runway, for the single valued result set. The correlation is of the form $D(r,\theta)=D(r) \times D(\theta)/r$ where $D(r)$ is the radial probability density, D(θ) is the angular probability density and r is the radial distance. The table also lists the evaluated value of the radial and angular probability density functions for the coordinates at which TMI-2 is located ($r = 2.7$ miles, $\theta = 34^{\circ}$). These correlations do not distinguish between the location of scheduled versus non-scheduled hits. There did not appear to be sufficient data to justify this distinction. However, separate correlations were developed for landings and takeoffs.

As may be noted, there is not much difference in the radial correlation for landing versus takeoff. For the angular correlation however, there is a significant difference; the takeoff hits being more widely dispersed from the runway centerline. The plots of the cumulative frequency distribution of the hit locations are given in Figures 2,3,4 and 5. These data are used in developing the hit location correlations, as described in the December 1978 testimony.

Appendix B is a derivation of the hit location correlation using Bayesian methodology. The mean values of the results therein developed are:

	Mean Value of Probability Density Function
Landings	
Radial ($r = 2.7$ mi.)	0.073/mile
Angular ($\theta = 34^{\circ}$)	0.069/radian
Takeoffs	
Radial ($r = 2.7$ mi.)	0.065/mile
Angular ($\theta = 34^{\circ}$)	0.136/radian

These mean values are derived directly from the histograms given on pages B-13 and B-20 of Appendix B. Note that the angular correlation histograms in Appendix B are on a "per degree" rather than a "per radian" basis and also need to be reduced by a factor of two to allow for hit symmetry on both sides of the runway centerline. These adjustments are incorporated into the mean values reported above.

Table 1

Annual Hit Frequency Results - Single Valued Calculations

f = NARD

Scheduled Operations		10^{-9}/year
Landings:	$f = 78 \times 0.0112 \times 0.30 \times 10^{-6} \times 0.0020 =$	0.5
Takeoffs:	$f = 42 \times 0.0033 \times 0.056 \times 10^{-6} \times 0.0054 =$	0.04
Non-Scheduled Operations		
Landings:	$f = 118 \times 0.0112 \times 1.7 \times 10^{-6} \times 0.0020 =$	4.5
Takeoffs:	$f = 64 \times 0.0033 \times 3.1 \times 10^{-6} \times 0.0054 =$	3.5
	Total	8.5

Table 2

Annual Hit Frequency Results - Probability Distribution Calculations

Frequency Interval	Probability of this Interval	Cum. Prob. through This Interval
10^{-9}/year		
3.1 - 6.4	0.63	0.63
6.4 - 9.6	0.23	0.86
9.6 -12.9	0.087	0.95
12.9 -16.2	0.033	0.982
16.2 -19.4	0.013	0.995
19.4 -22.7	0.0041	0.999
22.7 -25.9	0.0011	1.00
25.9 -29.2	0.00020	1.00
29.2 -32.4	0.000015	1.00
32.4 -35.7	0.0000002	1.00

mean = 6.6×10^{-9}

---

f = NARD
N per Table 4
A per Table 5
R per Appendix A
D per Appendix B

FIGURE 1

PROBABILITY DISTRIBUTION OF HIT FREQUENCY

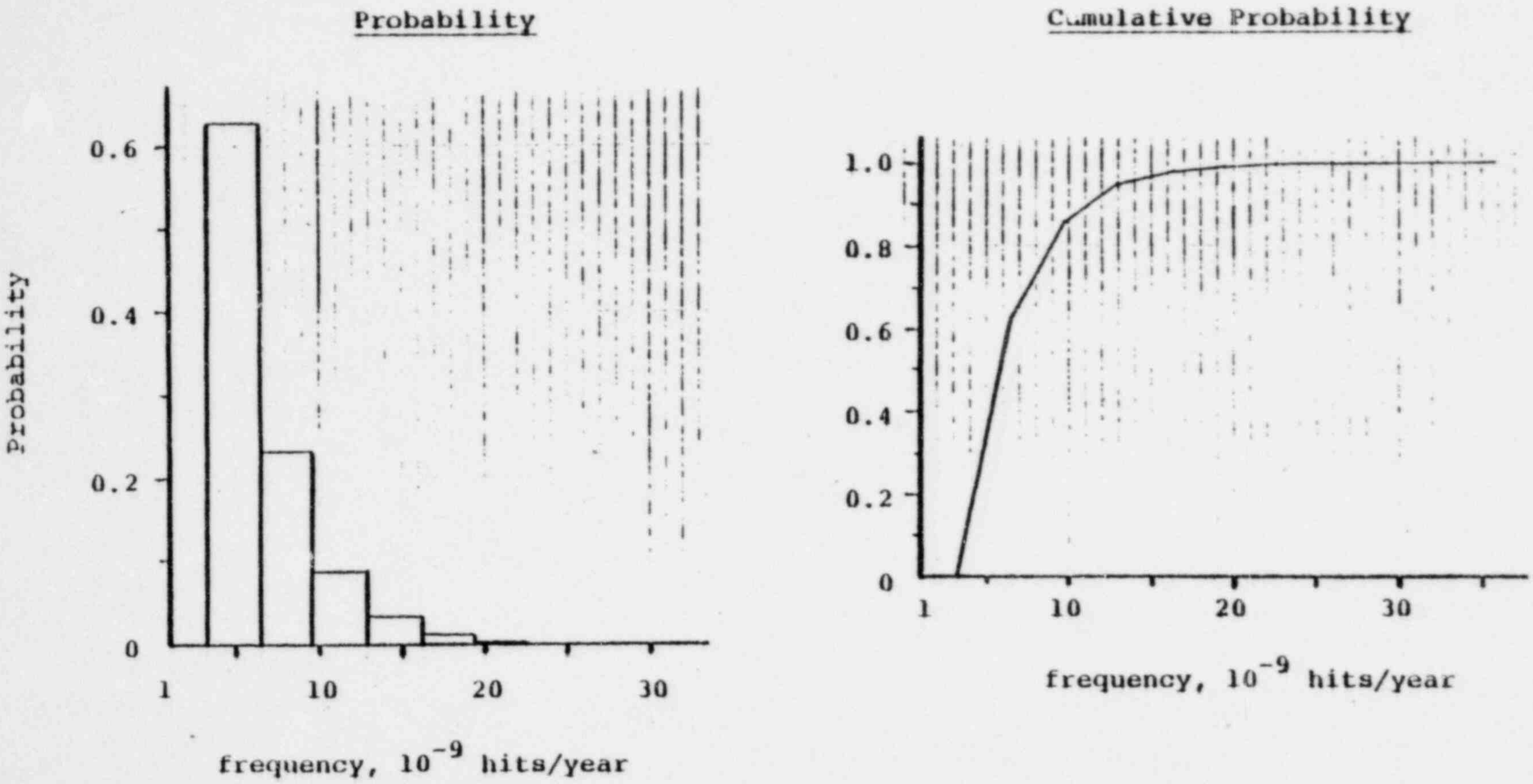


Table 3A

Probability Density of Hit Frequency
Scheduled Takeoffs

Frequency Interval 10^{-11}/year	Probability of this Interval	Cum. Prob. Through this Interval
0.3 - 2.6	0.60	0.6
2.6 - 5.0	0.30	0.9
5.0 - 7.3	0.07	0.97
7.3 - 9.6	0.02	0.99
9.6 -12.0	0.007	1.0
12.0 -14.3	0.002	1.0
14.3 -16.6	0.0006	1.0
16.6 -18.9	0.0002	1.0
18.9 -21.3	0.00004	1.0
21.3 -23.6	0.00000	1.0

Mean = 2.50×10^{-11}

Table 3B

Probability Density of Hit Frequency
Scheduled Landings

Frequency Interval 10^{-10}/year	Probability of this Interval	Cum. Prob. Through this Interval
0.3 - 2.5	0.18	0.18
2.5 - 4.7	0.44	0.62
4.7 - 7.0	0.20	0.82
7.0 - 9.2	0.11	0.93
9.2 - 11.5	0.04	0.97
11.5 - 13.7	0.02	0.99
13.7 - 15.9	0.008	1.00
15.9 - 18.2	0.003	1.00
18.2 - 20.4	0.005	1.00
20.4 - 22.7	0.00006	1.00

Mean = 4.76×10^{-10}

Table 3C

Probability Density of Hit Frequency

Non-Scheduled Takeoffs

Frequency Interval 10^{-9}/year	Probability of this Interval	Cum.Prob. through this Interval
0.1 - 1.0	0.11	0.11
1.0 - 1.8	0.32	0.43
1.8 - 2.7	0.33	0.76
2.7 - 3.6	0.14	0.90
3.6 - 4.4	0.08	0.98
4.4 - 5.3	0.016	1.00
5.3 - 6.2	0.006	1.00
6.2 - 7.1	0.002	1.00
7.1 - 7.9	0.0003	1.00
7.9 - 8.8	0.00003	1.00

Mean = 2.11×10^{-9}

Table 3D

Probability Density of Hit Frequency

Non Scheduled Landings

Frequency Interval 10^{-9}/year	Probability of This Interval	Cum. Prob. Through This Interval
0.2 - 2.7	0.44	0.44
2.7 - 5.2	0.29	0.73
5.2 - 7.7	0.15	0.88
7.7 - 10.2	0.065	0.95
10.2 - 12.7	0.032	0.98
12.7 - 15.2	0.012	0.99
15.2 - 17.7	0.005	1.00
17.7 - 20.2	0.003	1.00
20.2 - 22.7	0.0008	1.00
22.7 - 25.3	0.0001	1.00

Mean = 4.03×10^{-9}

Table 4

Assumed Annual Number of Operations by Heavy Aircraft

(Utilizing Airspace at TMI end of Runway)

Landings on Runway 31	
Scheduled operations	78
Non-scheduled operations	118
	196
Takeoffs on Runway 31	
Scheduled operations	42
Non-scheduled operations	64
	106
	302

Total operations by heavy aircraft are assumed to be 600/year (both runways).

Table 5

Assumed Target Area of TMI-2

Landing Hits	0.0112 mile^2
Takeoff Hits	0.0033 mile^2

Table 6

Historical Landing and Takeoff Destruct Accident Rate

U.S. Air Carriers - Contiguous U.S.

Accidents On or Off the Runway, But Within 5 Miles

Time Period Years	Accident Rate, R			
	Landings		Takeoffs	
	Sched.	Non-Sched.	Sched.	Non-Sched.
	per 10^6 landings		per 10^6 takeoffs	
5 Years (1973-77)	0.36	0	0	3.4
10 Years (1968-77)	0.35	2.5	0.09	2.5
15 Years (1963-77)	0.38	5.2	0.12	3.4
22 Years (1956-77)	0.46	4.7	0.21	2.8

Table 7

U.S. Air Carrier Accident Rate

For

Landing and Takeoff Accidents in the Contiguous U.S.

Aircraft Destruct Accident On or Off Runway But Within 5 Miles

Scheduled Operations

Annual and Cumulative Past Average Rates, 1956-1977

Period		Landings				Takeoffs				Landings Plus Takeoffs			
1st Year	Last Year	Ops. 10^3	Accids.	Accid/10^6 Ops Year	Accid/10^6 Ops Cum[(1)]	Ops. 10^3	Accids.	Accid/10^6 Ops Year	Accid/10^6 Ops Cum[(1)]	Ops. 10^3	Accids.	Accid/10^6 Ops Year	Accid/10^6 Ops Cum[(1)]
1956	1977	3188	2	.627	.463	3188	2	.627	.214	6376	4	.627	.339
1957		3444	2	.581	.457	3444	1	.290	.199	6888	3	.436	.328
1958		3302	2	.606	.451	3302	3	.909	.193	6604	5	.757	.323
1959		3551	5	1.406	.445	3557	1	.281	.165	7114	6	.843	.305
1960		3501	1	.286	.399	3501	1	.286	.160	7002	2	.286	.280
1961		3400	1	.294	.405	3400	1	.294	.154	6800	2	.294	.279
1962		3303	3	.908	.410	3303	2	.606	.147	6606	5	.757	.279
1963		3414	2	.586	.385	3414	1	.293	.123	6828	3	.439	.254
1964		3554	2	.563	.374	3554	1	.281	.114	7108	3	.422	.244
1965		3772	2	.530	.362	3772	1	.265	.104	7544	3	.398	.233
1966		3926	2	.509	.351	3926	0	0	.092	7852	2	.255	.222
1967		4478	1	.223	.338	4478	1	.223	.100	8956	2	.223	.219
1968		4836	3	.620	.350	4836	2	.414	.087	9672	5	.517	.219
1969		4934	1	.203	.318	4934	1	.203	.049	9868	2	.203	.183
1970		4669	0	0	.333	4669	0	0	.028	9338	0	0	.181
1971		4558	1	.219	.383	4558	0	0	.032	9116	1	.110	.208
1972		4601	3	.652	.411	4601	1	.217	.037	9202	4	.435	.224
1973		4651	4	.860	.361	4651	0	0	0	9302	4	.430	.180
1974		4275	2	.468	.228	4275	0	0	0	8550	2	.234	.114
1975		4269	1	.234	.151	4269	0	0	0	8538	1	.117	.076
1976		4411	1	.227	.111	4411	0	0	0	8822	1	.113	.056
1977		4560	0	0	0	4560	0	0	0	9120	0	0	0

---

(1) This is a backwards cumulative, i.e., from 1977 to the stated first year.

Table 8

U.S. Air Carrier Accident Rate

For

Landing and Takeoff Accidents in the Contiguous U.S.

Aircraft Destruct Accidents on or Off Runway but Within 5 Miles

Non-Scheduled Operations (1)

Annual and Cumulative Past Average Rates, 1956 - 1977

Period		Landings				Takeoffs				Landing plus Takeoff			
1st Year	Last Year	Ops. 10^3	Accids.	Accid/10^6/ops		Ops. 10^3	Accids.	Accid/10^6/ops		Ops. 10^3	Accids.	Accid/10^6/ops	
				Year	Cum (2)			Year	Cum (2)			Year	Cum (2)
1956	1977	90	0	0	4.72	90	0	0	2.76	180	0	0	3.74
7		90	0	0	4.90	90	0	0	2.86	180	0	0	3.88
8		90	0	0	5.08	90	0	0	2.97	180	0	0	4.02
9		90	2	22.2	5.29	90	0	0	3.08	180	2	11.1	4.18
60		125	0	0	4.59	125	1	8.00	3.21	250	1	4.0	3.90
1		140	1	7.14	4.87	140	0	0	2.92	280	1	3.57	3.89
2		175	0	0	4.70	175	0	0	3.13	350	0	0	3.92
3		155		12.9	5.17	155	0	0	3.45	310	2	6.45	4.31
4		95	[illegible]	10.5	4.42	95	1	10.5	3.78	190	2	10.5	4.10
5		95	1	10.5	4.03	95	0	0	3.36	190	1	5.26	3.69
6		85	1	11.8	3.58	85	1	11.8	3.58	170	2	11.8	3.58
7		90	1	11.8	3.05	90	1	11.1	3.05	180	2	11.1	3.05
8		105	1	9.52	2.46	105	0	0	2.46	210	1	4.76	2.46
9		115	0	0	1.79	115	0	0	2.69	230	0	0	2.24
70		125	2	16.0	2.0	125	1	8.0	3.00	250	3	12.0	2.50
1		155	0	0	0	155	0	0	2.29	310	0	0	1.14
2		135	0	0	0	135	0	0	2.78	270	0	0	1.39
3		130	0	0	0	130	0	0	3.42	260	0	0	1.71
4		105	0	0	0	105	0	0	4.40	210	0	0	2.20
5		110	0	0	0	110	1	9.09	5.71	220	1	4.54	2.86
6		115	0	0	0	115	0	0	4.17	230	0	0	2.08
1977		125	0	0	0	125	1	8.00	8.00	250	1	4.00	4.00

---

(1) Accidents during training, ferry and test operations (non-revenue operations) are not included in these data.

(2) This is a backwards cumulative, from 1977 to the stated first year.

Table 9

Hit Location Probability Density Function

(Scheduled plus Non-Scheduled Combined)
(Single Valued Calculation)

Landings

Radial

$D(r) = 0.44e^{-r/1.51}$

$D(2.7) = 0.073/\text{mile}$

Angular

$D(\theta) = 0.28e^{-\theta/25^{\circ}}$

$D(34^{\circ}) = 0.072/\text{radian}$

Joint Probability Density

$D(r,\theta) = D(r) \times D(\theta)/r$

$D(r,\theta) = 0.123e^{-r/1.51}e^{-\theta/25}/r$

$D(2.7,34) = 0.0020/\text{mile}^2$

Takeoffs

Radial

$D(r) = 0.29e^{-r/1.84}$

$D(2.7) = 0.067/\text{mile}$

Angular

$D(\theta) = 0.44e^{-\theta/48^{\circ}}$

$D(34) = 0.22/\text{radian}$

Joint Probability Density

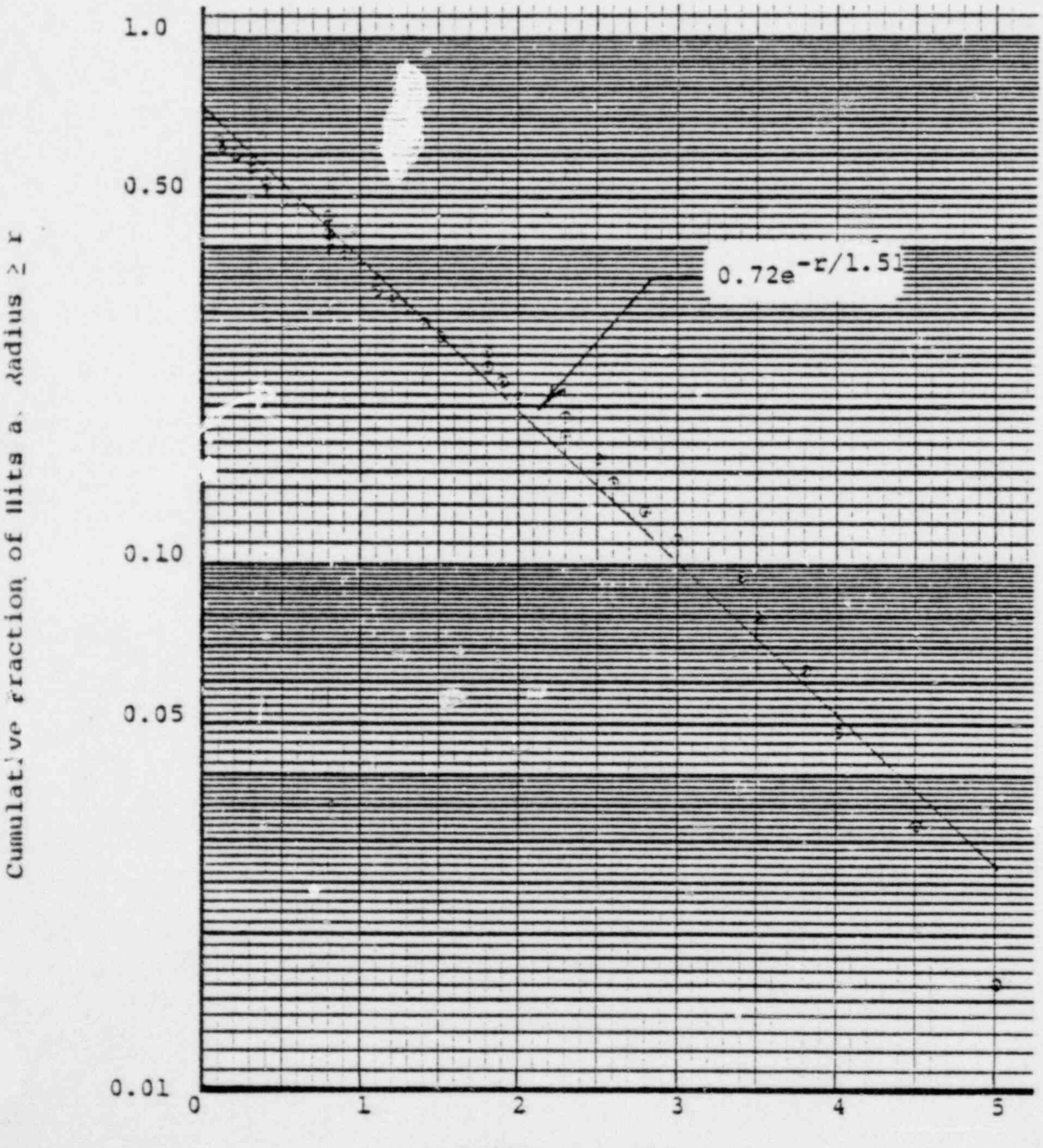
$D(r,\theta) = D(r) \times D(\theta)/r$

$D(r,\theta) = 0.13e^{-r/1.84}e^{-\theta/48}/r$

$D(2.7,34) = 0.0054/\text{mile}^2$

Figure 2

Cumulative Frequency Distribution with Radial Distance from Runway Landing Accidents



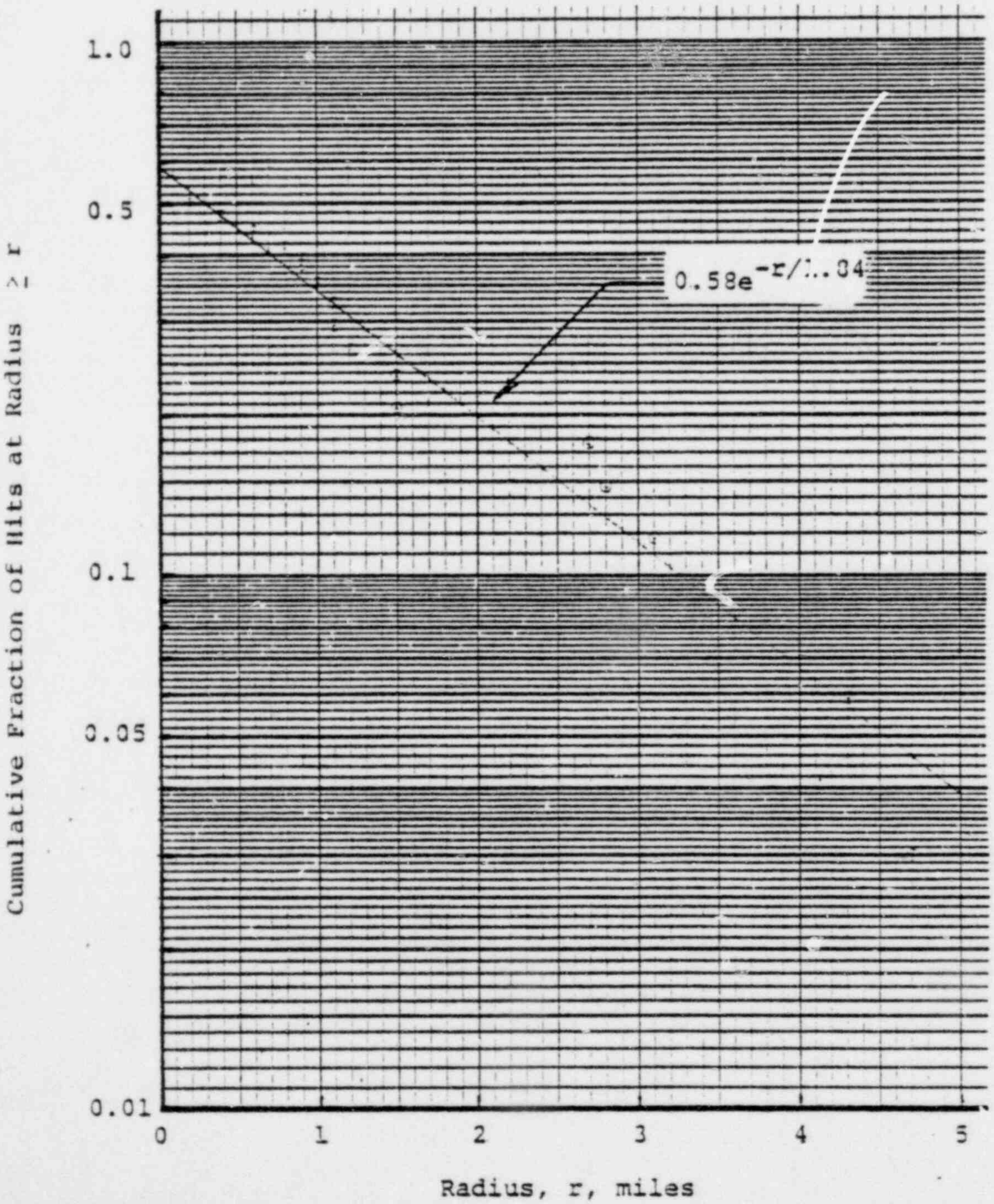
The construction of this figure incorporates 63 data points of which 40 occurred at $0 < r \leq 5$ miles.

Figure 3

Cumulative Frequency Distribution

with Radial Distance From Runway

Takeoff Accidents

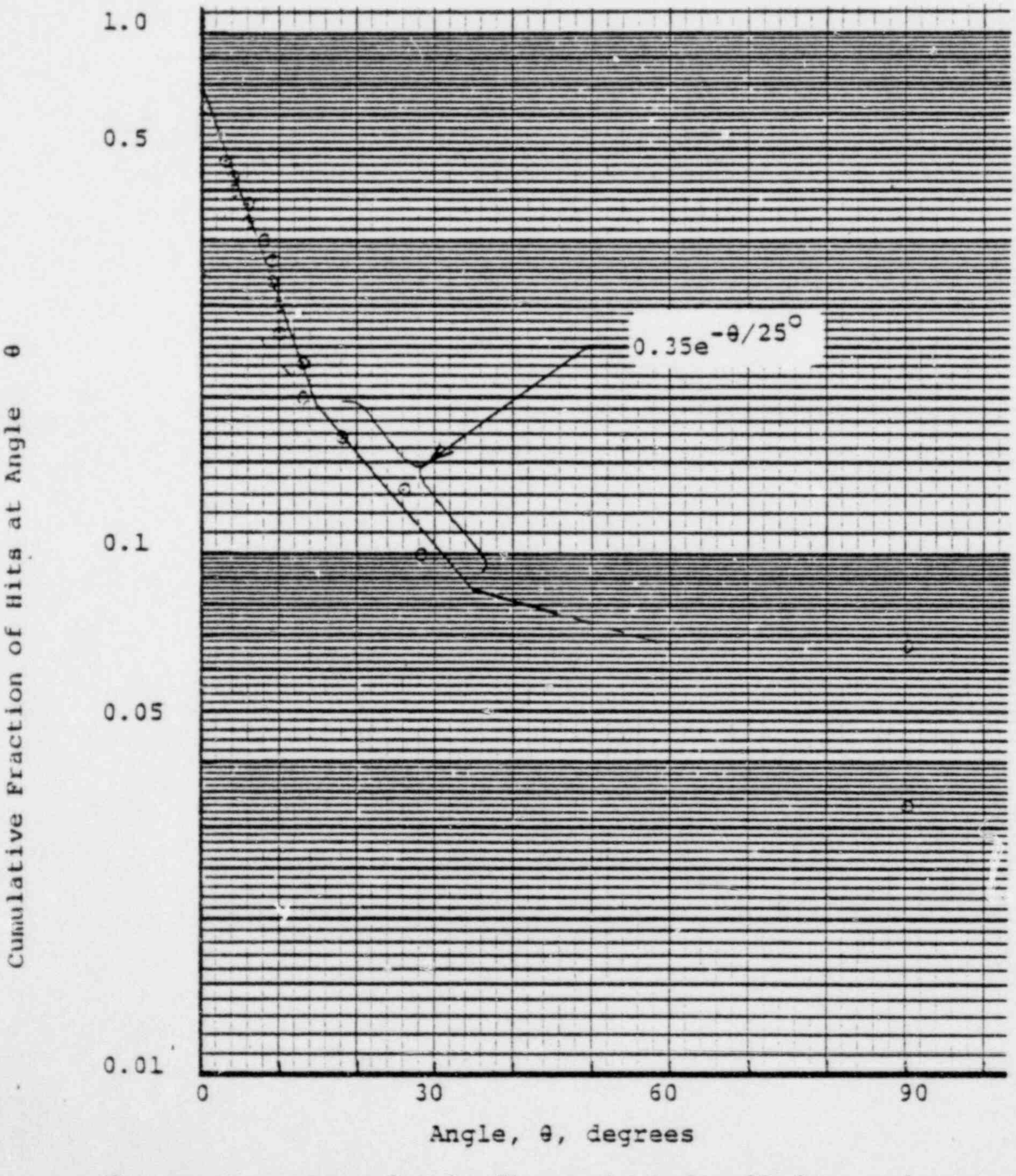


The construction of this figure incorporates 34 data points, of which 17 occurred at 0 < r ≤ 5 miles.

Figure 4

Cumulative Frequency Distribution
with Angle from Runway Centerline

Landing Accidents

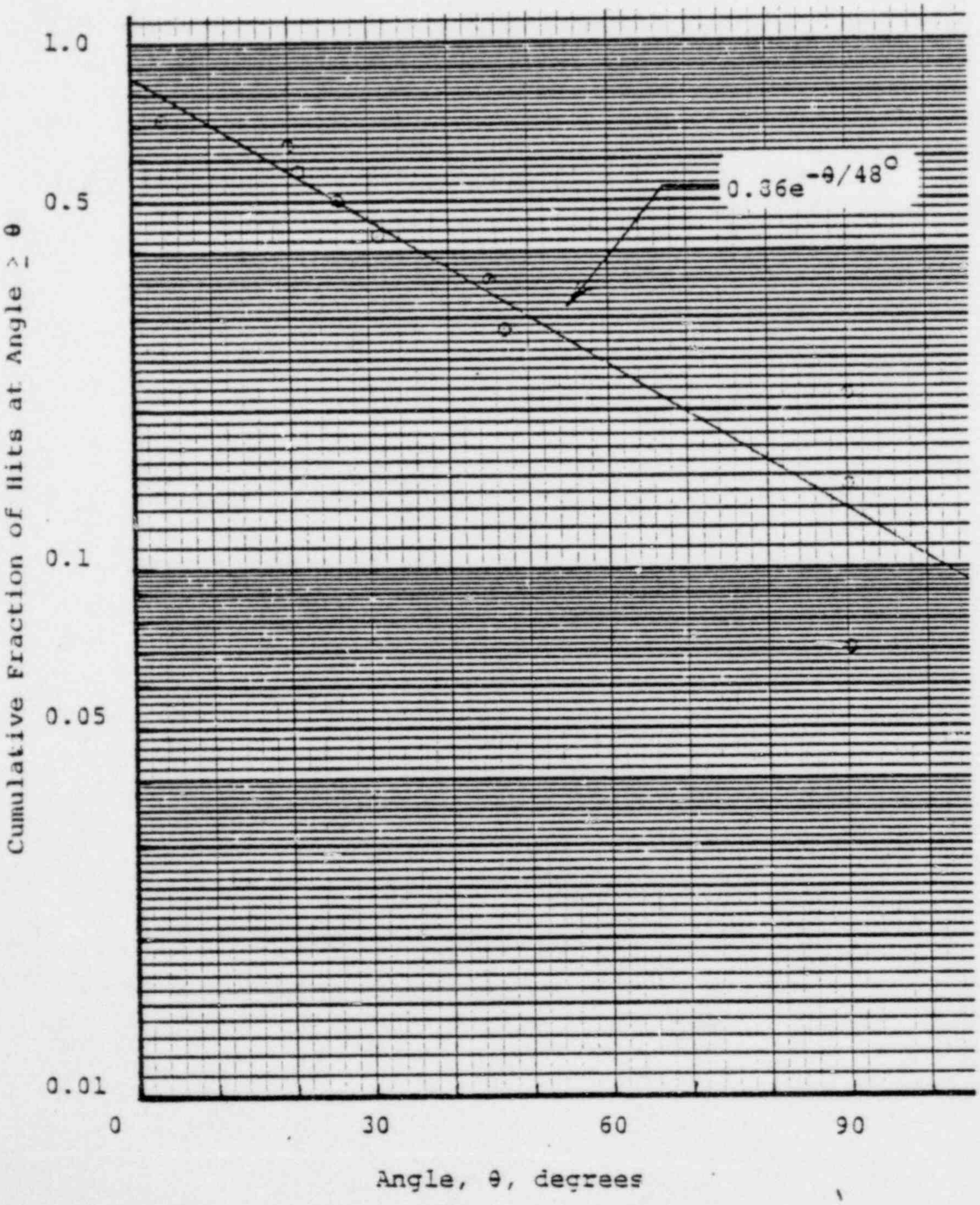


The construction of this figure includes 30 data points, of which 17 occurred at $0 < \theta \leq 90°$.

Figure 5

Cumulative Frequency Distribution with Angle from Runway Centerline

Takeoff Accidents



The construction of this figure includes 14 data points, of which 10 occurred at $0 < \theta \leq 90^\circ$.

APPENDIX A

PREDICTION OF ACCIDENT RATES FROM HISTORICAL DATA

by

Dr. S. Kaplan

A.1 PURPOSE

The purpose of this appendix is to develop an estimate of the aircraft accident rate, f, applicable to the plant in 1978. Since, of course, we do not know the value of f exactly, we express our estimate in the form of a probability curve against f. The width and shape of this curve will then communicate our degree of confidence in this estimate.

A.2 METHOD

The historical data curve in Figure A.1 shows, beginning in the early 1960's, a clear downward trend in accident rates reflecting, presumably, a steady improvement in aircraft equipment, flight safety technology, and safety consciousness. Such improvement will no doubt continue.

A direct linear extrapolation of the curve to 1978, however, would yield a crash rate very close to zero. A further extrapolation would go negative. Clearly then our extrapolation must reflect a leveling out of the curve.

Where and how quickly the curve levels out is fundamentally a matter of judgment. This judgment cannot be avoided. No statistical technique or mechanical procedure can or should be looked to as a replacement for such judgment. However, it is possible to put forth a mathematical framework which serves as a guide to judgment, and as a way of expressing our state of knowledge about the accident rate in light of all the information available. Such a framework can be provided by the well-known Bayes' Theorem.

The particular manner in which we shall apply Bayes' Theorem in the present case is as follows:

(1) We regard the historical data curve in Figure A. 1 as the result of sampling from an underlying population whose crash frequency varies with time according to the functional form:

$$f(t) = a + (b-a)\, e^{-\lambda(t-t_o)} \tag{1}$$

which reflects a gradual decrease and a leveling out at value a. In other words we are saying that the "true" frequency in 1965, for example, is f(1965) as calculated from Equation (1). In that year we selected (see Table 11) a sample of 3867 departures (7734 operations) out of which we had a total of four accidents (see Table 4).*

(2) In this form, Equation (1), we shall fix the year t_o and assign a value to b. We then determine or "fit" the remaining two parameters, a and λ, using Bayes' Theorem. That is, we regard the data in Tables 4 and 11, the experience of the past, as evidence. On the basis of this evidence, we derive by Bayes' Theorem a probability distribution on the space of a, λ pairs.

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

$$f(1978) = a + (b-a)\, e^{-\lambda(1978\ -\ t_o)} \tag{2}$$

the accident rate in 1978.

We shall call the above procedure a "Bayesian Extrapolation" process. It can be viewed in a way as analogous to a least square fitting

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* OT data is not included in the current calculations since they are not pertinent to the Harrisburg Airport.

technique, but far more satisfying and suitable for our purpose. The details are as follows:

A. 3 BAYESIAN EXTRAPOLATION

Tables 4 and 11 give us for each year, t, a doublet (n_t, m_t) which tells the number of crashes and the number of operations in that year. Denote by B the set of such doublets from the year to on:

$$B = \left\{(n_t, m_t)\right\}_{t=t_o}^{1977} \tag{3}$$

B then, is the experience of the past. Next we assume that the underlying frequency has the time dependence in (1), with b and t_o fixed from inspection of the data. We now ask: What can we say about the values of a, λ in light of the experience B?

For this purpose we write Bayes' theorem in the form:

$$p(a,\lambda | B) = p(a,\lambda) \left[\frac{p(B|a,\lambda)}{p(B)}\right] \tag{4}$$

where:

p(a, λ) is the probability we assign to the pair a, λ 'prior' to having information B

p(a, λ | B) is our probability of a, λ after having information B (the posterior)

p(B|a,λ), the 'likelihood', is the probability of experiencing B given the values a, λ.

p(B) is the prior probability of B, i.e.,

$$p(B) = \int_a \int_\lambda p(a,\lambda)\, p(B|a,\lambda)\, da\, d\lambda \tag{5}$$

A.4 EVALUATION OF THE LIKELIHOOD

To evaluate $p(B|a, \lambda)$ we note that each pair a, λ implies a specific function of time $f(t)$ through equation (1). In any particular year then the probability of observing the pair (n_t, m_t) is:

$$p(n_t, m_t|a, \lambda) = \binom{m_t}{n_t} \left[f(t)\right]^{n_t} \left[1-f(t)\right]^{m_t - n_t} \tag{6}$$

For the size m_t we are dealing with, the right side of (6) may be replaced by

$$p(n_t, m_t|a, \lambda) = \frac{\left[m_t f(t)\right]^{n_t}}{n_t!} e^{-\left[m_t f(t)\right]} \tag{7}$$

The probability of experiencing the entire set B then is:

$$p(B|a, \lambda) = \prod_{t=t_o}^{1977} \frac{\left[m_t f(t)\right]^{n_t}}{n_t!} e^{-\left[m_t f(t)\right]} \tag{8}$$

A.5 NUMERICAL PROCEDURE – SPECIFICATION OF THE PRIOR

To carry out the process numerically we established a discretization as follows:

$$a: \{0.0,\ 0.05,\ 0.1,\ 0.2,\ 0.3,\ 0.4,\ 0.5,\ 0.6\} (\times 10^{-6})$$

$$\lambda: \left\{\frac{1}{1}, \frac{1}{2}, \frac{1}{3}, \ldots \frac{1}{25}\right\} (\text{yrs}^{-1}) \tag{9}$$

We then chose a uniform prior over the set of discrete points (a_i, λ_j), saying thus that as far as our knowledge goes each such pair is as likely as any other within the grid. With this choice (4) becomes:

$$p_{ij} = p(a_i, \lambda_j|B) = \frac{p(B|a_i, \lambda_j)}{\sum_{i,j} p(B|a_i, \lambda_j)} \tag{10}$$

with the right side computed from (8) using the f(t) given by (1). We choose $t_o = 1955$, $b = 1.0 \times 10^{-6}$. The results of this calculation are the discrete probability distributions (DPDs) tabulated in Table A. 1 and at the right in Figure A. 1.

Observe that the most likely a, λ combination is in the vicinity of $a = 0$, $\lambda = 1/14$. The mean values of a, λ are $\bar{a} = .089$, $\bar{\lambda} = 1/11.1$. As a matter of interest, the f(t) corresponding to the $\bar{a}$, $\bar{\lambda}$ combination is plotted in Figure A. 1 against the historical data.

As may be noted in the Figure, the Bayesian extrapolation appears to give a rather conservative result compared with a direct extrapolation of the most recent portion of the historical data. This effect results from our choice of the form (Equation 1) and from the fact that our procedure gives as much weight to the experience of the early years as to that of the recent years.

A. 6 CATEGORIZATION OF DATA

In the preceding sections we have considered all the data in a combined fashion. We now wish to ask whether the crash rate is different for scheduled and nonscheduled aircraft and for landing and takeoff operations. Accordingly we now break the data into four categories: Scheduled Landings, Nonscheduled Landings, Scheduled Takeoffs, Nonscheduled Takeoffs, and repeat the Bayesian analysis for each category. The historical data in Tables 4 and 11 are displayed graphically for each data category in Figures A. 2 through A. 5. The a, λ and b values used for each category are as follows:

- Scheduled Landings

$$b = 1.0 \times 10^{-6} \quad t_o = 1955$$

$$a = \{0.0, 0.05, 0.1, 0.2, 0.3, 0.4, 0.5, 0.6\} \ (x\ 10^{-6})$$

$$\lambda = \left\{\frac{1}{5}, \frac{1}{6}, \frac{1}{7}, \ldots \frac{1}{25}\right\} \ (\text{yrs}^{-1})$$

- Nonscheduled Landings

$$b = 16 \times 10^{-6} \quad t_o = 1955$$

$$a = \{0.0,\ 0.05,\ 0.1,\ 0.2,\ 0.3,\ 0.4,\ 0.5,\ 0.6\}\ (\times 10^{-6})$$

$$\lambda = \left\{\frac{1}{3}, \frac{1}{4}, \frac{1}{5}, \frac{1}{6}, \frac{1}{7}, \cdots \frac{1}{17}, \frac{1}{18}, \frac{1}{20}\right\} (\text{yrs}^{-1})$$

- Scheduled Takeoffs

$$b = 0.8 \times 10^{-6} \quad t_o = 1955$$

$$a = \{0.0,\ 0.025,\ 0.05,\ 0.075,\ 0.1,\ 0.2\}\ (\times 10^{-6})$$

$$\lambda = \left\{\frac{1}{1.0}, \frac{1}{2.0}, \frac{1}{3.0}, \cdots \frac{1}{14}, \frac{1}{15}, \frac{1}{17}, \frac{1}{20}\right\} (\text{yrs}^{-1})$$

- Nonscheduled Takeoffs

$$b = 10 \times 10^{-6} \quad t_o = 1955$$

$$a = \{0.0,\ 1.0,\ 2.0,\ 3.0,\ 4.0,\ 5.0,\ 6.0\}\ (\times 10^{-6})$$

$$\lambda = \left\{\frac{1}{0.1}, \frac{1}{0.5}, \frac{1}{1.0}, \frac{1}{2.0}, \frac{1}{3.0}, \cdots \frac{1}{10}\right\} (\text{yrs}^{-1})$$

The discrete probability distributions on the a, λ grids are given in Tables A.2 through A.5. The resulting distributions for f(1978) are displayed at the right of Figures A.2 through A.5. The smooth curve on each of these figures is a plot of Equation 1, using the mean a and λ from the discrete probability distribution. These mean values and the resulting "mean" time dependent failure rate, f(t), are given in Table A.6.

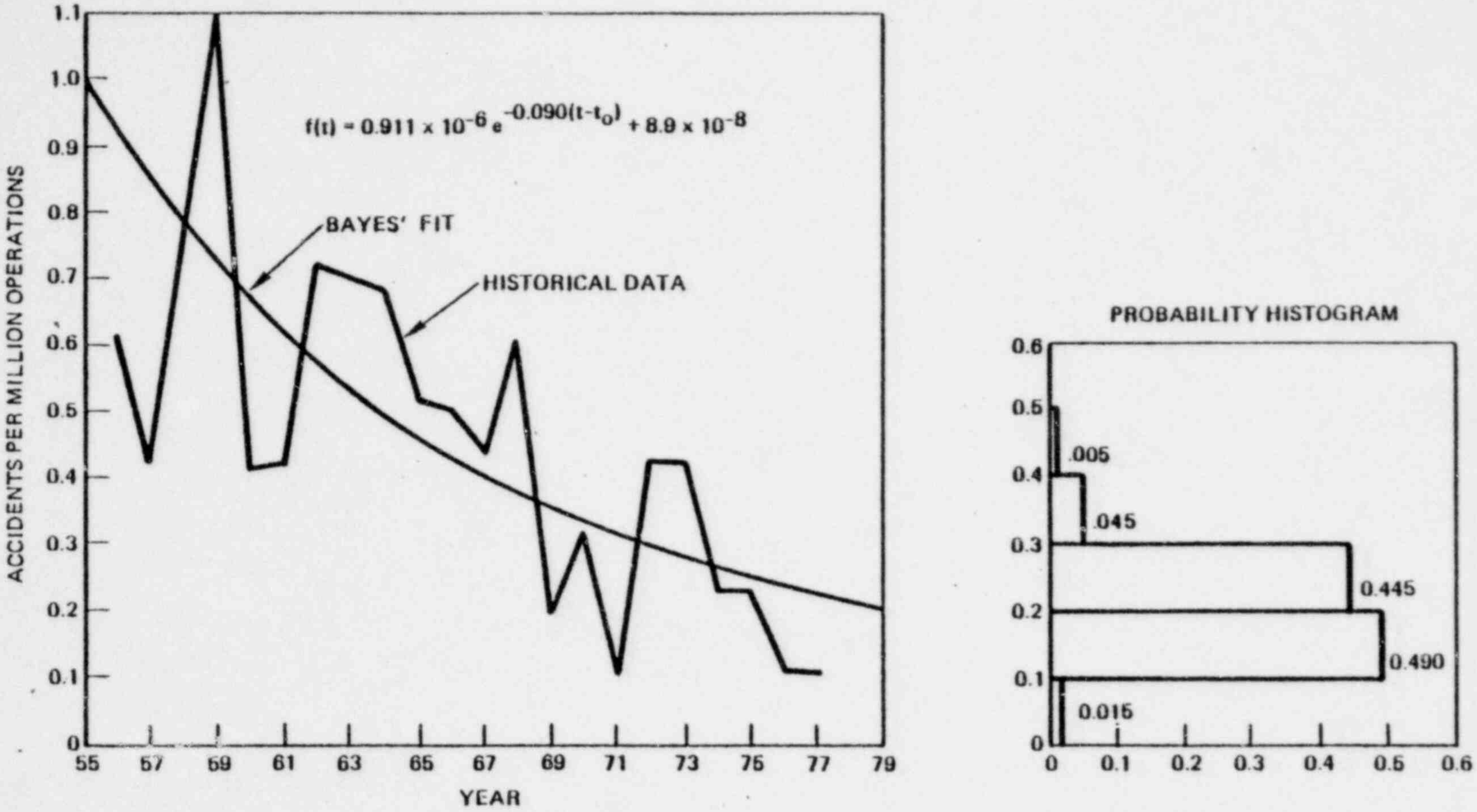


FIGURE A. 1. CRASH RATE VERSUS TIME LANDINGS AND TAKEOFFS COMBINED

TABLE A.1. DPD ON (a, λ) SPACE FOR FORM

$$f(t) = (1-a)\,e^{-\lambda(t-t_o)} + a$$

$$t_o = 1955$$

LANDINGS AND TAKEOFFS COMBINED

1/λ \ a	0.0	0.05	0.1	0.2	0.3	0.4	0.5	0.6	Σ
1	0.	0.	0.	0.	.6452E-05	.2780E-03	.1137E-03	.2370E-05	.4005E-03
2	0.	0.	0.	.6460E-08	.7297E-04	.7450E-03	.1400E-03	.1966E-05	.9600E-03
3	0.	0.	0.	.8160E-06	.6633E-03	.1724E-02	.1547E-03	.1493E-05	.2544E-02
4	0.	0.	0.	.4194E-04	.3384E-02	.2677E-02	.1288E-03	.9320E-06	.6233E-02
5	0.	0.	.5413E-07	.7711E-03	.9184E-02	.2737E-02	.8075E-04	.4800E-06	.1277E-01
6	0.	.8820E-08	.1052E-04	.5463E-02	.1426E-01	.1975E-02	.4056E-04	.2152E-06	.2175E-01
7	.9287E-09	.4005E-05	.4617E-03	.1755E-01	.1423E-01	.1101E-02	.1753E-04	.8472E-07	.3331E-01
8	.1295E-05	.2388E-03	.4331E-02	.3053E-01	.1022E-01	.5138E-03	.6927E-05	.3517E-07	.4584E-01
9	.1299E-03	.3299E-02	.1819E-01	.3362E-01	.5813E-02	.2142E-03	.2616E-05	.1383E-07	.6127E-01
10	.2353E-02	.1818E-01	.3644E-01	.2660E-01	.2823E-02	.8370E-04	.9741E-06	.5511E-08	.8648E-01
11	.1358E-01	.3820E-01	.4968E-01	.1660E-01	.1237E-02	.3170E-04	.3655E-06	.2253E-08	.1194E+00
12	.3593E-01	.5393E-01	.4526E-01	.8911E-02	.5103E-03	.1192E-04	.1401E-06	.9525E-09	.1446E+00
13	.5551E-01	.5302E-01	.3226E-01	.4281E-02	.2040E-03	.4528E-05	.5536E-07	.4162E-09	.1453E+00
14	.5291E-01	.4643E-01	.1939E-01	.1924E-02	.8068E-04	.1754E-05	.2265E-07	.1910E-09	.1207E+00
15	.4808E-01	.2584E-01	.1037E-01	.8317E-03	.3205E-04	.6986E-06	.9624E-08	0.	.8515E-01
16	.3265E-01	.1462E-01	.5142E-02	.3530E-03	.1292E-04	.2871E-06	.4251E-08	0.	.5276E-01
17	.1952E-01	.7617E-02	.2428E-02	.1493E-03	.5316E-05	.1221E-06	.1951E-08	0.	.2972E-01
18	.1060E-01	.3764E-02	.1116E-02	.6355E-04	.2245E-05	.5374E-07	.9298E-09	0.	.1554E-01
19	.5527E-02	.1801E-02	.5063E-03	.2742E-04	.9750E-06	.2450E-07	.4595E-09	0.	.7865E-02
20	.2755E-02	.8475E-03	.2273E-03	.1206E-04	.4362E-06	.1156E-07	.2351E-09	0.	.3845E-02
21	.1345E-02	.3965E-03	.1045E-03	.5416E-05	.2011E-06	.5640E-08	.1243E-09	0.	.1851E-02
22	.6498E-03	.1859E-03	.4617E-04	.2492E-05	.9557E-07	.2842E-08	0.	0.	.8844E-03
23	.3136E-03	.8788E-04	.2255E-04	.1176E-05	.4678E-07	.1477E-08	0.	0.	.4253E-03
24	.1521E-03	.4206E-04	.1075E-04	.5689E-06	.2357E-07	.7903E-09	0.	0.	.2055E-03
25	.7447E-04	.2044E-04	.5225E-05	.2824E-06	.1221E-07	.4350E-09	0.	0.	.1004E-03
Σ	.2882E+00	.2605E+00	.2279E+00	.1478E+00	.6275E-01	.1210E-01	.6872E-03	.7598E-05	.1000E+01

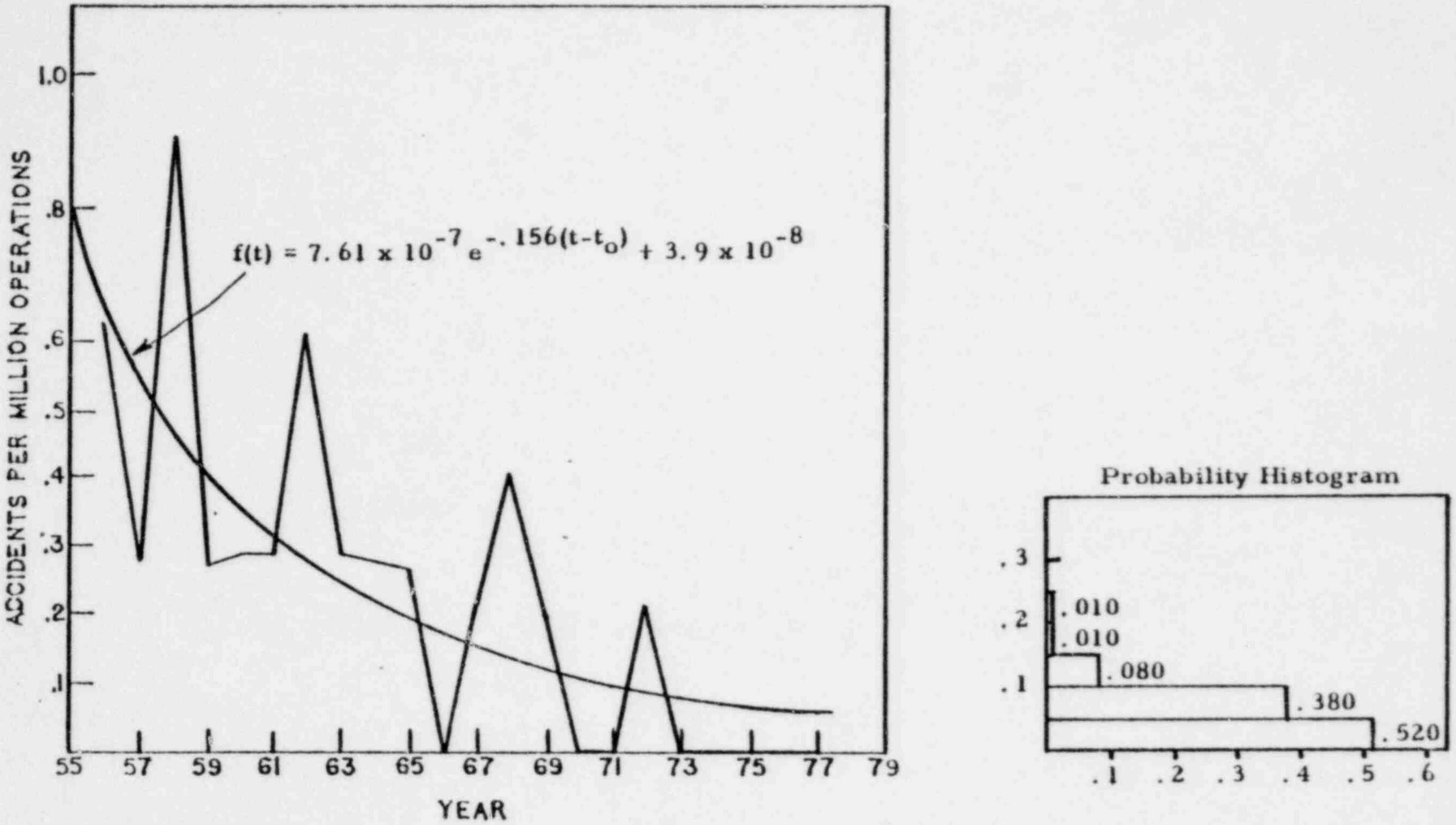


FIGURE A.2. CRASH RATE VERSUS TIME, SCHEDULED TAKEOFFS

TABLE A.2. SCHEDULED TAKEOFFS

1/λ \ a	0.0	0.025	0.050	0.075	0.10	0.20	Σ
1	0.	0.	.8820E-07	.4425E-05	.4366E-04	.5440E-03	.5922E-03
2	0.	.1517E-06	.1642E-04	.2166E-03	.8101E-03	.1593E-02	.2633E-02
3	.2467E-07	.5470E-04	.7853E-03	.2940E-02	.5517E-02	.2685E-02	.1198E-01
4	.1409E-03	.2598E-02	.8846E-02	.1483E-01	.1642E-01	.2840E-02	.4568E-01
5	.7928E-02	.2242E-01	.3228E-01	.3193E-01	.2464E-01	.2078E-02	.1213E+00
6	.4743E-01	.5756E-01	.5072E-01	.3617E-01	.2213E-01	.1171E-02	.2152E+00
7	.8564E-01	.6785E-01	.4514E-01	.2641E-01	.1399E-01	.5578E-03	.2396E+00
8	.7893E-01	.4960E-01	.2604E-01	.1458E-01	.7085E-02	.2415E-03	.1765E+00
9	.4950E-01	.2724E-01	.1403E-01	.6813E-02	.3152E-02	.9992E-04	.1009E+00
10	.2495E-01	.1276E-01	.6218E-02	.2907E-02	.1311E-02	.4089E-04	.4818E-01
11	.1115E-01	.5474E-02	.2592E-02	.1190E-02	.5312E-03	.1692E-04	.2096E-01
12	.4704E-02	.2260E-02	.1056E-02	.4822E-03	.2154E-03	.7176E-05	.8725E-02
13	.1942E-02	.9252E-03	.4316E-03	.1975E-03	.8882E-04	.3138E-05	.3588E-02
14	.8035E-03	.3829E-03	.1794E-03	.8274E-04	.3762E-04	.1424E-05	.1488E-02
15	.3380E-03	.1620E-03	.7655E-04	.3571E-04	.1647E-04	.6713E-06	.6294E-03
17	.6483E-04	.3172E-04	.1537E-04	.7378E-05	.3512E-05	.1671E-06	.1230E-03
20	.6951E-05	.3544E-05	.1796E-05	.9043E-06	.4528E-06	.2765E-07	.1368E-04
Σ	.3135E+00	.2494E+00	.1904E+00	.1388E+00	.9600E-01	.1188E-01	.1000E+01

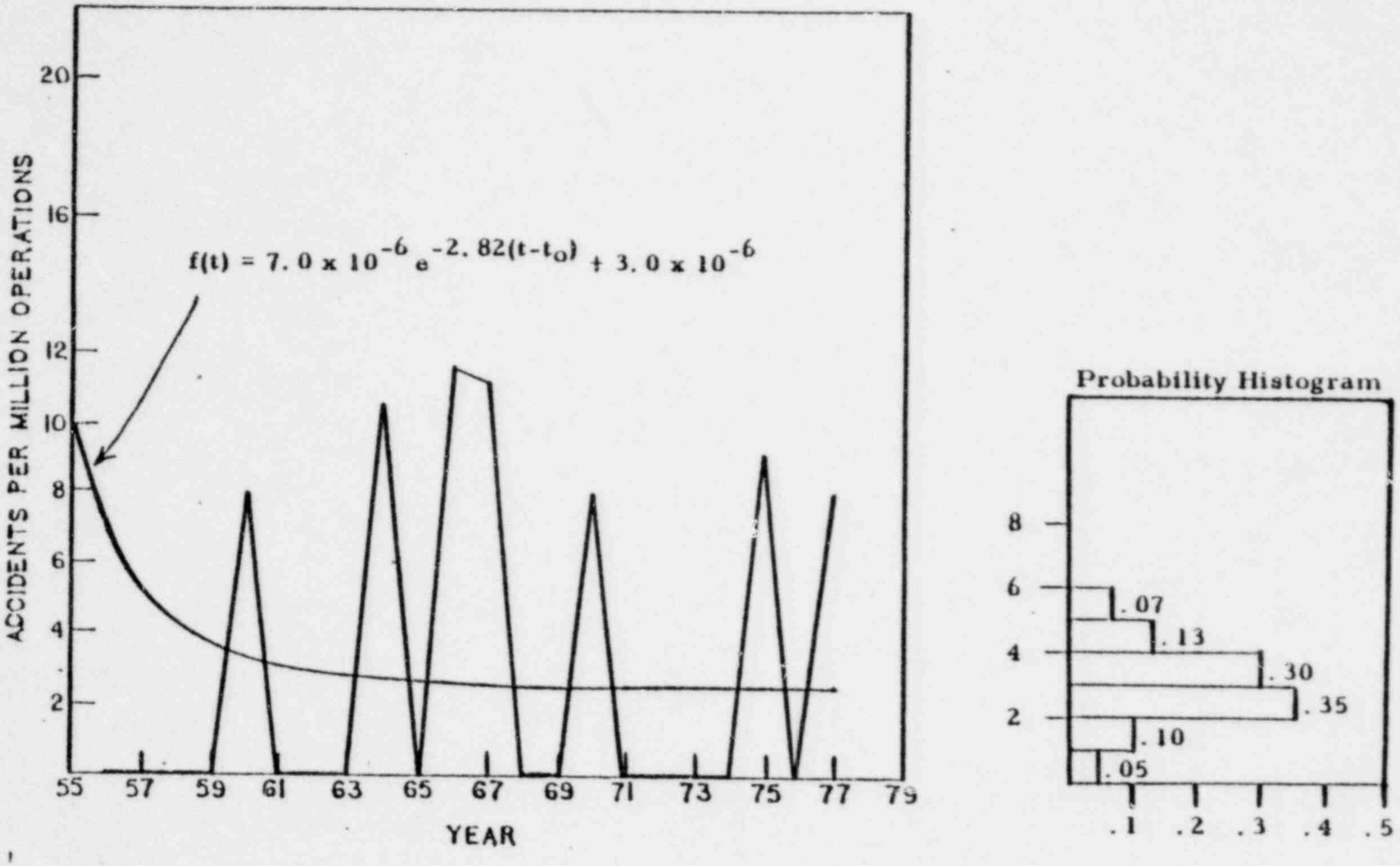


FIGURE A.3. CRASH RATE VERSUS TIME, NONSCHEDULED TAKEOFFS

TABLE A. 3. NONSCHEDULED TAKEOFFS

1/λ \ a	0.0	1.0	2.0	3.0	4.0	5.0	6.0	Σ
0.1	0.	.5696E-02	.5952E-01	.8020E-01	.4738E-01	.1782E-01	.5036E-02	.2159E+00
0.5	0.	.5196E-02	.5313E-01	.7208E-01	.4355E-01	.1661E-01	.4760E-02	.1966E+00
1	0.	.3892E-02	.4008E-01	.5636E-01	.3487E-01	.1378E-01	.4095E-02	.1536E+00
2	0.	.3171E-02	.2600E-01	.3537E-01	.2250E-01	.9368E-02	.2974E-02	.9938E-01
3	.1433E-06	.3587E-02	.1993E-01	.2438E-01	.1528E-01	.6543E-02	.2186E-02	.7196E-01
4	.1193E-05	.4640E-02	.1672E-01	.1736E-01	.1082E-01	.4699E-02	.1637E-02	.5637E-01
5	.4399E-04	.5945E-02	.1445E-01	.1351E-01	.7880E-02	.3453E-02	.1247E-02	.4652E-01
6	.3512E-03	.7122E-02	.1247E-01	.1038E-01	.5850E-02	.2588E-02	.9668E-03	.3974E-01
7	.1213E-02	.7886E-02	.1065E-01	.8058E-02	.4426E-02	.1976E-02	.7621E-03	.3497E-01
8	.2557E-02	.8127E-02	.8980E-02	.6305E-02	.3398E-02	.1535E-02	.6108E-03	.3151E-01
9	.3967E-02	.7900E-02	.7500E-02	.4975E-02	.2649E-02	.1213E-02	.4974E-03	.2870E-01
10	.5058E-02	.7349E-02	.6226E-02	.3959E-02	.2095E-02	.9743E-03	.4111E-03	.2607E-01
Σ	.1319E-01	.7071E-01	.2757E+00	.3340E+00	.2007E+00	.8056E-01	.2518E-01	.1000E+01

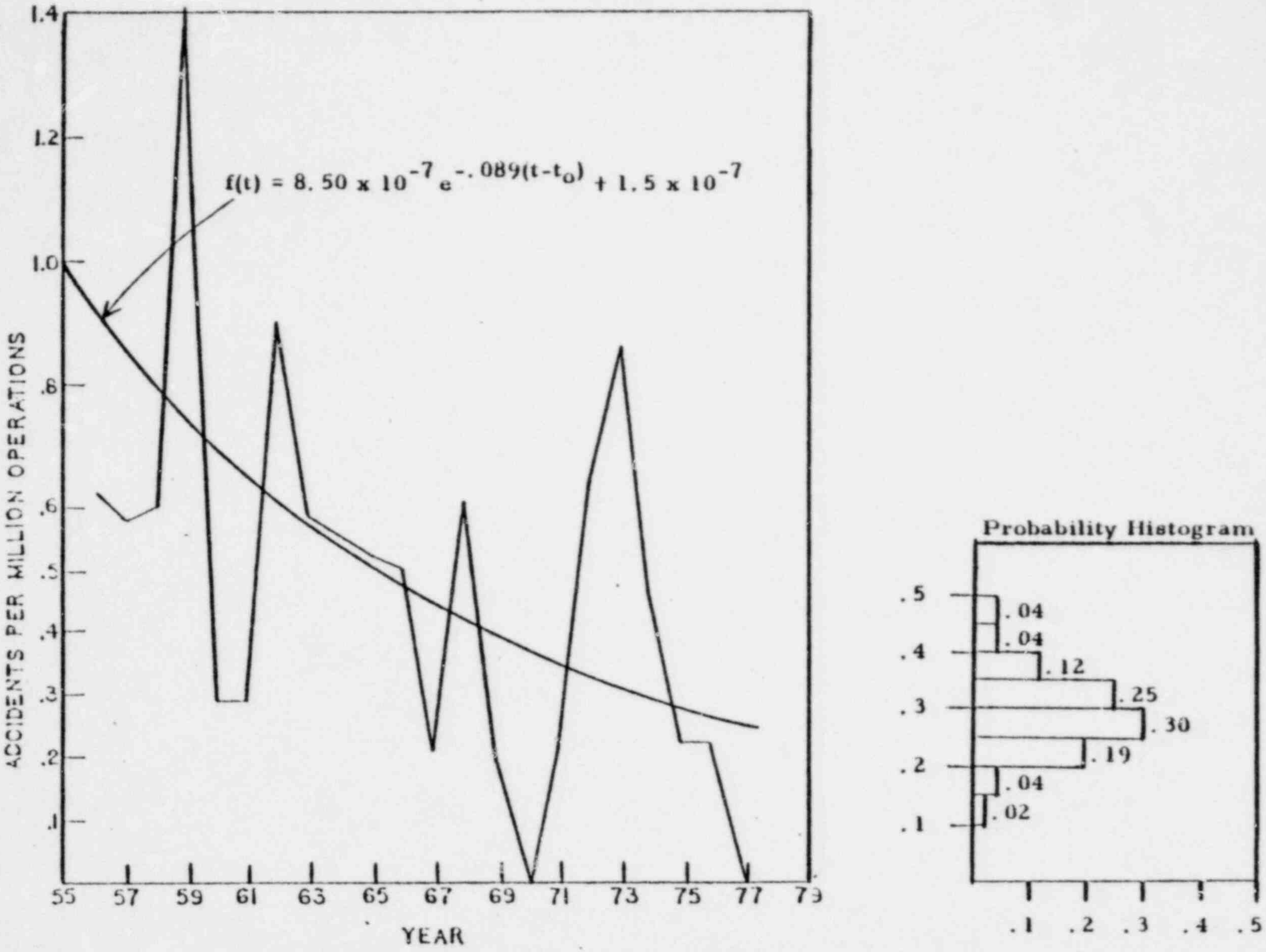


FIGURE A.4. CRASH RATE VERSUS TIME, SCHEDULED LANDINGS

TABLE A.4. SCHEDULED LANDINGS

1/λ \ a	0.0	0.05	0.1	0.2	0.3	0.4	0.5	0.6	Σ
5	0.	.7676E-08	.5280E-05	.2270E-02	.1684E-01	.1604E-01	.4305E-02	.4845E-03	.3995E-01
6	.1496E-09	.9071E-06	.6600E-04	.6419E-02	.2184E-01	.1408E-01	.3137E-02	.3321E-03	.4590E-01
7	.1219E-06	.2952E-04	.6754E-03	.1290E-01	.2345E-01	.1107E-01	.2146E-02	.2197E-03	.5048E-01
8	.9645E-05	.3447E-03	.2896E-02	.1962E-01	.2178E-01	.8068E-02	.1414E-02	.1433E-03	.5427E-01
9	.1746E-03	.1867E-02	.7722E-02	.2399E-01	.1817E-01	.5596E-02	.9153E-03	.9330E-04	.5853E-01
10	.1199E-02	.5766E-02	.1437E-01	.2456E-01	.1405E-01	.3766E-02	.5894E-03	.6121E-04	.6466E-01
11	.4274E-02	.1187E-01	.2047E-01	.2279E-01	.1030E-01	.2494E-02	.3808E-03	.4067E-04	.7260E-01
12	.9689E-02	.1821E-01	.2395E-01	.1911E-01	.7289E-02	.1642E-02	.2484E-03	.2746E-04	.8017E-01
13	.1597E-01	.2262E-01	.2429E-01	.1504E-01	.5053E-02	.1083E-02	.1641E-03	.1886E-04	.8424E-01
14	.2099E-01	.2409E-01	.2220E-01	.1134E-01	.3464E-02	.7188E-03	.1101E-03	.1319E-04	.8293E-01
15	.2344E-01	.2297E-01	.1884E-01	.8308E-02	.2366E-02	.4818E-03	.7507E-04	.9396E-05	.7649E-01
16	.2328E-01	.2021E-01	.1516E-01	.5978E-02	.1619E-02	.3268E-03	.5204E-04	.6810E-05	.6664E-01
17	.2123E-01	.1680E-01	.1176E-01	.4258E-02	.1113E-02	.2246E-03	.3669E-04	.5021E-05	.5543E-01
18	.1820E-01	.1341E-01	.8901E-02	.3021E-02	.7715E-03	.1566E-03	.2629E-04	.3761E-05	.4449E-01
19	.1493E-01	.1040E-01	.6628E-02	.2144E-02	.5398E-03	.1107E-03	.1914E-04	.2861E-05	.3478E-01
20	.1188E-01	.7920E-02	.4889E-02	.1527E-02	.3817E-03	.7940E-04	.1415E-04	.2208E-05	.2669E-01
21	.9241E-02	.5958E-02	.3570E-02	.1093E-02	.2729E-03	.5774E-04	.1061E-04	.1727E-05	.2022E-01
22	.7088E-02	.4451E-02	.2633E-02	.7882E-03	.1974E-03	.4256E-04	.8069E-05	.1368E-05	.1521E-01
23	.5383E-02	.3315E-02	.1935E-02	.5730E-03	.1445E-03	.3178E-04	.6216E-05	.1097E-05	.1139E-01
24	.4075E-02	.2469E-02	.1427E-02	.4202E-03	.1070E-03	.2404E-04	.4846E-05	.8892E-06	.8528E-02
25	.3077E-02	.1843E-02	.1058E-02	.3110E-03	.8009E-04	.1840E-04	.3825E-05	.7283E-06	.6371E-02
Σ	.1941E+00	.1945E+00	.1935E+00	.1868E+00	.1498E+00	.6611E-01	.1367E-01	.1470E-02	.1000E+01

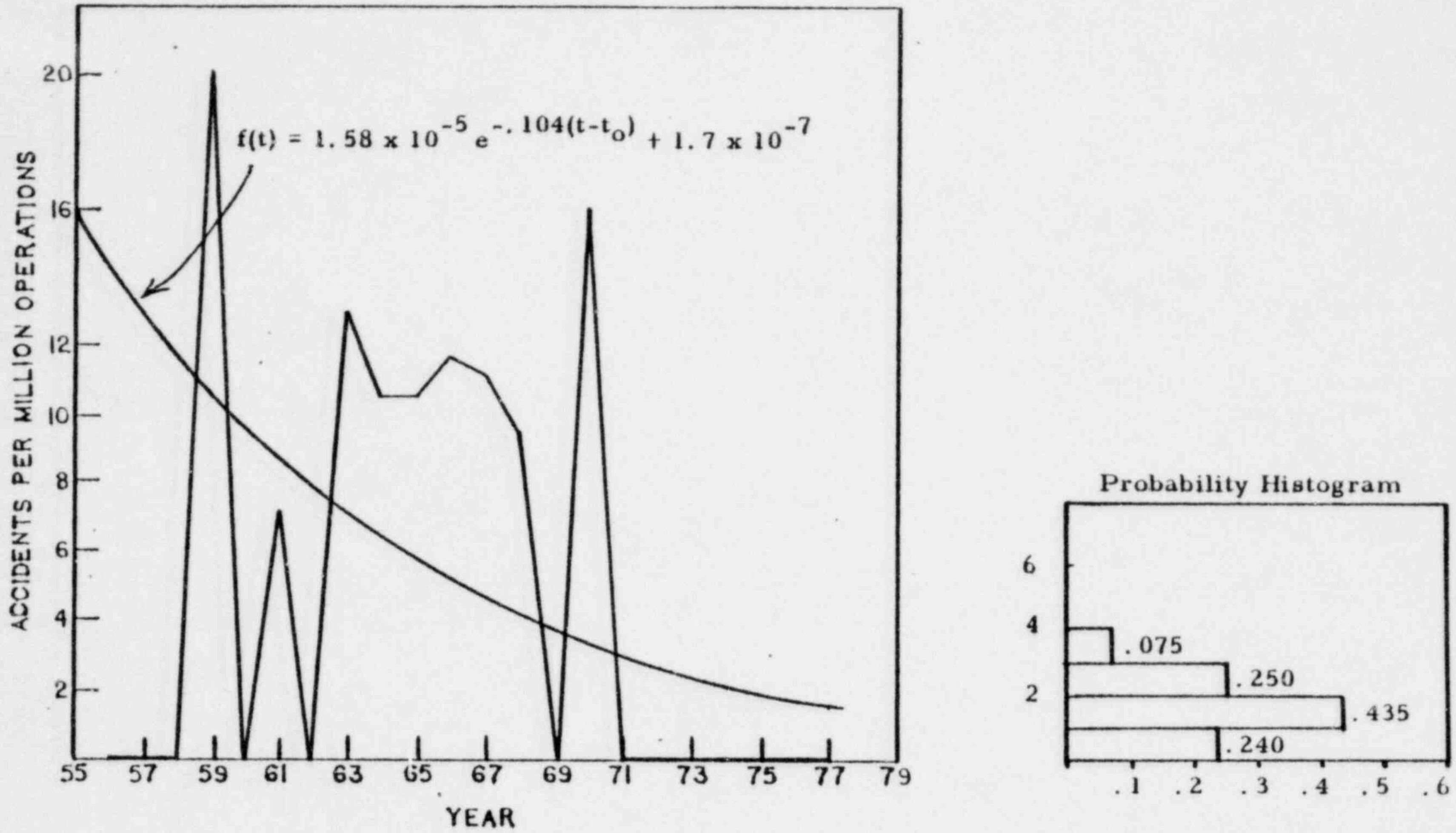


FIGURE A.5. CRASH RATE VERSUS TIME, NONSCHEDULED LANDINGS

TABLE A.5. NONSCHEDULED LANDINGS

1/λ \ a	0.0	0.05	0.1	0.2	0.3	0.4	0.5	0.6	Σ
3	.2511E-09	.9984E-08	.2965E-07	.1605E-06	.5897E-06	.1703E-05	.4156E-05	.8952E-05	.1560E-04
4	.6193E-05	.9561E-05	.1419E-04	.2842E-04	.5163E-04	.8692E-04	.1377E-03	.2075E-03	.5422E-03
5	.3365E-03	.4034E-03	.4706E-03	.6550E-03	.8690E-03	.1122E-02	.1413E-02	.1743E-02	.7022E-02
6	.2871E-02	.3121E-02	.3379E-02	.3910E-02	.4481E-02	.5062E-02	.5654E-02	.6249E-02	.3474E-01
7	.8983E-02	.9318E-02	.9647E-02	.1028E-01	.1088E-01	.1144E-01	.1196E-01	.1242E-01	.8494E-01
8	.1573E-01	.1591E-01	.1607E-01	.1634E-01	.1655E-01	.1669E-01	.1677E-01	.1680E-01	.1307E+00
9	.1943E-01	.1935E-01	.1926E-01	.1904E-01	.1878E-01	.1847E-01	.1812E-01	.1773E-01	.1502E+00
10	.1934E-01	.1909E-01	.1883E-01	.1829E-01	.1773E-01	.1716E-01	.1658E-01	.1600E-01	.1430E+00
11	.1684E-01	.1652E-01	.1620E-01	.1555E-01	.1492E-01	.1429E-01	.1367E-01	.1307E-01	.1211E+00
12	.1349E-01	.1318E-01	.1287E-01	.1227E-01	.1169E-01	.1112E-01	.1057E-01	.1004E-01	.9524E-01
13	.1027E-01	.1001E-01	.9755E-02	.9255E-02	.8774E-02	.8311E-02	.7867E-02	.7442E-02	.7169E-01
14	.7595E-02	.7392E-02	.7191E-02	.6801E-02	.6429E-02	.6073E-02	.5734E-02	.5410E-02	.5263E-01
15	.5535E-02	.5379E-02	.5227E-02	.4935E-02	.4656E-02	.4391E-02	.4139E-02	.3900E-02	.3816E-01
16	.4006E-02	.3893E-02	.3781E-02	.3566E-02	.3361E-02	.3167E-02	.2983E-02	.2808E-02	.2757E-01
17	.2904E-02	.2820E-02	.2738E-02	.2580E-02	.2431E-02	.2290E-02	.2156E-02	.2030E-02	.1995E-01
18	.2113E-02	.2052E-02	.1992E-02	.1877E-02	.1769E-02	.1666E-02	.1569E-02	.1477E-02	.1451E-01
20	.1145E-02	.1112E-02	.1080E-02	.1019E-02	.9605E-03	.9055E-03	.8534E-03	.8042E-03	.7879E-02
Σ	.1300E+00	.1296E+00	.1285E+00	.1264E+00	.1243E+00	.1223E+00	.1202E+00	.1181E+00	.1000E+01

TABLE A.6. BAYES' FIT FOR TIME DEPENDENT FAILURE RATE

LANDING AND TAKEOFF COMBINED

$b = 1.0 \times 10^{-6}$

$\bar{a} = 8.9 \times 10^{-8}$

$\bar{\lambda} = .090$

$\bar{f}(t) = .911 \times 10^{-6} e^{-.090 (t-t_o)} + 8.9 \times 10^{-8}$

TAKEOFF

Scheduled:

$b = .8 \times 10^{-6}$

$\bar{a} = 3.9 \times 10^{-8}$

$\bar{\lambda} = .156$

$\bar{f}(t) = 7.61 \times 10^{-7} e^{-.156 (t-t_o)} + 3.9 \times 10^{-8}$

Nonscheduled:

$b = 10 \times 10^{-6}$

$\bar{a} = 3.0 \times 10^{-6}$

$\bar{\lambda} = 2.82$

$\bar{f}(t) = 7.0 \times 10^{-6} e^{-2.82(t-t_o)} + 3.0 \times 10^{-6}$

LANDING

Scheduled:

$b = 1.0 \times 10^{-6}$

$\bar{a} = 1.5 \times 10^{-7}$

$\bar{\lambda} = .089$

$\bar{f}(t) = 8.50 \times 10^{-7} e^{-.089(t-t_o)} + 1.5 \times 10^{-7}$

Nonscheduled:

$b = 16 \times 10^{-6}$

$\bar{a} = 1.7 \times 10^{-7}$

$\bar{\lambda} = .104$

$\bar{f}(t) = 1.58 \times 10^{-5} e^{-.104(t-t_o)} + 1.7 \times 10^{-7}$

APPENDIX B

DETERMINATION OF THE SPATIAL DENSITY FUNCTIONS

by

Dr. S. Kaplan

In this appendix we apply the Bayesian approach to find discrete probability distributions (DPDs) for the spatial distribution quantities D(r), D(θ) introduced on page 18. We begin with the radial distribution.

B.1 THE RADIAL DENSITY $D(r) = \left[\frac{-d}{dr} R(r)\right]_{r=r_o}$

Figure B.1 shows, for landings and takeoffs combined, the fraction, R(r), of crashes occurring beyond radius r, plotted as a function of r. This plot is directly from the data of Table 3 and thus is a staircase function with a 'step' occurring at the radius of each crash in the table.

From this staircase function we wish to know the density of crash frequency (frequency per unit radius) at the radius of the TMI plant. For this purpose we note that the staircase function in the vicinity of r = 2.7 miles is well approximated by the straight line:

$$R\ (r) = .65e^{-r/1.7}$$

We take this function as representing the fraction of crashes at radius greater than r.

Since we need the fraction per unit radius, we evaluate the derivative of this function at the radius of the TMI plant.

$$D(r) \approx -\frac{d}{dr} R\ (2.7) = \frac{.65}{1.7}\ e^{-\frac{2.7}{1.7}} = .078 \text{ per mile}$$

To obtain a feeling for the bounds on this value we plot two additional lines in Figure B.1.

$$R_2(r) = .63e^{-r/1.6}$$

$$R_3(r) = .62e^{-r/1.9}$$

which yield

$$-\frac{d}{dr} R_2(2.7) = .073$$

$$-\frac{d}{dr} R_3(2.7) = .079$$

These calculations give us a hueristic feeling for the uncertainty in the desired quantity D(r). For a more quantitative evaluation we turn to a Bayesian approach.

B.1.1 Bayesian Approach

The data shown in the figure suggests that R(r) may be well fit by a step at r = 0 followed by a decaying exponential, i.e.:

$$R(r) = \begin{cases} 1.0 & , r = 0 \\ ae^{-\lambda r} & , r > 0 \end{cases} \tag{1}$$

This being so, the derivative of R(r) contains a delta function at r = 0:

$$\left[\frac{-d}{dr} R(r)\right] = (1-a)\,\delta(r) + \lambda a e^{-\lambda r} \tag{2}$$

We seek to estimate the value of this derivative at the radius of the plant. Thus we seek:

$$D(r) = \left[\frac{-d}{dr} R(r)\right]_{r_o} = \lambda a e^{-\lambda r_o} \tag{3}$$

where $r_o = 2.7$ miles. We shall obtain this estimate by first obtaining a DPD on the space of doublets, (a, λ), and then converting this to a DPD against the desired derivative through (3). To begin this process we discretize the sets of possible a's and λ's

$$a_1, a_2, a_3, \ldots, a_I = \left\{a_i\right\} \tag{4}$$

$$\lambda_1, \lambda_2, \lambda_3, \ldots, a_J = \left\{\lambda_j\right\} \tag{5}$$

We then consider the space of a, λ doublets:

$$\left\{\left(a_i, \lambda_j\right)\right\} . \tag{6}$$

On this space we shall erect a discrete probability distribution by assigning a probability, p_{ij}, to each such doublet:

$$\left\{< p_{ij}, \left(a_i, \lambda_j\right) >\right\} \quad . \tag{7}$$

To explain the next step let us introduce the notation:

$$\zeta(a, \lambda) = \lambda a e^{-\lambda r_o} \tag{8}$$

and

$$\zeta_{ij} = \zeta\left(a_i, \lambda_j\right) = \lambda_j a_i e^{-\lambda_j r_o} \tag{9}$$

Then the DPD (7) converts, through (9) to a DPD for ζ:

$$\left\{< p_{ij}, \zeta_{ij} >\right\} \tag{10}$$

This is then the DPD for our desired derivative (3).

B.1.2 Obtaining the DPD on (a, λ) Space

We obtain the DPD on (a, λ) space by applying Bayes' theorem in the form:

$$p\left(a_i, \lambda_j \middle| B\right) = p(a_i, \lambda_j) \frac{p(B | a_i, \lambda_j)}{\sum\limits_{i,j} p(a_i, \lambda_j)\, p(B | a_i, \lambda_j)} \quad . \tag{11}$$

where:

B	is the information we get from our historical data
$p(a_i, \lambda_j \mid B)$	is the probability we assign to the doublet (a_i, λ_j) after we have the information B
$p(a_i, \lambda_j)$	is the probability we assign to the doublet (a_i, λ_j) prior to having the information B
$p(B \mid a_i, \lambda_j)$	is the likelihood of event B happening given that a_i, λ_j are true.

In our case B is the set of radii at which crashes occurred. Thus, from Table 3, B is the set:

$$B = \{ 0.0,\ 4.7,\ 0,\ 3.5,\ 0.9,\ 0.8,\ 4.0,\ \ldots \text{ etc.} \}$$

We note that B contains a total of 97 points. 40 points have $r = 0$, and the remainder we will write as:

$$\{r_n\} = \{r_1, r_2, \ldots, r_{57}\}. \tag{12}$$

From (2) then the probability of these 97 crashes occurring the way they did is:

$$p(B \mid a_i, \lambda_j) = (1-a_i)^{40} (a_i \ \lambda_j)^{57} \exp\left\{ - \lambda_j \sum_{n=1}^{57} r_n \right\} \tag{13}$$

For our case we have:

$$\sum_{n=1}^{57} r_n = 96.2 \text{ miles} \tag{14}$$

so that

$$p(B \mid a_i, \lambda_j) = (1-a_i)^{40} (a_i \lambda_j)^{57} e^{(-\lambda_j 96.2)} \tag{15}$$

All that remains then before carrying out the calculations (11) is to specify the a_i and λ_j numerically and then to set the prior.

We choose a_i, λ_j as follows:

$$\{a_i\} \equiv \{0.4, .45, .5, .55, .6, .65, .7\} \tag{16}$$

$$\{\lambda_j\} \equiv \left\{\frac{1}{.75}, \frac{1}{1.0}, \frac{1}{1.25}, \cdots \frac{1}{3.25}\right\} \tag{17}$$

To reflect an initial state of no knowledge we shall choose the prior to be uniform over the a_i, λ_j. Equation (11) then reduces, using (15), to:

$$p(a_i, \lambda_j | B) = \frac{(1-a_i)^{40} (a_i\lambda_j)^{57} e^{-\lambda_j 96.2}}{\sum_{i,j} (1-a_i)^{40} (a_i\lambda_j)^{57} e^{-\lambda_j 96.2}} \tag{18}$$

B.1.3 Results

The results of this calculation are shown in Table B.1. Applying these results as in (9) and (10) we obtain the DPD in Figure B.2A as the Bayesian probability for our desired derivative. We take this histogram as representing our state of knowledge with respect to the radial density at the location of the TMI plant.

As a matter of interest, we also show on Figure B.1 the function R(r) using the average a,λ obtained from the Bayes' calculation.

B.2 THE RADIAL DENSITIES $D_L(r) = \left[\frac{-d}{dr} R_L(r)\right]_{r=r_o}$ AND $D_T(r) = \left[\frac{-d}{dr} R_T(r)\right]_{r=r_o}$

In this section we repeat the analysis of Section B.1 to determine the radial dependence separately for landing and takeoff accidents.

Landings

In the case of landings, B is the set of radii at which landing crashes occurred. Thus, from Table 3, B is the set:

$B = \{0, 0, 3.5, 0.8, 0.4, \ldots, \text{etc.}\}$

We note that B contains a total of 63 points. Twenty-three points have r=0, and the remainder have sum

$$\sum_{n=1}^{40} r_n = 64.3 \text{ miles.} \tag{19}$$

Then, as in (15) the probability of these 63 crashes occurring as they did is:

$$p(B|a_i, \lambda_j) = (1-a_i)^{23} (a_i \lambda_j)^{40} e^{\left\{-\lambda_j 64.3\right\}} \tag{20}$$

For this calculation the same a and λ sets were chosen as in Section B.1.

The results are shown in Table B.2 and Figure B.2B. The Bayes' fit using the mean a, λ is shown as the straight line in Figure B.3. The staircase function is the historical data.

Takeoffs

In the case of takeoff crashes, B, from Table 3, is the set:

$B = \{0,\ 4.7,\ 0.9,\ 4.0,\ 3.1,\ 0.6,\ \ldots,\ \text{etc.}\}$

B for takeoff contains a total of 34 points, seventeen having r=0. The remainder have the sum

$$\sum_{n=1}^{17} r_n = 31.9 \text{ miles.} \tag{21}$$

The probability of these 34 takeoff crashes occurring as they did is:

$$p(B|a_i, \lambda_j) = (1-a_i)^{17} (a_i\lambda_j)^{17} e^{\left\{-\lambda_j\ 31.9\right\}} \tag{22}$$

The results for the takeoff calculation are shown in Table B.3 and Figure B.2C. Figure B.4 compares the mean Bayes' fit with the historical takeoff crash data.

The mean values of D(r), $D_L(r)$, $D_T(r)$ are summarized for comparison as follows:

$$\bar{D}(r) = .070 \tag{23}$$

$$\bar{D}_T(r) = .064 \tag{24}$$

$$\bar{D}_L(r) = .073 \tag{25}$$

B.3 THE ANGULAR DENSITY QUANTITY $\left[-\frac{d}{d\theta}\Theta(\theta)\right]_{\theta=\theta_o}$

We next apply the same kind of reasoning to the θ dependence, using as data only those crashes occurring at a radius of one-half mile or greater. However, it is evident from Figure B.5 that a simple exponential is not going to give a good fit to the angular data. We need therefore to modify the procedure used for the radial dependence.

In doing this we need to recognize that the most important point is that the fit be good in the neighborhood of 34°, the location of the plant. At the same time we wish to include the experience at the extremes of the θ range, 0 and 90°. Finally, if we can, we prefer to retain a fitting function with two parameters, rather than going to the complication of a three or four parameter form.

The following approach appears to satisfy these requirements. We define $\Theta(\theta)$ as the fraction of crashes occurring at angle θ or greater. We then choose the forms :

$$\Theta(\theta) = ae^{-\lambda\theta} + b \quad , \quad 0 \leq 0 \leq 70^{\circ} \tag{26}$$

and use them to fit the data within the range 0 to 70°. Within this range we may expect, from Figure B. 5, that this form has the flexibility to give a good fit. Outside the range of course it cannot fit since it levels off whereas the actual data goes to zero. To blend in appropriately at $\theta = 70^{\circ}$, and to account for the data at 90°, we choose the b value:

$$b = .114 \tag{27}$$

We then use a Bayesian procedure to establish probability distributions on a, λ in the following way.

From (19) we have the frequency density:

$$\left[\frac{-d}{d\theta}\Theta(\theta)\right] = (1-a-b)\,\delta(\theta) + a\lambda e^{-\lambda\theta} \tag{28}$$

We now take B to be the set of crash points in the range 0 to 70° (and having $r \geq .5$ mi). Thus, from Table 3:

$$B = \left\{0, 0, 47, 6, 0, 26, 0, \ldots, \text{etc.}\right\}$$

a total of 39 crashes with 17 at $\theta = 0$. Thus

$$p(B|a, \lambda) = (1-a-b)^{17}\,(a\lambda)^{22}\,e^{-\lambda \sum_{1}^{22} \theta_i} \tag{29}$$

where

$$\sum_{1}^{22} \theta_i = 361 \tag{30}$$

The resulting DPD is shown in Table B. 4. The corresponding distribution for the desired derivative quantity is shown in Figure B. 6A. As a matter of interest, Figure B. 5 shows the goodness of fit of the curve (26), using the mean a, λ, to the experimental data.

B. 4 THE QUANTITIES $\left[-\frac{d}{d\theta}\Theta_L(\theta)\right]_{\theta_0}$ AND $\left[-\frac{d}{d\theta}\Theta_T(\theta)\right]_{\theta_0}$

We now apply the analysis of the previous section to the landing and takeoff data separately. For landings there is a total of 30 crashes; 13 at θ=0 and 2 at 90°. We therefore set

$$b = \frac{2}{30} = .0667 \tag{31}$$

and summing over the points less than 90° we have

$$\sum_{i=1}^{15} \theta_i = 167 . \tag{32}$$

The resulting distribution over the (a, λ) space is shown in Table B. 5. The histogram for the desired derivative is plotted as Figure B. 6B. The Bayes' fit with average a, λ is plotted with the historical data in Figure B. 7.

For takeoffs there is a total of 14 crashes, 4 at θ=0 and 3 at 90°. In this case

$$b = \frac{3}{14} = .214 . \tag{33}$$

The sum of angles in this case is:

$$\sum_{i=1}^{7} \theta_i = 194 \ . \qquad (34)$$

The results are given in Table B.6 and Figures B.6C and B.8.

The mean values of the distributions shown in Figure B.6 are summarized as follows:

$$\frac{-d}{d\theta}\Theta(\theta)\Big|_{34^\circ} = 4.006 \times 10^{-3}$$

$$\frac{-d}{d\theta}\Theta_T(\theta)\Big|_{34^\circ} = 4.927 \times 10^{-3}$$

$$\frac{-d}{d\theta}\Theta_L(\theta)\Big|_{34^\circ} = 2.536 \times 10^{-3}$$

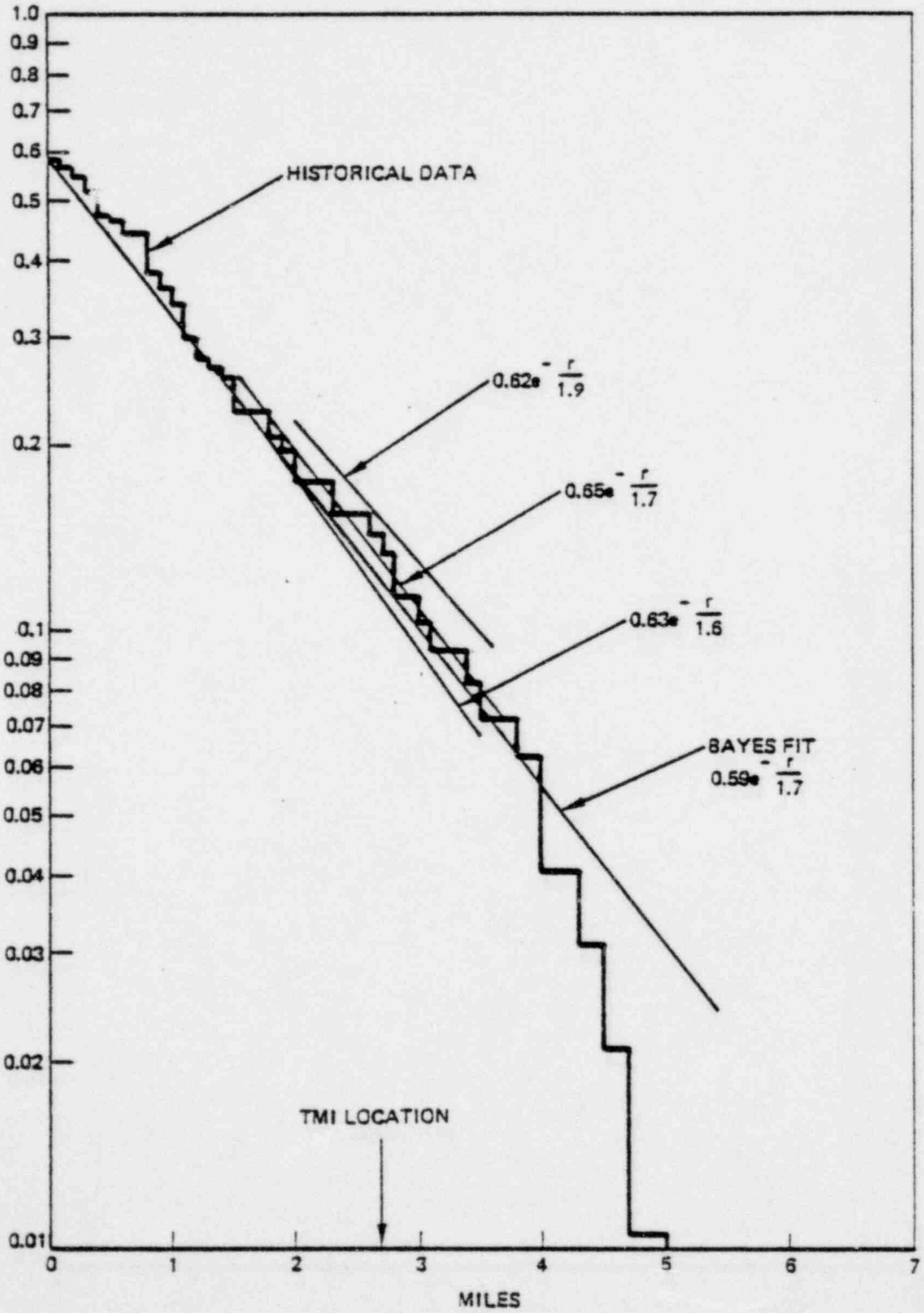


Figure B.1. Fraction of Crashes Occurring at Radius r or Greater (Takeoffs and Landings Combined)

Table B. 1

Bayesian Results for All Crashes Combined Radial Distribution

$p(a_i, \lambda_j \mid B)$

λ \ a	.4	.45	.5	.55	.6	.65	.7	Σ
.75	.2402E-07	.3757E-06	.3568E-05	.1139E-04	.1460E-04	.6699E-05	.9609E-06	.3740E-04
1.0	.1006E-04	.2552E-03	.2267E-02	.7733E-02	.7913E-02	.4550E-02	.6526E-03	.2540E-01
1.25	.1146E-03	.2911E-02	.2609E-01	.6822E-01	.1131E+00	.5190E-01	.7445E-02	.2898E+00
1.5	.1671E-03	.4237E-02	.3798E-01	.1284E+00	.1648E+00	.7554E-01	.1084E-01	.4218E+00
1.75	.7972E-04	.2022E-02	.1812E-01	.6127E-01	.7854E-01	.3605E-01	.5170E-02	.2013E+00
2.0	.2027E-04	.5141E-03	.4608E-02	.1558E-01	.1997E-01	.9167E-02	.1315E-02	.5118E-01
2.25	.3594E-05	.9115E-04	.3170E-03	.2763E-02	.3541E-02	.1625E-02	.2331E-03	.9074E-02
2.5	.5194E-06	.1317E-04	.1161E-03	.3972E-03	.5117E-03	.2348E-03	.3368E-04	.1311E-02
2.75	.6723E-07	.1705E-05	.1528E-04	.5167E-04	.6624E-04	.3040E-04	.4360E-05	.1697E-03
3.0	.8267E-08	.2097E-06	.1679E-05	.6359E-05	.3146E-05	.3738E-05	.5362E-06	.2087E-04
3.25	.3961E-02	.1005E-01	.9004E-01	.3049E+00	.3703E+00	.1791E+00	.2569E-01	.1000E+01
Σ								

Average a = .586

Average λ = .5821 = 1/1.72

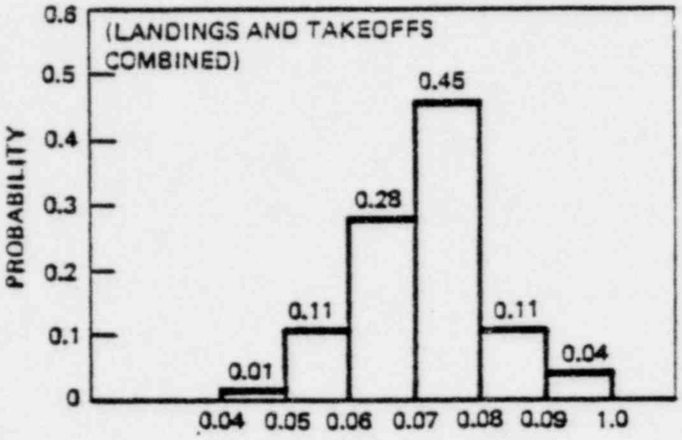


Figure B.2A. The Quantity $\left[\frac{-d}{dr} R(r)\right]_{r = 2.7}$

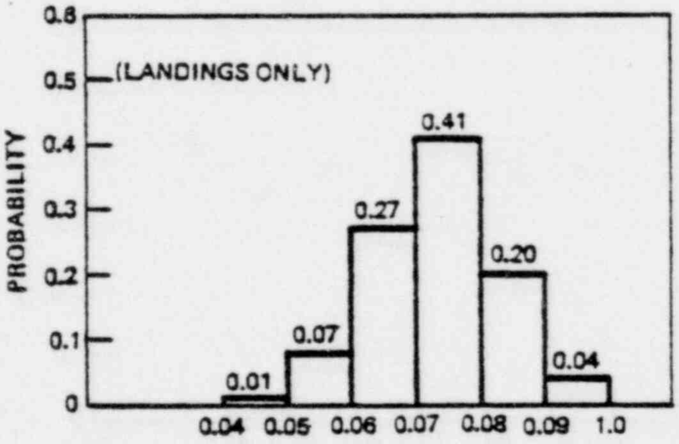


Figure B.2B. The Quantity $\left[\frac{-d}{dr} R_L(r)\right]_{r = 2.7}$

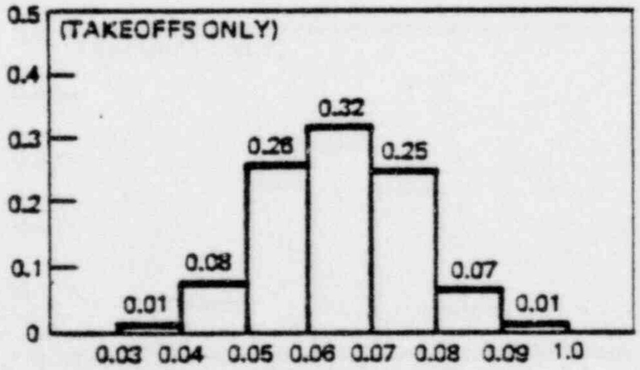


Figure B.2C. The Quantity $\left[\frac{-d}{dr} R_T(r)\right]_{r = 2.7}$

Table B.2

Bayesian Results for Landing Crashes Only Radial Distribution

$p(a_i, \lambda_j | B)$

λ \ a	.4	.45	.5	.55	.6	.65	.7	Σ
.75	0.	.4163E-09	.3146E-08	.1206E-07	.2724E-07	.3109E-07	.1739E-07	.9195E-07
1.0	.5666E-06	.8516E-05	.6435E-04	.2561E-03	.5583E-03	.6361E-03	.3557E-03	.1852E-02
1.25	.2897E-04	.4354E-03	.3293E-02	.1326E-01	.2694E-01	.3252E-01	.1819E-01	.9620E-01
1.5	.1042E-03	.1567E-02	.1134E-01	.4796E-01	.1027E+00	.1170E+00	.6544E-01	.3461E+00
1.75	.9993E-04	.1502E-02	.1135E-01	.4552E-01	.9845E-01	.1122E+00	.6274E-01	.3316E+00
2.0	.4728E-04	.7106E-03	.5369E-02	.2154E-01	.4653E-01	.5307E-01	.2968E-01	.1570E+00
2.25	.1513E-04	.2275E-03	.1719E-02	.6874E-02	.1491E-01	.1699E-01	.9501E-02	.5026E-01
2.5	.3597E-05	.5858E-04	.4426E-03	.1775E-02	.3840E-02	.4375E-02	.2447E-02	.1294E-01
2.75	.6923E-06	.1341E-04	.1013E-03	.4065E-03	.8792E-03	.1002E-02	.5502E-03	.2963E-02
3.0	.1925E-06	.2895E-05	.2190E-04	.8754E-04	.1930E-03	.2165E-03	.1211E-03	.6404E-03
3.25	.4081E-07	.6133E-06	.4034E-05	.1599E-04	.4024E-04	.4581E-04	.2562E-04	.1355E-03
Σ	.3011E-03	.4526E-02	.3420E-01	.1372E+00	.2967E+00	.3380E+00	.1591E+00	.1000E+01

Average a = .625

Average λ = .6066 = 1/1.65

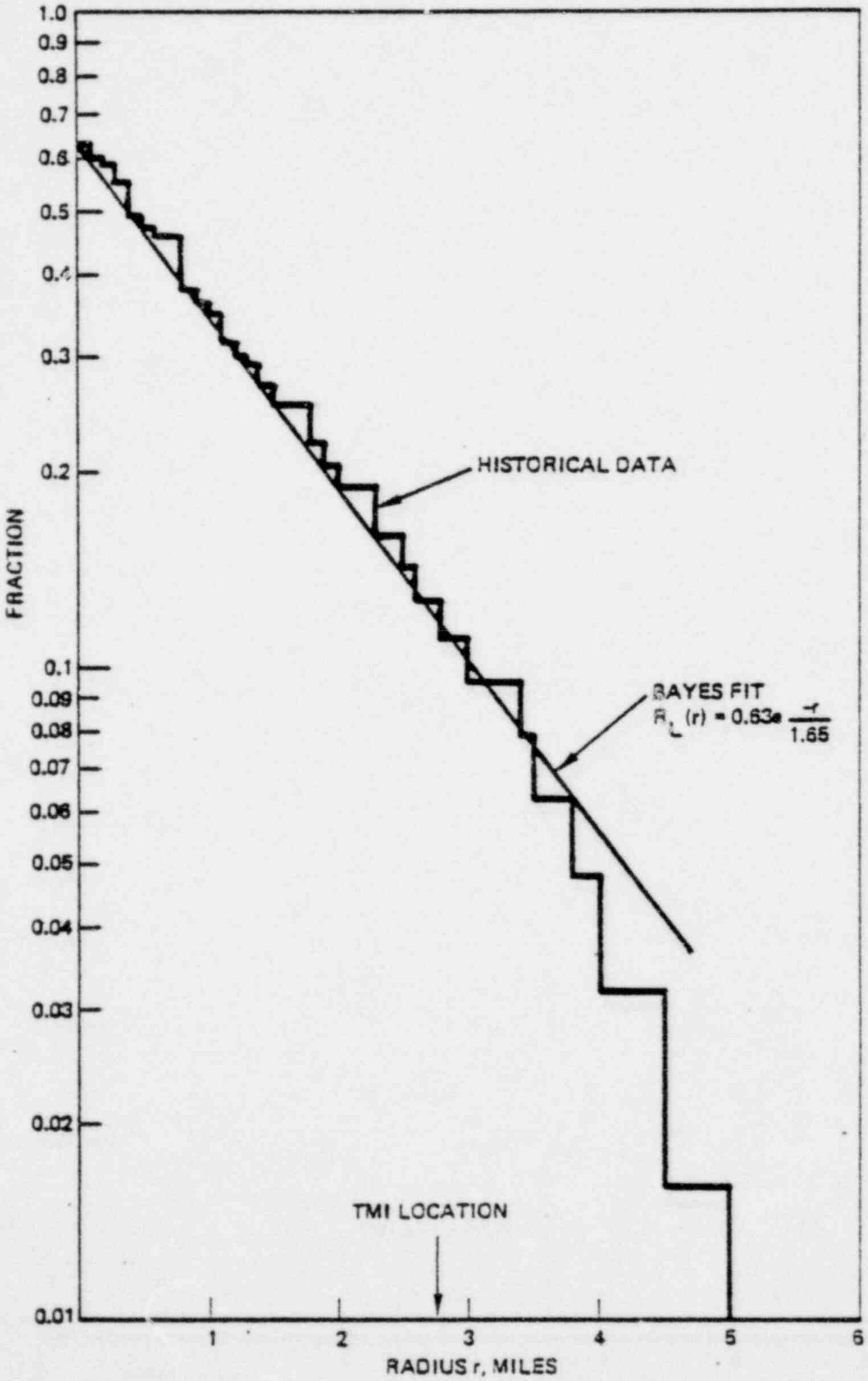


Figure B.3. Fraction of Landing Crashes Occurring at Radius r or Greater

Table B.3

Bayesian Results for Takeoff Crashes Only Radial Distribution

$p(a_i, \lambda_j | B)$

λ \ a	.4	.45	.5	.55	.6	.65	.7	Σ
.75	.1293E-05	.2161E-05	.2587E-05	.2161E-05	.1293E-05	.5206E-06	.1335E-06	.1619E-04
1.0	.4032E-03	.6602E-03	.8670E-03	.6602E-03	.4032E-03	.1024E-03	.4165E-04	.3170E-02
1.25	.5350E-02	.9030E-02	.1072E-01	.9030E-02	.5350E-02	.2157E-02	.5533E-03	.4221E-01
1.5	.1690E-01	.2805E-01	.3379E-01	.2805E-01	.1690E-01	.6839E-02	.1754E-02	.1338E+00
1.75	.2570E-01	.4350E-01	.5100E-01	.4350E-01	.2570E-01	.1038E-01	.2663E-02	.2032E+00
2.0	.2600E-01	.4387E-01	.5204E-01	.4387E-01	.2600E-01	.1047E-01	.2686E-02	.2049E+00
2.25	.2060E-01	.3485E-01	.4135E-01	.3485E-01	.2060E-01	.8320E-02	.2134E-02	.1620E+00
2.5	.1422E-01	.2399E-01	.2640E-01	.2399E-01	.1422E-01	.5728E-02	.1469E-02	.1121E+00
2.75	.8974E-02	.1514E-01	.1790E-01	.1514E-01	.8974E-02	.3615E-02	.9271E-03	.7074E-01
3.0	.5375E-02	.9070E-02	.1070E-01	.9070E-02	.5375E-02	.2165E-02	.5553E-03	.4237E-01
3.25	.3124E-02	.5271E-02	.6253E-02	.5271E-02	.3124E-02	.1258E-02	.3227E-03	.2462E-01
Σ	.1269E+00	.2141E+00	.2539E+00	.2141E+00	.1269E+00	.5116E-01	.1311E-01	.1000E+01

Average a = .5103

Average λ = .5094 = 1/1.96

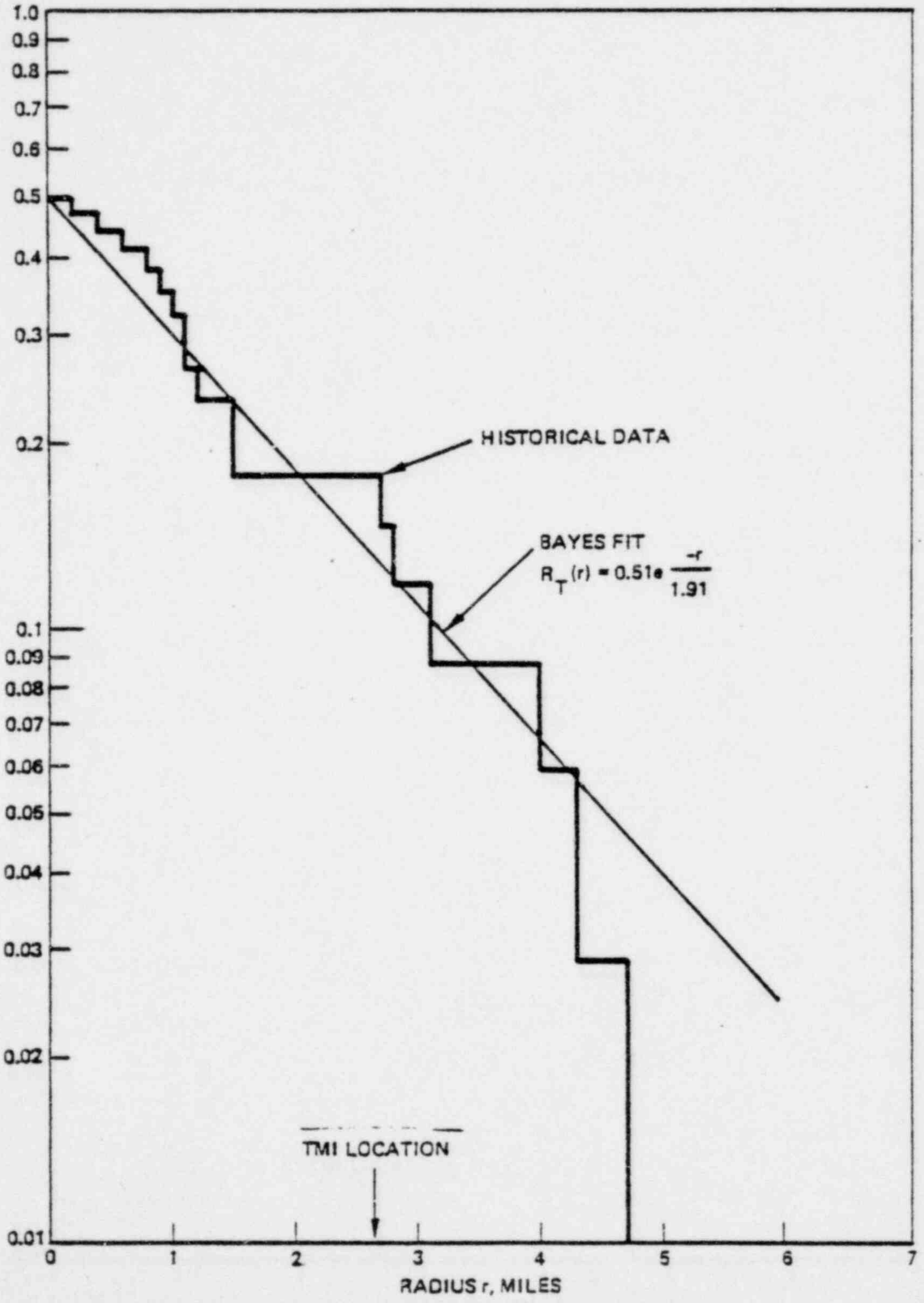


Figure B.4. Fraction of Takeoff Crashes Occurring at Radius r or Greater

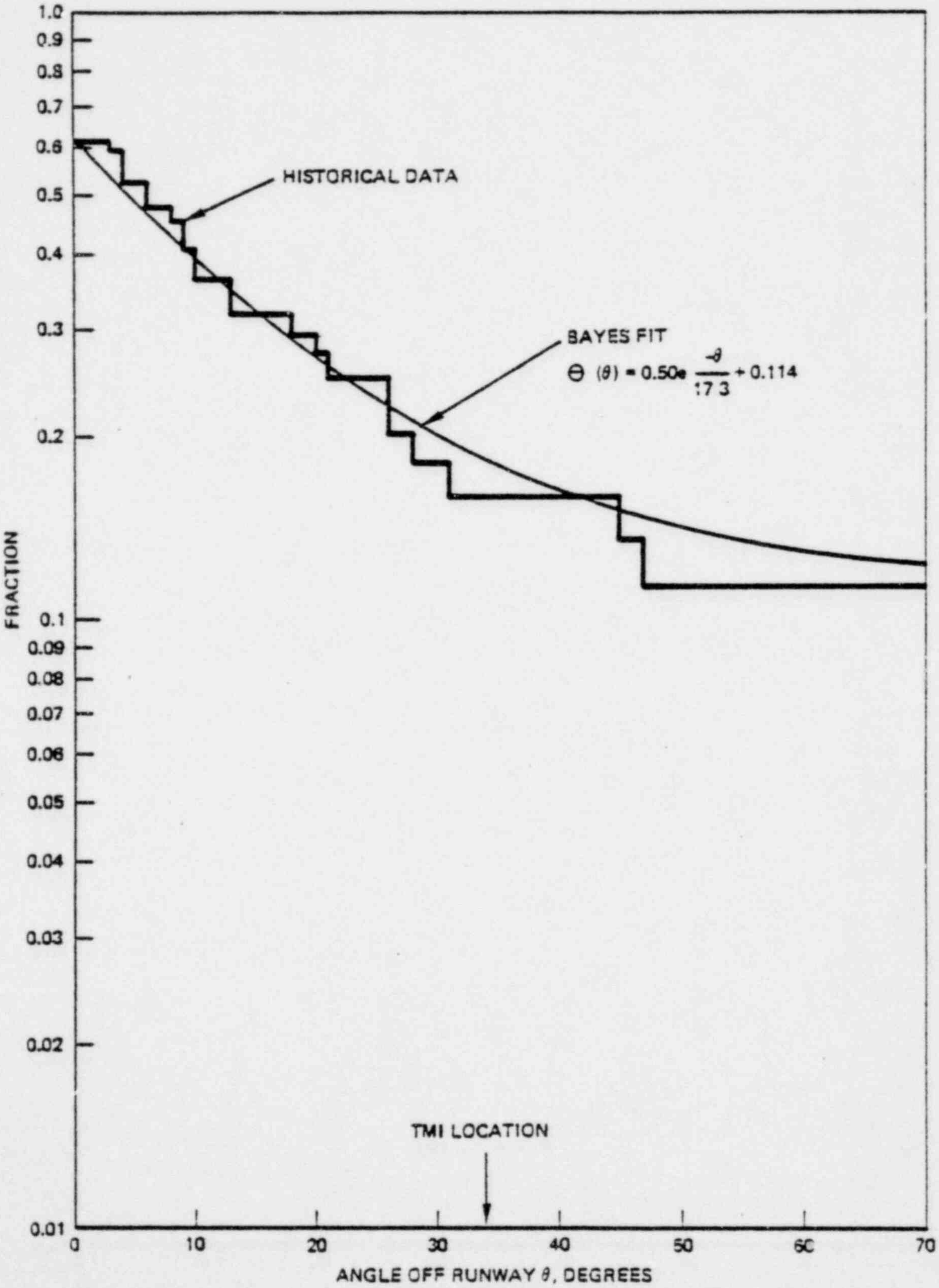


Figure B.5. Angular Distribution of Crashes Landings and Takeoffs Combined

Table B.4

Bayesian Results for Angular Distribution Landings and Takeoffs Combined

$p(a_i, \lambda_j | B)$

$1/\lambda$ \ a	.2	.3	.4	.5	.6	.7	Σ
5	0.	0.	0.	0.	0.	0.	0.
10	.3926E-06	.2018E-03	.4700E-02	.1269E-01	.4281E-02	.8470E-04	.2195E-01
15	.8834E-05	.4539E-02	.1057E+00	.2853E+00	.9628E-01	.1905E-02	.4938E+00
20	.6464E-05	.3321E-02	.7736E-01	.2688E+00	.7045E-01	.1394E-02	.3613E+00
25	.1763E-05	.9059E-03	.2110E-01	.5695E-01	.1922E-01	.3802E-03	.9355E-01
30	.3544E-06	.1821E-03	.4241E-02	.1145E-01	.3863E-02	.7642E-04	.1981E-01
35	.6657E-07	.3420E-04	.7966E-03	.2150E-02	.7255E-03	.1435E-04	.3721E-02
40	.1280E-07	.6579E-05	.1532E-03	.4135E-03	.1396E-03	.2761E-05	.7157E-03
45	.2615E-08	.1344E-05	.3130E-04	.8446E-04	.2850E-04	.5639E-06	.1462E-03
50	.5745E-09	.2951E-06	.6874E-05	.1825E-04	.6261E-05	.1239E-06	.3211E-04
Σ	.1789E-04	.9192E-02	.2141E+00	.5776E+00	.1950E+00	.3858E-02	.1000E+01

Average a = .497

Average λ = .0579 = 1/17.3

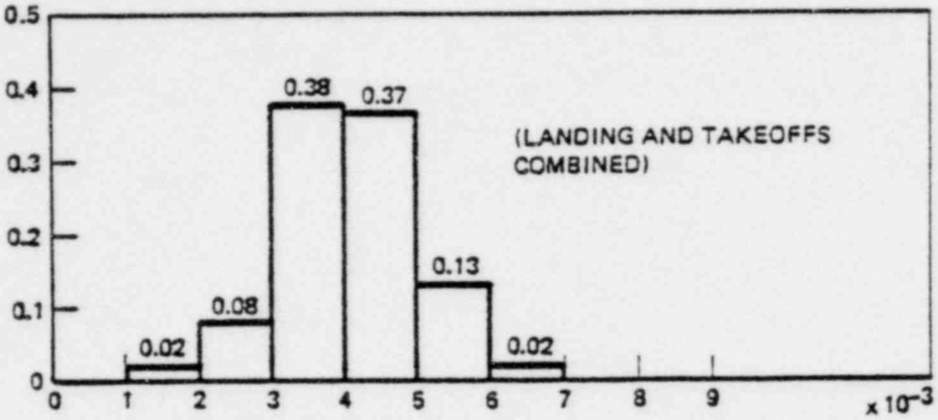


Figure B.6A. The Quantity $\left[\frac{-d}{d\theta} \quad \Theta \ (\theta)\right]$ 34°

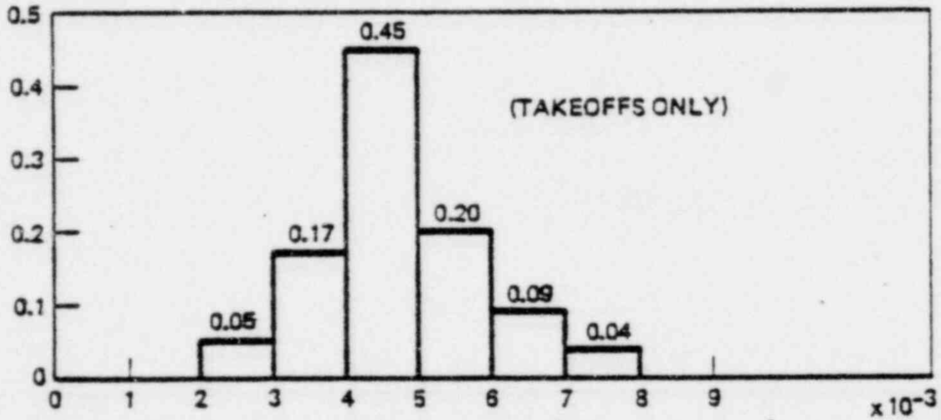


Figure B.6B. The Quantity $\left[\frac{-d}{d\theta} \quad \Theta_T \ (\theta)\right]$ 34°

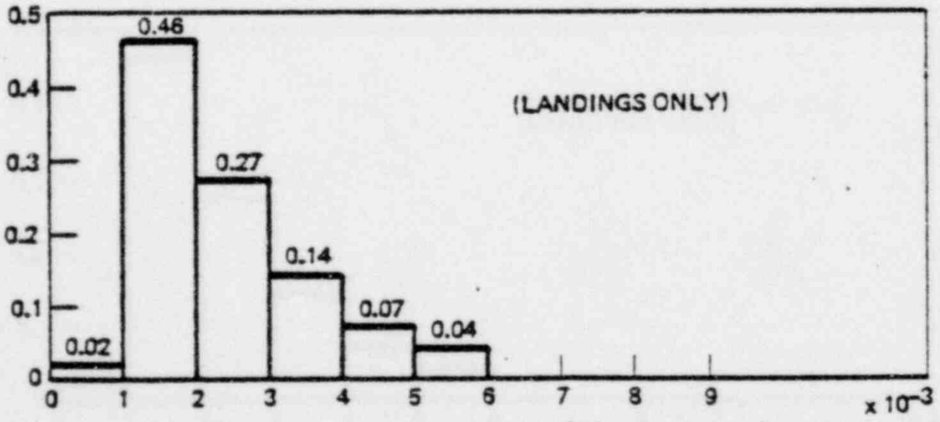


Figure B.6C. The Quantity $\left[\frac{-d}{d\theta} \quad \Theta_L \ (\theta)\right]$ 34°

Table B.5

Bayesian Results for Angular Distribution Landings Only

a / 1/λ	.2	.3	.4	.5	.6	.7	Σ
5	.4861E-06	.3165E-04	.2536E-03	.4048E-03	.2466E-03	.2413E-04	.1041E-02
10	.2654E-03	.1728E-01	.1385E+00	.2647E+00	.1347E+00	.1318E-01	.5887E+00
15	.1586E-03	.1032E-01	.6273E-01	.1581E+00	.8044E-01	.7870E-02	.3397E+00
20	.3427E-04	.2231E-02	.1788E-01	.3418E-01	.1738E-01	.1701E-02	.7341E-01
25	.6405E-05	.4170E-03	.3342E-02	.6368E-02	.3250E-02	.3179E-03	.1372E-01
30	.1266E-05	.8241E-04	.6604E-03	.1262E-02	.6421E-03	.6282E-04	.2711E-02
35	.2776E-06	.1808E-04	.1449E-03	.2764E-03	.1407E-03	.1378E-04	.5948E-03
40	.6801E-07	.4429E-05	.3549E-04	.6764E-04	.3451E-04	.3376E-05	.1457E-03
45	.1848E-07	.1204E-05	.9045E-05	.1844E-04	.9378E-05	.9174E-06	.3966E-04
50	.5516E-08	.3591E-06	.2678E-05	.5501E-05	.2798E-05	.2738E-06	.1182E-04
75	0.	.2497E-08	.2601E-07	.3825E-07	.1946E-07	.1903E-08	.8211E-07
100	0.	0.	.4666E-09	.8918E-09	.4537E-09	0.	.1812E-08
125	0.	0.	0.	0.	0.	0.	0.
Σ	.4666E-03	.3039E-01	.2436E+00	.4656E+00	.2368E+00	.2317E-01	.1000E+01

Average a = .498

Average λ = .0840 = 1/19.9

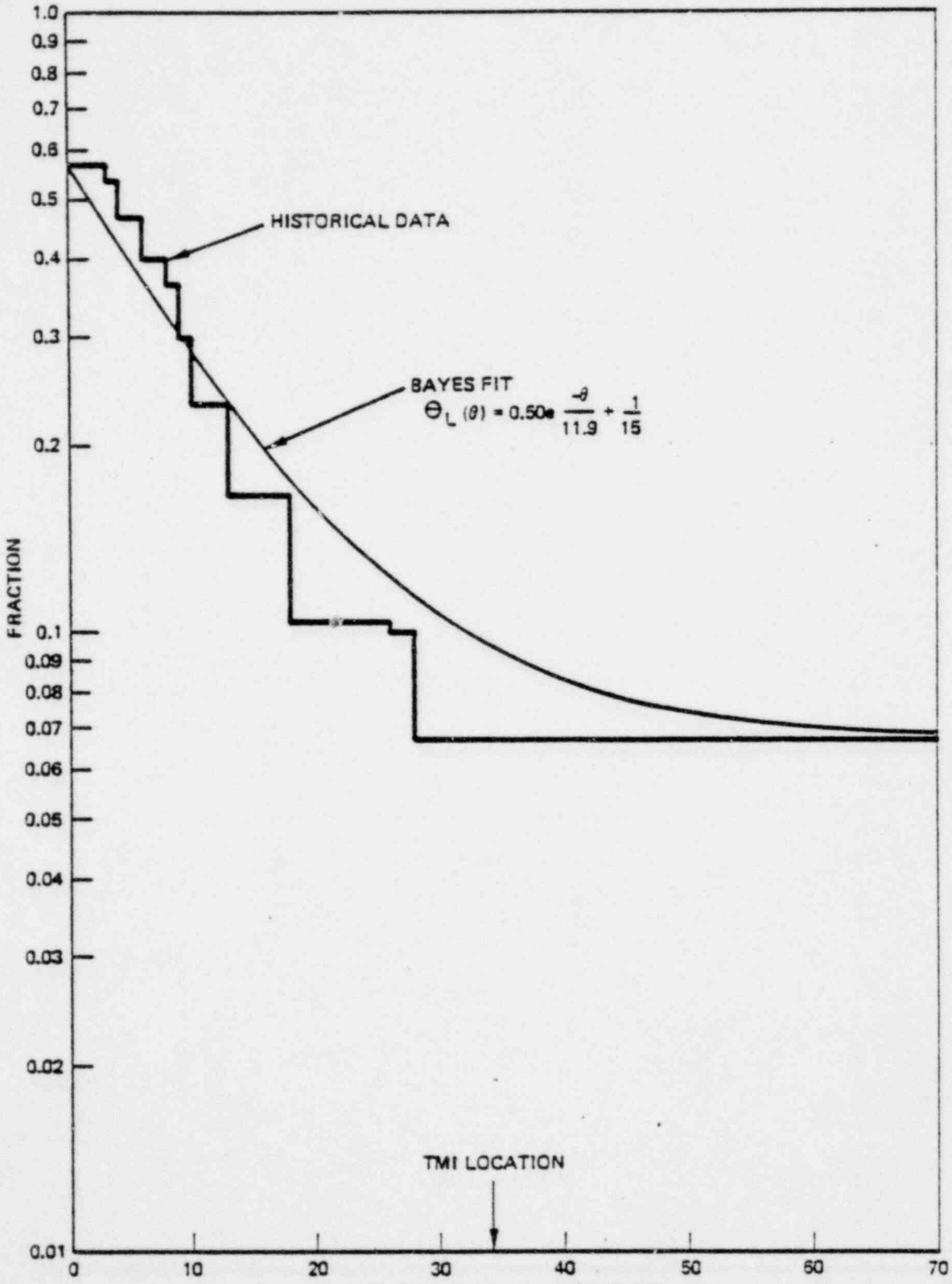


Figure B.7. Angular Distribution of Crashes Landings Only

Table B.6

Bayesian Results for Angular Distribution Takeoffs Only

1/λ \ a	.2	.3	.4	.5	.6	.7	Σ
5	0.	0.	.1225E-09	.1761E-09	.1129E-09	0.	.4115E-09
10	.1058E-04	.8550E-04	.2549E-03	.3663E-03	.2346E-03	.3157E-04	.9836E-03
15	.3982E-03	.3219E-02	.9597E-02	.1379E-01	.8840E-02	.1189E-02	.3703E-01
20	.1346E-02	.1690E-01	.3249E-01	.4669E-01	.2993E-01	.4024E-02	.1254E+00
25	.1968E-02	.1591E-01	.4742E-01	.6844E-01	.4368E-01	.5873E-02	.1830E+00
30	.2002E-02	.1618E-01	.4823E-01	.6932E-01	.4443E-01	.5974E-02	.1861E+00
35	.1714E-02	.1385E-01	.4130E-01	.5935E-01	.3804E-01	.5115E-02	.1594E+00
40	.1346E-02	.1088E-01	.3243E-01	.4666E-01	.2967E-01	.4016E-02	.1251E+00
45	.1011E-02	.8175E-02	.2437E-01	.3502E-01	.2245E-01	.3018E-02	.9405E-01:
50	.7444E-03	.6017E-02	.1794E-01	.2578E-01	.1652E-01	.2222E-02	.6923E-01
75	.1583E-03	.1294E-02	.3827E-02	.5499E-02	.3525E-02	.4740E-03	.1477E-01
100	.4047E-04	.3271E-03	.9752E-03	.1601E-02	.6984E-03	.1208E-03	.3763E-02
125	.1251E-04	.1011E-03	.3015E-03	.4332E-03	.2777E-03	.3734E-04	.1163E-02
Σ	.1075E-01	.8692E-01	.2591E+00	.3724E+00	.2387E+00	.3209E-01	.1000E+01

Average a = .484

Average λ = .0338 = 1/29.6

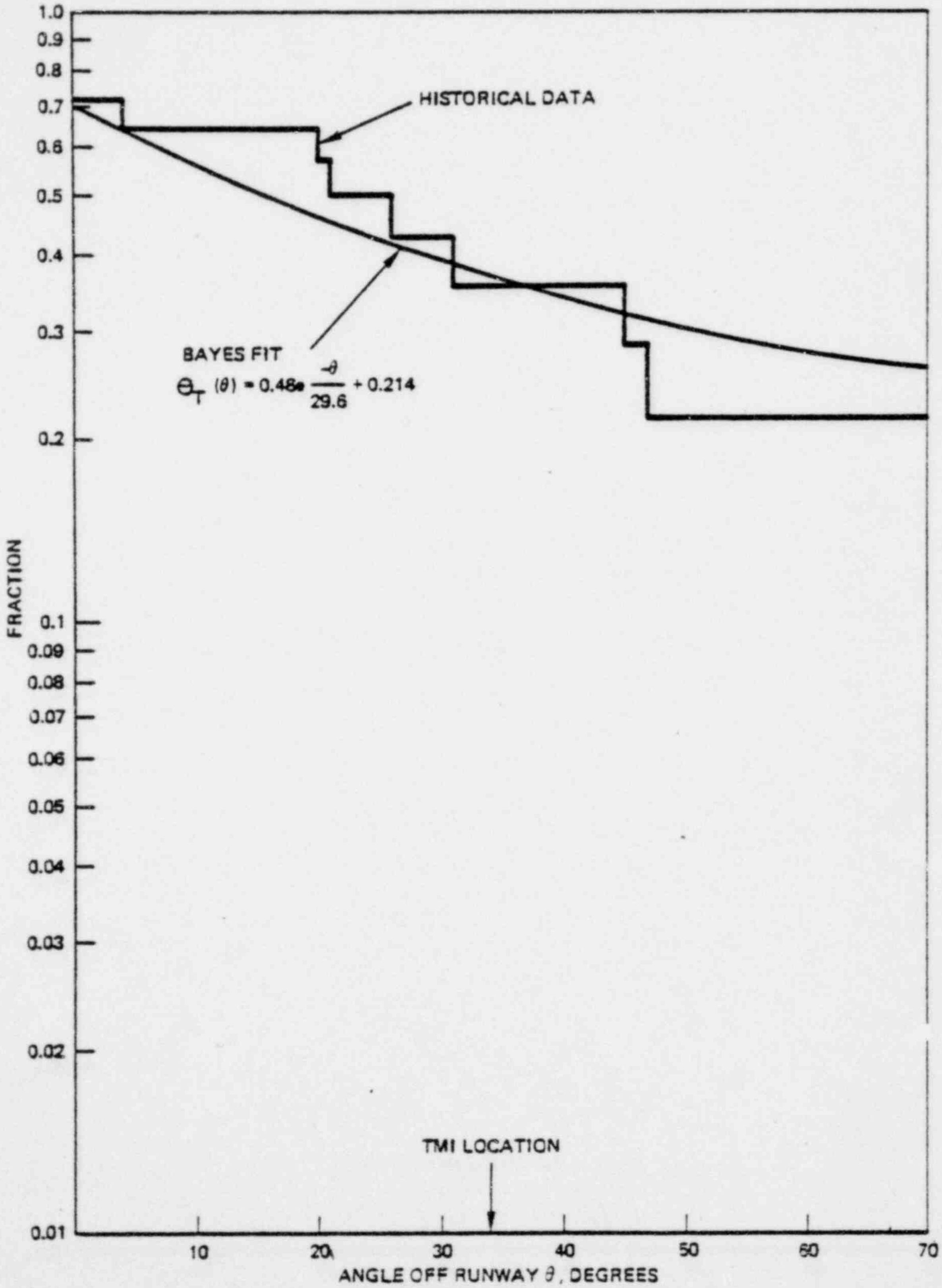


Figure B.8. Angular Distribution of Crashes Takeoffs Only

DR. KEPFORD: Mr. Chairman.

CHAIRMAN ROSENTHAL: Yes.

DR. KEPFORD: Might I borrow a copy of the counsel for the applicant's testimony? I'm not really sure I've seen this.

CHAIRMAN ROSENTHAL: Oh, I'm sure it was served on you. This was a little better than a year ago.

DR. KEPFORD: Oh, is this the, is this the March 20, 1979?

CHAIRMAN ROSENTHAL: No, this was January 9th, 1979, a year ago. This was supplemental testimony that was offered by Mr. Vallance. As Mr. Trowbridge indicated, this was before it had been determined that there would be a further hearing.

Do you have a --

MR. TROWBRIDGE: Dr. Kepford, for your benefit, what this supplemental testimony did was to break the infrequencies down into landings and takeoffs separately. In Mr. Vallance's original testimony, they had been lumped together.

DR. KEPFORD: Okay. I have before me the March 20, '79. Are these --

CHAIRMAN ROSENTHAL: No, this is January 9.

Mr. Trowbridge, could you show him what it looks like and -- oh --

MR. TROWBRIDGE: I just provided him a copy.

CHAIRMAN ROSENTHAL: Oh, just provided -- even

24

better.

DR. KEPFORD: Thank you.

(Pause.)

DR. KEPFORD: Okay.

CHAIRMAN ROSENTHAL: Okay, Dr. Kepford?

DR. KEPFORD: Thank you, Mr. Trowbridge.

MR. TROWBRIDGE: Mr. Vallance, I now turn to your supplemental testimony of John M. Vallance, dated March 20, 1979.

Do you have that in front of you?

MR. VALLANCE: Yes, I do.

MR. TROWBRIDGE: This testimony, Mr. Chairman, by way of general explanation, is in response to questions asked by the Board in ALAB 525.

Mr. Vallance, is this testimony true and correct, to the best of your knowledge and belief?

MR. VALLANCE: Yes, it is.

MR. TROWBRIDGE: Does it remain valid with the passage of time?

MR. VALLANCE: Yes, it does.

MR. TROWBRIDGE: Do you adopt is as your testimony in this proceeding?

MR. VALLANCE: Yes, I do.

MR. TROWBRIDGE: And Dr. Kaplan, attached physically to Mr. Vallance's testimony is a further piece of testimony

25

labeled "Supplemental Testimony of Dr. Stanley Kaplan," dated March 20, 1979. Do you have that document?

DR. KAPLAN: Yes.

MR. TROWBRIDGE: Is the testimony true and correct to the best of your information and belief?

DR. KAPLAN: Yes.

MR. TROWBRIDGE: And was it prepared by you or under your supervision?

DR. KAPLAN: Yes.

MR. TROWBRIDGE: And is it affected by the passage of time?

DR. KAPLAN: No.

MR. TROWBRIDGE: Do you adopt it as your testimony in these proceedings?

DR. KAPLAN: Yes.

MR. TROWBRIDGE: Mr. Chairman, I offer the two March 20, 1979, pieces of testimony in evidence and request that they be physically incorporated in the transcript.

CHAIRMAN ROSENTHAL: Without objection, they will be so entered.

(Copies of the aforementioned documents follow:)

March 20, 1979

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

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

SUPPLEMENTAL TESTIMONY OF JOHN M. VALLANCE

INTRODUCTION

This testimony responds to the questions in paragraph II.A.1 of ALAB 525. The testimony is intended to clarify certain details of the spatial distribution model used in my prior testimony in this hearing, particularly for take-off hits.

DISCUSSION

Basically, the spatial distribution model consists of creating approximations of hit location patterns based on fitting actual historical data. The first step is to examine the historical data to create a statement of the relative fraction of hits that occur at $r = 0$ (a hit on the runway), and at $0 < r \leq 5$ miles (an off-runway hit). In this regard, note that the accident rate used in our analysis is for hits "on plus off the runway" (Tables 7 and 8 of Vallance testimony, January 9, 1979), and the rate is stated individually for takeoffs and landings.

Next, the radial probability density function, D(r), is created to fit the off-runway hit location data. Thus, D(r), as it was developed in my previous testimony, contains a factor to account for the fraction of the hits that are off-runway, and then a factor for the decay in the hit density with increasing radial distance from the runway (r).

The off-runway hits are further processed into hits occurring on the extended runway centerline, at $\theta = 0$, and hits away from the centerline, at $0 < \theta \leq 180^\circ$. The angular probability density function, $D(\theta)$, is then created to fit the off-centerline hit location data. Thus, $D(\theta)$ contains a factor to account for the fraction of the hits that are at non-zero theta values (off the extended runway centerline) and then a factor for the decay of the hit density with increasing θ.

In the angular correlation, hits occurring less than ½ mile from the runway are excluded from the $D(\theta)$ correlation base.

Now let's look at the numerical values of the various hit location categories and check to be sure the integral of the probability density functions show the correct value. The analytic equations for D(r) and $D(\theta)$ are given on page 22 of my January 9, 1979 testimony. Figure 3 and 5 of that testimony (attached hereto as Exhibits 1 and 2) give a plot of the cumulative probability density of takeoff hits with r and with θ. Footnotes on these figures give numerical values of the total hits in the data base and their location category.

Radial

Consider Figure 3 of my January 9, 1979 testimony (Exhibit 1).

The points shown in the figure represent the off-runway hits as a fraction of total hits. There are 17 points shown for off-runway hits and there are 17 points (not shown) for runway hits ($r = 0$). The first off-runway hit is at a cumulative fraction of 0.5, since 50% of the hits occurred at $r = 0$ (on the runway). The solid line on the figure is a least mean squares fit of the off-runway hit data points and is chosen to represent the cumulative distribution of hits on a continuous basis over the interval 0 to 5 miles. This line is described by the equation $N(r) = 0.58e^{-r/1.84 \text{ miles}}$. We take the derivative of $N(r)$ and calculate an integration constant so that the summation of the area under $D(r)$, in the limits of 0 to 5 miles, yields the correct value. This normalization serves to make the correlation valid over the entire range of interest. In this case, the correct value of the integral is 0.5, to reflect the fact that only ½ of the hits in the $D(r)_T$ data base occur at values of $r > 0$ (see footnote of Figure 3 of January 9, 1979 testimony which states that of 34 takeoff hits in the data base, 17 of them were on the runway and 17 at $0 < r \leq 5$ miles).

Now check the integral of the analytic value of $D(r)$. For this:

$$D(r) = 0.29e^{-r/1.84}$$ (page 22 of Vallance January 9, 1979 testimony)

$$\int_0^5 D(r)dr = 0.29\int_0^5 e^{-r/1.84}dr$$

$$= 1.84 \times 0.29\left[1-e^{-5/1.84}\right]$$

$$\int_0^5 D(r)dr = 0.5$$

So this checks out as representing the data (50% of the hits are in the region $0 < r < 5$ miles).

Angular

Now consider Figure 5 of my January 9, 1979 testimony (Exhibit 2). In this set of data, there are 10 points in the region $0 < \theta < 180^\circ$ and there are (not shown) 4 points for values of $\theta = 0$ (i.e., 4 of the 14 points were on the runway centerline). Again, a least mean squares fit of the data was used to generate the solid line chosen to represent the continuous distribution of the non-zero hits. The equation of the cumulative distribution on this basis is $0.86e^{-\theta/48^\circ}$. An integration constant is utilized to cause the summation of the curve of its derivative to equate to the correct value. In this case, the correct value is $\frac{1}{2} \times 10/14 = 0.36$. The $\frac{1}{2}$ factor is due to the assumption of symmetry with respect to the number of hits on each side of the extended runway centerline and 10/14 is for the hits occurring at values of $\theta > 0$.

Now check the integral of $D(\theta)$.

$$D(\theta) = 0.44e^{-\theta/48^\circ} \quad \text{(page 22 of Vallance January 9, 1979 testimony)}$$

$$\int_0^{180} D(\theta) = 0.44\int_0^{180} e^{-\theta/48} d\theta$$

$$= 0.838 \times 0.44 \left[1-e^{-180/48}\right]$$

$$\int_0^{180} D(\theta)d\theta = 0.36$$

So this checks out also. The correlation and the integration constant were developed based on representing the continuous function in the full range of 0 to 180° on each side of the runway centerline. It so happens that the data base used does not contain any hits for which θ is greater than 90°. However, there can be hits at $\theta > 90°$ and, therefore, the correlation was developed on the basis of the trend line in the 0 - 90° region extending into the 90 - 180° region with the same slope. If the value of $D(\theta)_T$ had been developed on the basis of assuming that no hits will occur in the 90 - 180° region and all hits will be in the 0 - 90° region, a different integration constant would result and the expression for $D(\theta)_T$ would give values about 15% larger than reported herein. It is my judgment that the integration should be done as I did it, namely, using limits of 0 to 180°.

Joint Probability

From the above, the integral of $D(r) \times D(\theta)$, evaluated from 0 to 5 miles and 0 to 180°, is 0.18. This is equivalent to saying that if a takeoff hit occurs within 5 miles of the runway, there is a 0.18 probability that it will hit somewhere off the runway, off the extended runway centerline, and in one of the 0 - 180° regions on either side of the runway.

The algorithms given on page 22 of my January 9, 1979 testimony apply to off-runway, off-centerline hits only, and should have been so qualified. For hits on the runway, the joint probability density $D(r) \times D(\theta)$ is 0.5. For hits on the extended runway centerline, $D(r)$ is as given on page 22 of the referenced testimony, but $D(\theta)$ is 4/14.

Exhibit 3, below, provides a graphic display of the estimated hit probabilities, if a hit occurs, in the various regions where the modeling details differ. The Exhibit illustrates that the estimated probabilities, calculated for each region in accordance with the model, sum to unity, as one would expect.

Specific Questions in ALAB 525

The above information answers the questions generally. Additional specific responses are indicated below:

Question II.A.1.a. Why the angular normalization integral is over the range 0 to 180° rather than 0 to 90°.

Answer-- This is addressed above on pages 4 and 5. I would simply repeat at this point that I cover the full 360° range of possibilities the way I did it. If we applied this model to a plant location of, say, 100°, the results would be applicable and consistent with the data base.

Questions II.A.1.b. and II.A.1.c. What is meant by the statement that crashes at 0° are allowed for.

Does the spatial distribution model have validity for values at $\theta = 0$, in view of the treatment of 0° crashes.

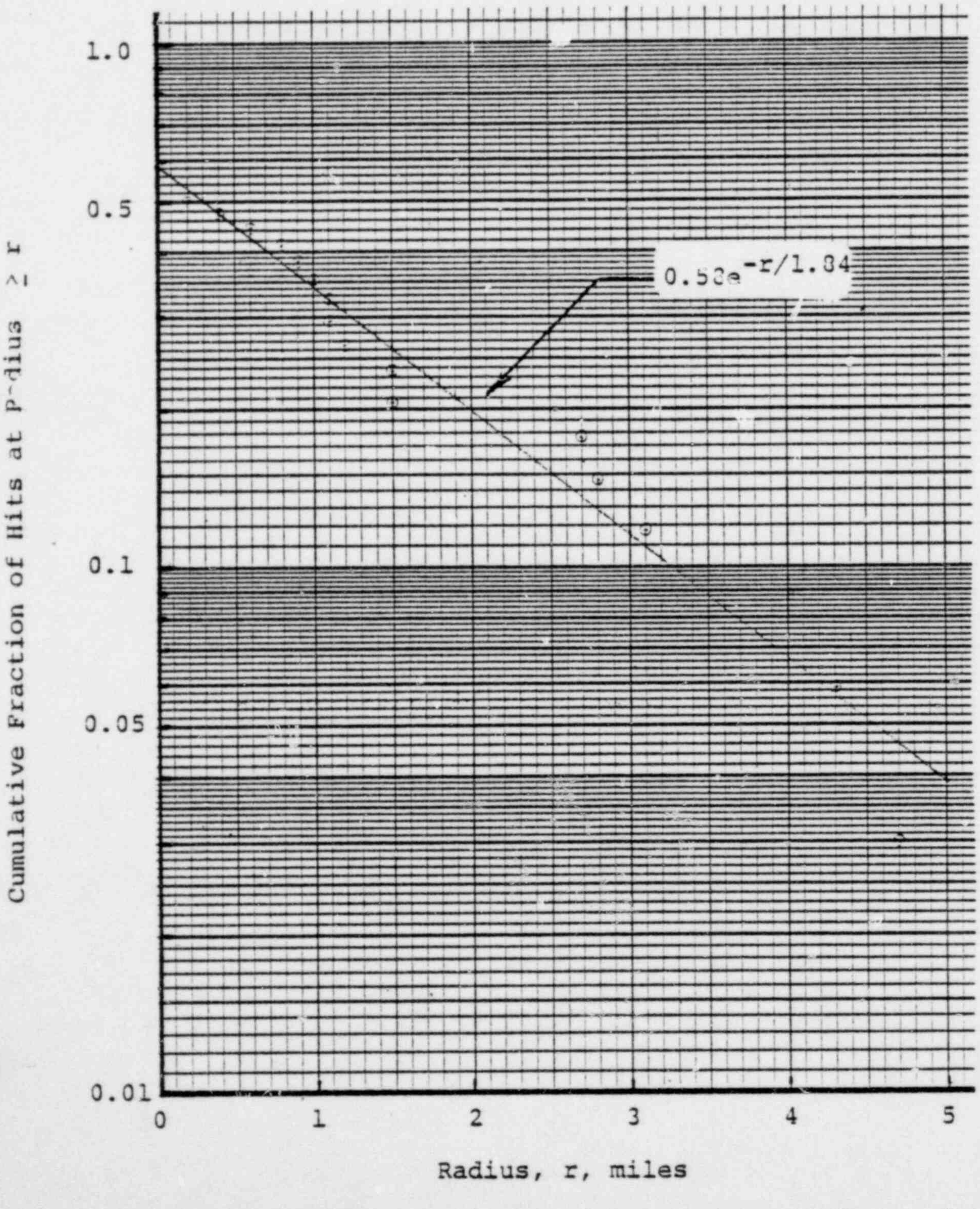
Answer-- The statement was intended to indicate that hits do occur at $\theta = 0^\circ$, and that the modeling for the non-zero hits accounts for this, as described above on pages 4 and 5. However, as noted above, the specific algorithms on page 22 of my January 9, 1979 testimony do not apply for $\theta = 0^\circ$ or for $r = 0$ miles. The model includes discontinuities at these regions. The adjustments incorporated in the model to permit generic application for these regions are specified above on page 5.

Exhibit 1:
Vallance January 9,
1979 Testimony

Figure 3

Cumulative Frequency Distribution
with Radial Distance From Runway

Takeoff Accidents



The construction of this figure incorporates 34 data points, of which 17 occurred at 0 < r ≤ 5 miles.

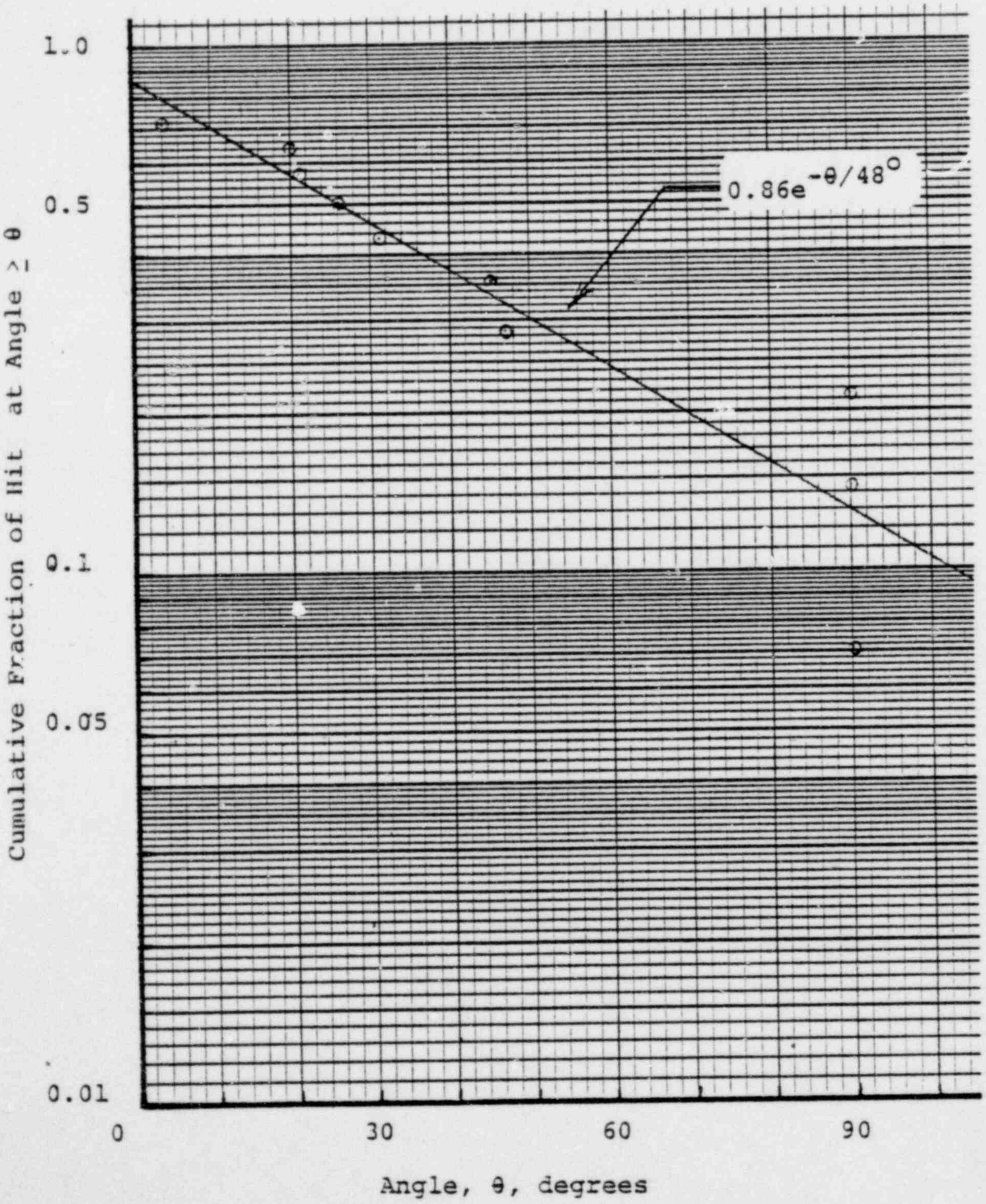
Exhibit 2:

Vallance January 9, 1979 Testimony

Figure 5

Cumulative Frequency Distribution with Angle from Runway Centerline

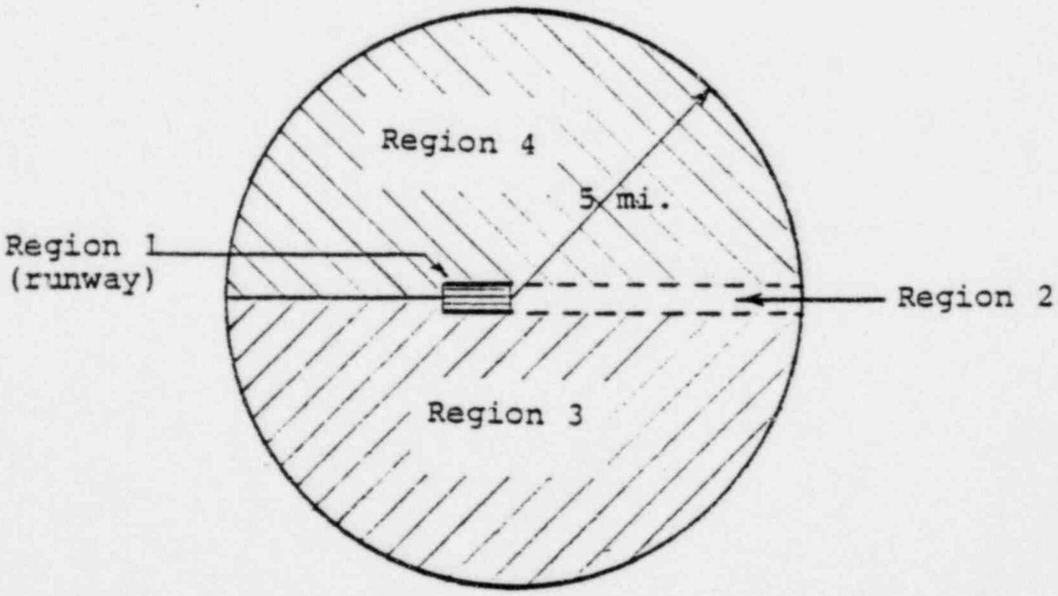
Takeoff Accidents



The construction of this figure includes 14 data points, of which 10 occurred at $0 < \theta \leq 90^\circ$.

Exhibit 3

Integrated Probability of a Hit in Various Regions Within Five Miles of the Runway, If a Takeoff Hit Occurs Within Five Miles of the Runway



For 1.0 Takeoff Hits at r $\leq$ 5 miles:

0.50	hits in Region 1 (runway hit)
0.14	hits in Region 2 (centerline hit)
0.18	hits in Region 3
0.18	hits in Region 4
1.00	

20 March 1979

UNITED STATES OF AMERICA

NUCLEAR REGULATORY COMMISSION

BEFORE THE ATOMIC SAFETY AND LICENSING APPEAL BOARD

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

SUPPLEMENTAL TESTIMONY OF DR. STANLEY KAPLAN

This supplement to our prior testimony responds to issues raised in paragraph II.A.2 of ALAB-525. The Board there discussed the method employed by Applicants in specifying the precision of the hit probability values and noted that "the results seem to imply that the variables whose probability was represented by the individual frequency distributions were assumed to be either independent in the statistical sense or at least not correlated in an insalubrious manner." ALAB-525, slip op. at p. 11. In particular, the Board requested clarification of the rationale for regarding the histograms for crash rate, radial crash density and angular density as being "independent" distributions. The purpose of the present testimony is to explain the basis for Applicants' multiplication of the probability distributions as independent.

At the outset, we acknowledge as correct the Board's observation that the method of histogram multiplication employed by Applicants to combine individual probability distributions for the crash rate and radial and angular crash densities in order to determine the areal crash density was based on a determination that these individual probability distributions were independent. A full explanation of the basis for this determination of independence and its place in our methodology unavoidably requires rather lengthy and complex articulation, much of it mathematical in nature. This full explanation is provided in the attached Annex to this testimony. For the convenience of the Board, we begin by summarily stating the main points of the analysis.

It can be demonstrated mathematically (see Annex, pp. 10-14) that an assumption of separable functional forms for the variables r and θ necessarily implies that the probability histograms for the radial and angular derivatives are independent. Thus, the key inquiry is whether the assumption of separable functional forms is itself justified; i.e., whether r and θ are separable. The NRC Staff statisticians have demonstrated to their satisfaction, using traditional statistical techniques, that r and θ are independent, or separable in present terms. Analysis from a Bayesian perspective (see Annex, pp. 9-10, 14-17) results in the same conclusion. There is no *a priori* basis for viewing r and θ as nonseparable. The historical crash data conform more closely to separable functional forms than to a reasonably specified set of nonseparable forms. Thus, the actual data support the selection of separable functional forms for the analysis. The use of such separable functional forms provides assurance of the required independence of the histograms, justifying application of the independent histogram multiplication methodology to determine what this Board has termed "the precision of the hit probability values." ALAB-525, slip op. at p. 10. Thus, the results presented on the basis of this methodology are believed to be accurate.

As a double-check on the sensitivity of the results to the determination of independence, further calculations have been performed which demonstrate that an alternative and more general specification of the model permitting a substantial degree of nonseparability of r and θ, *i.e.*, not dependent on the determination of independence, has a fairly small effect on the final probability curves. (See Annex, pp. 15-27 and Figures 7.1 and 7.2.) This reinforces our confidence in the validity of our results.

ANNEX

1. INTRODUCTION AND PURPOSE

In its Memorandum and Order of February 1, 1979[1] (see page 10 and 11, Item 2) the Board questioned the manner in which the probability histograms are multiplied together in Vallance's testimony (as revised December 8, 1978, page 24). In particular, the Board questioned the rationale for regarding the histograms for crash rate, radial crash density and angular density as being "independent" distributions in this multiplication. The purpose of the present testimony is to answer this question.

2. OUTLINE OF APPROACH

We remark at the outset that this question is subtle and probes to the heart of fundamental matters. It will therefore be necessary to prepare the backdrop with considerable care before proceeding to answer the question itself. We beg the reader's indulgence, therefore, in this preparation and we shall endeavor to be as concise and as clear as possible.

Next we note also, upon reflection, that this question really contains three subquestions, subtly interwoven. The first of these is basically a conceptual question, having to do with the fundamental meaning of probability and with whether separability of the spatial variables necessarily implies independence of the probabilities. It can be answered definitively either with a qualitative, semi-intuitive approach or an explicit analytical approach. We shall do both in the following sections.

The second subquestion has to do with the crash data itself and asks whether this data supports the belief that the spatial crash distribution is separable in the radial and angular variables. This question has been looked at by the NRC statisticians (see testimony of Moore & Abramson, November 30, 1978, pages 3 and 4) who apparently satisfy themselves that the variables are independent. This question also can be addressed very satisfactorily and very thoroughly using a Bayesian approach and a class of nonseparable fitting functions. The amount of computational work involved here could become very large depending on the class chosen. We therefore adopt a 'first approximation' treatment which we feel catches the majority of the nonseparable effect and yet keeps computer time within reason.

The third subquestion concerns the separability of space and time. That is, is the spatial distribution of crashes a function of time? Intuitively one might expect some dependence here since type of aircraft, instrumentation, etc., varies with time. A look at this question is shown in Figures 8.1 through 8.4 which give the scatter diagrams for crashes before and after January 1, 1965. Needless to say the data, that is the number of crashes, is far too sparse to allow a time pattern to be definitively seen.

The question of time dependence of the spatial pattern can be pursued in a manner similar to that used to address nonseparability of r, θ (i. e., the second subquestion). This pursuit, however, becomes computationally even more complicated, especially when combined with spatial nonseparability. Moreover, we expect that the result of a Bayesian application here will yield essentially the same result, i. e., the same crash frequency at the TMI location, as our previous calculation. Therefore, we do not pursue this matter any further at this time, but of course stand ready to do so should the Board consider it worthwhile.

To understand the discussion which we shall give of the subquestions it is essential to understand the sense in which we use the word "probability," and the distinction we make between the idea of probability and that of "frequency." It is essential also to be clear on the notion of "probability of frequency" which in our December 8 testimony, was the conceptual context we chose within which to address the Board's original request for a recalculation of crash likelihood including estimate of uncertainty.

To make sure, therefore, that we are fully understood we shall begin in the next section by defining these basic words and concepts, and then review the overall pattern of the argument in the December 8 testimony. This will then allow us to proceed to the subquestions which are the subject of the present note.

3. PROBABILITY, FREQUENCY, AND PROBABILITY OF FREQUENCY

We adopt the following definition of probability, given by E. T. Jaynes:

> "Probability theory is an extension of logic, which describes the inductive reasoning of an idealized being who represents degrees of plausibility by real numbers. The numerical value of any probability (A/B) will in general depend not only on A and B, but also on the entire background of other propositions that this being is taking into account. A probability assignment is 'subjective' in the sense that it describes a state of knowledge rather than any property of the 'real' world; but it is completely 'objective' in the sense that it is independent of the personality of the user; two beings faced with the same total background of knowledge must assign the same probabilities."

Thus, as we shall use it, probability is a numerical measure of our state of knowledge or state of certainty. It is thus by definition a subjective or 'soft' number. The word 'frequency,' on the other hand, we shall use to refer to the result of an experiment involving repeated trials. It is thus a 'hard' or 'objective' number and is so, at least in concept, even if the experiment is only a thought experiment or an experiment to be done in the future.

Now with the above definition of probability it would make no sense to ask for the uncertainty of a probability because the probability is already the numerical expression of uncertainty and we would thus be asking for the uncertainty of the uncertainty. Nevertheless, there is a valid thought behind this question. To provide a linguistic framework for handling this thought we introduce the notion of 'probability of frequency' as follows.

Suppose, with respect to the Three Mile Island site, we envision a thought experiment in which millions and millions of planes fly into and out of the Harrisburg Airport. At the end of this time we look over the records and ask what fraction of these flights crashed into the TMI plant. In other words, what was the frequency, F, of collisions with the plant?

At least in concept this quantity F, collisions per flight, is a tangible number which would be known at the end of this experiment. Our problem today is to predict what this number would be. Since we do not know this number, we naturally express our prediction in the form of a probability distribution against F.

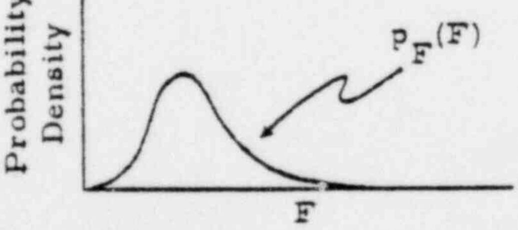


FIGURE 3.1 - PROBABILITY OF FREQUENCY CURVE

Thus we come to the notion of the 'probability of frequency' curve as a way of expressing our state of knowledge. Denoting this curve by $p_F(F)$, the expected value of the frequency is:

$$\overline{F} = \int_0^\infty p_F(F)\,F dF \quad . \qquad (3.1)$$

This number is the "expected frequency." It is also the probability we assign to the prospect of a collision on the next flight.

From the curve we can also get percentile values, e.g., F_{90} and F_{10}, where

$$.90 = \int_0^{F_{90}} p_F(F) df$$

$$.10 = \int_0^{F_{10}} p_F(F) dF \quad .$$

We could then describe ourselves as being 80 percent confident that the frequency F, if we were to actually measure it, would lie between F_{10} and F_{90}. These confidence bounds give a measure or indication of our certainty in the prediction of F.* The full story of our certainty is expressed by the entire curve $p_F(F)$ itself.

This notion of probability of frequency thus constitutes an appropriate framework for answering the Board's original request. We therefore adopted it in our December 8 testimony, and it therefore is also part of the backdrop for the present testimony.

4. RECAP OF DECEMBER 8 ANALYSIS

In the December 8 analysis, the number of crashes per year is expressed in the form:

$$c = 1/2 \sum_{\kappa} N_\kappa f_\kappa S_\kappa(r_o, \theta_o) A_\kappa \quad .$$

---

*Note that we use the term "confidence" or "confidence bounds" in a Bayesian sense[2] which is slightly different from the way the orthodox statistician uses the term (see for example [3], p. 387, and [4], p. 29).

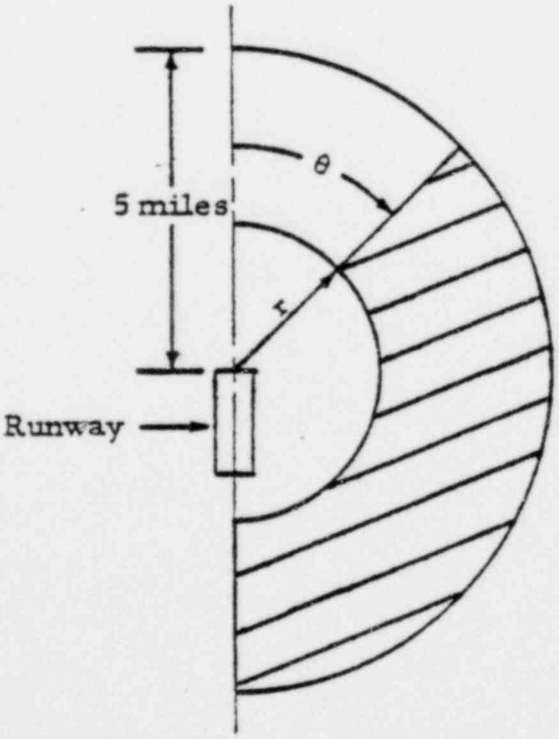
Here κ denotes a category of flight operation, e.g., scheduled takeoff, N_κ is the number of operations of that category per year at the relevant end of the Harrisburg runway, f_κ is the crash rate (i.e., crashes per operation) for that category, and A_κ is the effective target area for that category. $S_\kappa(r, \theta)$ is the spatial density, crashes per square mile, of crashes for that category, and $S_\kappa(r_o, \theta_o)$ is the spatial density at the coordinates r_o, θ_o, of the TMI plant. Finally the value 1/2 is in effect a reduction of the N_κ to account for two-sided symmetry about the runway center line.

The Board's current question relates to these numbers $S_\kappa(r_o, \theta_o)$. We next review the December 8 derivation of these numbers in such a way as to form a basis for the analysis in the present testimony.

For this purpose introduce:

$$\phi(r, \theta) \equiv \text{fraction of crashes occurring beyond radius } r \text{ and angle } \theta. \qquad (4.1)$$

More explicitly $\phi(r, \theta)$ represents, of all crashes occurring within five miles of the end of the runway and on the right side of the runway, that fraction of crashes which occurs in the shaded area of the following diagram:



Note that this fraction could be different for each category, so that ϕ should have a subscript κ. For simplicity however, we shall omit the subscripts from here on and regard them as understood. In terms of ϕ, the crash density is:

$$S(r,\theta) = \frac{1}{r}\frac{\partial}{\partial r}\frac{\partial}{\partial \theta}\phi(r,\theta) \tag{4.2}$$

(where θ is measured in radians).

In the December 8 testimony the fraction ϕ is assumed separable in r and θ, that is:

$$\phi(r,\theta) = R(r)\Theta(\theta) \tag{4.3}$$

so that:

$$\begin{aligned} S(r,\theta) &= \left[\frac{1}{r}\frac{d}{dr}R(r)\right]\left[\frac{d}{d\theta}\Theta(\theta)\right] \\ &\equiv \frac{1}{r}D(r)\,D(\theta), \end{aligned} \tag{4.4}$$

and

$$S(r_o,\theta_o) = \frac{1}{r_o}D(r_o)\,D(\theta_o) \quad . \tag{4.5}$$

The quantities $D(r_o)$, $D(\theta_o)$ were obtained from the data in the form of probability histograms by the following procedure:

4.1 The Quantity $D(r_o)$

Since $D(r_o)$ is just the derivative of $R(r)$ at r_o, we regard our problem as having to infer what the function $R(r)$ is from the data on crash radii. Since the data is insufficient to define $R(r)$ precisely, we need to obtain in some form a probabilistic statement expressing our state of knowledge of what $R(r)$ is.

We do this by conceiving of $R(r)$ as being embedded in, being one point in, a set or "space" of functions $\mathcal{A}$:

$$R(r) \in \mathcal{A} \tag{4.6}$$

We then seek, based on the crash data, to erect a probability distribution over the function space $\mathcal{A}$ to express our knowledge of where R is.

Since $\mathscr{A}$ is an infinite dimensional space we approximate this procedure by establishing in $\mathscr{A}$ a grid as follows:

$$R_{ij}(r) = a_i e^{-\lambda_j r} \quad ; \quad R_{ij}(o) = 1.0 \tag{4.7}$$

where a_i, λ_j are selected from a discrete set of possible values

$$\{a_i\} = \{a_1, a_2, a_3, \dots, a_I\} \tag{4.8a}$$

$$\{\lambda_j\} = \{\lambda_1, \lambda_2, \lambda_3, \dots, \lambda_J\} \ . \tag{4.8b}$$

Our experimental data consists of the set of crash radii, which set we label B,

$$B \equiv \{r_1, r_2, r_3, \dots, r_\ell\} \tag{4.9}$$

In light of the information B, we next ask ourselves: What is our confidence that the "true" function R(r) has the "value" $R_{ij}(r)$?

This question is answered simply, using Bayes' theorem as described in Appendix B of the December 8 testimony. The result is a probability value, p_{ij}, assigned to each i, j combination. The set of doublets:

$$\{\langle p_{ij}, R_{ij}(r)\rangle\} \tag{4.10}$$

thus may be thought of as constituting a probability histogram erected over the function space $\mathscr{A}$.

From this it is very simple to derive a probability histogram for the quantity $D(r_o)$:

$$\{\langle p_{ij}, D_{ij}(r_o)\rangle\} \tag{4.11}$$

where:

$$D_{ij}(r_o) = \left[\frac{d}{dr} R_{ij}(r)\right]_{r=r_o} \ . \tag{4.12}$$

Thus in (4.11) we have an FPD, a finite probability distribution or probability histogram, expressing our state of knowledge of the quantity $D(r_o)$ based on the information B, the set of crash radii.

Dispensing now with the double index, we can rewrite (4.11) in the form:

$$\{\langle p_n, D_n(r_o)\rangle\} \quad , \quad \sum_n p_n = 1.0 \tag{4.11a}$$

4.2 The Quantity D(θ)

A similar process was applied for the angular variable, resulting in an FPD over a mesh of angular functions:

$$\{\langle q_{ij}, \Theta_{ij}(\theta)\rangle\} \tag{4.13}$$

and similarly an FPD for the desired quantity $D(\theta_o)$

$$\{\langle q_{ij}, D_{ij}(\theta_o)\rangle\} \tag{4.14}$$

where

$$D_{ij}(\theta_o) = \left[\frac{d}{d\theta}\Theta_{ij}(\theta)\right]_{\theta=\theta_o} . \tag{4.15}$$

This FPD expresses our state of knowledge of the quantity $D(\theta_o)$ based on the set of angles $\{\theta_1, \theta_2, \ldots, \theta_\ell\}$ at which crashes occurred. The details are in Appendix B of the December 8 testimony.

Again dispensing with the double subscript we rewrite (4.14) in the form:

$$\{\langle q_m, D_m(\theta_o)\rangle\} \quad , \quad \sum_m q_m = 1.0 \tag{4.14a}$$

4.3 Multiplication of the Distributions

To determine the spatial density $S(r_o, \theta_o)$ we need to multiply the quantities $D(r_o)$, $D(\theta_o)$ as in (4.5). These quantities are expressed as probability histograms in (4.11a) and (4.14a). If these histograms are now regarded as independent they may be multiplied to yield a histogram for $S(r_o, \theta_o)$ according to the simple convolution rule:

$$S(r_o, \theta_o) = \{\langle p_n q_m, S_{nm}\rangle\} \tag{4.15a}$$

where

$$S_{nm} = D_n(r_o) D_m(\theta_o) . \tag{4.15b}$$

This is what was done in the December 8 testimony, page 24, and this is what is being questioned by the Board. We now therefore turn to this question directly.

5. SUBQUESTION 1, QUALITATIVE DISCUSSION OF INDEPENDENCE

We now ask Subquestion 1: Are the probability histograms (4.11a) and (4.14a) independent?

What is the precise meaning of this question? To nail it down, construct a table as follows:

TABLE 5.1

		q_1 $D_1(\theta_o)$	q_2 $D_2(\theta_o)$	$\cdots$ $\cdots$	q_m $D_m(\theta_o)$	$\cdots$ $\cdots$
p_1	$D_1(r_o)$	α_{11}	α_{12}	$\cdots$		
p_2	$D_2(r_o)$	α_{21}	$\cdot$	$\cdots$		
$\vdots$	$\vdots$	$\vdots$				
p_n	$D_n(r_o)$	$\cdot$			α_{nm}	
$\vdots$	$\vdots$					

(5.1)

Now let $\{\alpha_{nm}\}$ represent a joint probability distribution on $D(r_o)$, $D(\theta_o)$. That is, let α_{nm} express our state of confidence in the pair

$$\langle D_n(r_o),\ D_m(\theta_o)\rangle \quad . \tag{5.2}$$

Also, of course:

$$\sum_{r,\,m} \alpha_{nm} = 1.0 \quad . \tag{5.3}$$

Now the question is: In Table 5. 1, does

$$\alpha_{nm} = p_n q_m \qquad (5.4)$$

for all pairs n, m? If it does, this is what we would mean by saying the histograms (4. 11a) and (4. 14a) are independent. Otherwise, they are "dependent" or "correlated."*

So, given that the p_n expresses our confidence in the $D_n(r_o)$ and the q_m our confidence in the $D_n(\theta_o)$, do we have any reason or evidence to assign to the combination $\langle D_n(r_o), D_m(\theta_o)\rangle$ any probability value other than the product $p_n q_m$? If we do not, and do not for all n, m combinations, then the histograms are independent.

Intuitively, this is the case. No such evidence or reason comes to mind. Therefore, we assign the joint probabilities as in (5. 4) and thus obtain an FPD for $S(r_o, \theta_o)$ as:

$$\{\langle p_n q_m, S_{nm}(r_o, \theta_o)\rangle\} \qquad (5.5a)$$

with

$$S_{nm}(r_o, \theta_o) = \frac{1}{r_o} D_n(r_o) D_m(\theta_o) \qquad (5.5b)$$

which is the same as (4. 15).

6. SUBQUESTION 1, ANALYTICAL APPROACH

In the previous section we qualitatively justified the independent multiplication in (4. 15) by simply noting that we had no reason for assigning a joint probability α_{nm} any different than the product $p_n q_m$. We have thus argued that the absence of knowledge of dependency is in effect a statement of the independence of our two FPDs for $D(r_o)$ and $D(\theta_o)$.

In the present section we address the same question analytically. The essence of the question is whether the assumption of a separable form (4. 3) necessarily implies that our state of knowledge distributions for $D(r_o)$ and $D(\theta_o)$ are independent. It is not obvious that it does,

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*salubriously or otherwise.

although it seems so intuitively. It turns out that this implication is indeed valid under one further, rather mild condition.

We shall demonstrate this by repeating the Bayesian argument of Appendix B but keeping the radial and angular variables combined. Thus although we assume separability in the function ϕ, as in Equation (4.3), we do not assume independence of our probability distributions. We will see, rather, that this independence follows as a consequence of separability in ϕ if also our prior state of knowledge with respect to ϕ is separable. Exactly what this means will become clear in the following.

Demonstration

What was done in Appendix B can be viewed as approximating the 'true' function $\phi(r,\theta)$ with a four parameter family of functions:

$$\phi(r,\theta,a_i,\lambda_j,\alpha_k,\mu_\ell) = R_{ij}(r)\Theta_{k\ell}(\theta) \qquad {}^*(6.1)$$

where

$$R_{ij}(r) = \begin{Bmatrix} 1.0, \ r=0 \\ a_i e^{-\lambda_j r}, \ r>0 \end{Bmatrix} \qquad (6.2a)$$

$$\Theta_{k\ell}(\theta) = \begin{Bmatrix} 1.0, \ \ =0 \\ \alpha_k e^{-\mu_\ell \theta} + b, \ 0<\theta<\pi/2 \end{Bmatrix} . \qquad (6.2b)$$

The functions R, Θ were chosen deliberately discontinuous at $r=0$, $\theta=0$, in order to represent the data properly at those points. The value b was assigned so that the curve would have the right asymptote at $\theta=90^\circ$.

To each member of this four parameter family there corresponds a spatial crash density according to (4.6) as follows:

$$S(r_o,\theta_o,i,j,k,\ell) = \frac{1}{r_o} D_{ij}(r_o) D_{k\ell}(\theta_o) \qquad (6.3)$$

where $D_{ij}(r_o)$ and $D_{k\ell}(\theta_o)$ are as in (4.12) and (4.15).

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*More precisely the true $\phi(r,\theta)$ is thought of as embedded in a space of functions, within which the family (6.1) is a finite subset. Hopefully, this subset comes close to the true $\phi(r,\theta)$.

We now seek to establish over this four parameter family a probability distribution which expresses our state of knowledge in light of the actual crash location experience.

The information we have on crash locations is summarized in the set B, as follows:

$$B = \left\{ \zeta ; \{r_h\}_{h=1}^{H} ; \{\langle r_m, 0\rangle\}_{m=1}^{M} ; \{\langle r_n, \theta_n\rangle\}_{n=1}^{N} ; \{\langle r_v, \pi/2\rangle\}_{v=1}^{V} \right\} \tag{6.4}$$

where

ζ = Number of crashes occurring at $r=0$;

H = Number of crashes occurring at $r<0.5$ mile;

M = Number of crashes occurring at $\theta=0$, $r\geq 0.5$ mile;

N = Number of crashes occurring at $\pi/2 > \theta > 0$, $r \geq 0.5$ mile;

V = Number of crashes occurring at $\theta = \pi/2$, $r \geq 0.5$ mile;

$\langle r_i, \theta_i\rangle$ - Coordinates of ith crash point.

We now wish to establish a probability distribution over the family of functions (6.1) in light of the evidence (6.4). For this purpose we write Bayes' theorem in the form:

$$p(i,j,k,\ell \mid B) = p_o(i,j,k,\ell) \frac{p(B \mid i,j,k,\ell)}{\sum_{i,j,k,\ell} p_o(i,j,k,\ell)\, p(B \mid i,j,k,\ell)} \; . \tag{6.5}$$

Here $p_o(i,j,k,\ell)$ is the prior probability that we assign to the combination a_i, λ_j, α_k, μ_ℓ and $p(B|i,j,k,\ell)$ is the likelihood that we would have experienced evidence B given this combination.

In light of (6. 1), (6. 2), (6. 3), (6. 4), and also (4. 2), we may write this likelihood as proportional to:

$$p(B|i,j,k,\ell) \propto \left[(1-a_i)^{\zeta} (a_i\lambda_j)^{M+N+H+V} e^{-\lambda_j\left(\sum_1^M r_m + \sum_1^N r_n + \sum_1^H r_h + \sum_1^V r_v\right)} \right]$$

$$\left[(1-\alpha_k - b)^M (\alpha_k \mu_\ell)^N e^{-\mu_\ell \sum_1^N \theta_n} \right] \qquad (6.6)$$

The first bracketed term on the right is a function of i, j only and the second if of k, ℓ only. Thus the likelihood is itself separable in the form:

$$p(B|i,j,k,\ell) \propto p_r(B|i,j)\ p_\theta(B|k,\ell) \quad . \qquad (6.7)$$

Putting this in (6. 5) we have:

$$p(i,j,k,\ell|B) = \frac{p_o(i,j,k,\ell)\ p_r(B|i,j)\ p_\theta(B|k,\ell)}{\sum_{i,j,k,\ell} p_o(i,j,k,\ell)\ p_r(B|i,j)\ p_\theta(B|k,\ell)} \quad .$$

$$(6.8)$$

Now if the prior is separable

$$p_o(i,j,k,\ell) = p_{or}(i,j)\ p_{o\theta}(k,\ell) \qquad (6.9)$$

then from (6. 8)

$$p(i,j,k,\ell|B) = \left[\frac{p_{or}(i,j)\ p_r(B|i,j)}{\sum_{i,j} p_{or}(i,j)\ p_r(B|i,j)} \quad \frac{p_{o\theta}(k,\ell)\ p_\theta(B|k,\ell)}{\sum_{k,\ell} p_{o\theta}(k,\ell)\ p_\theta(B|k,\ell)} \right] .$$

$$(6.10)$$

The bracketed quantities on the right are exactly the posterior probabilities obtained in Appendix B, i. e.,

$$p(i,j,k,\ell|B) = p(i,j|B)\ p(k,\ell|B) \qquad (6.11)$$

or, in terms of the notation of Sections 4.1 and 4.2

$$p(i, j, k, \ell | B) = p_{ij} q_{k\ell} \quad . \tag{6.11a}$$

Thus if the prior is separable, (6.9), then so also is the posterior (6.11). In this case our histogram for the spatial density

$$\{\langle p(i, j, k, \ell | B) \,,\; S(r_o, \theta_o, i, j, k, \ell)\rangle\} \tag{6.12}$$

becomes:

$$\{\langle p(i, j | B)\, p(k, \ell | B) \,,\; \frac{1}{r_o} D_{ij}(r_o)\, D_{k,\ell}(\theta_o)\rangle\} \tag{6.13}$$

But according to our convolution rule (4.15) for multiplying FPDs this histogram, (6.13), is the product of the histograms:

$$\left\{\langle p(i, j | B) \,,\; \frac{1}{r_o} D_{ij}(r_o)\rangle\right\} \cdot \left\{\langle p(k, \ell | B) \,,\; D_{k\ell}(\theta_o)\rangle\right\} \tag{6.14}$$

or in the notation of Section 4

$$\left\{\langle p_{ij} \,,\; \frac{1}{r_o} D_{ij}(r_o)\rangle\right\} \cdot \left\{\langle q_{k\ell} \,,\; D_{k\ell}(\theta_o)\rangle\right\} \tag{6.15}$$

which reproduces the result of Section 4.3.

Thus we have shown that our probability distributions for the radial and angular derivatives are independent if our prior state of knowledge over the family (6.1) is separable. The prior chosen in Appendix B of course was separable. We have no reason now, even from the broader perspective of this section, to do otherwise. Thus we can conclude for all essential purposes that the assumption of the separable form (4.3) already implies that the probability histograms for the radial and angular derivatives are independent.

7. SUBQUESTION 2, SPATIAL SEPARABILITY

In the previous two sections we have shown that if the spatial variables are assumed separable then the uncertainties in the r and θ derivatives are independent. We now turn to the question of whether the experimental data actually supports the assumption of separability.

As mentioned earlier, Moore and Abramson have apparently given an affirmative answer to this question using statisticians' methods. A person of Bayesian persuasion would approach this matter by not treating the question as if it had only two possible answers, yes or no, separable or not. Rather he would embed the question in a context within which there was a continuum of separability ranging from totally separable to highly nonseparable. He would then allow the experimental evidence to dictate where we fall within this continuum--or more accurately to erect a probability distribution over this continuum. This is the approach we shall follow in the present section.

To carry out this program we return to the four parameter family of fitting functions (6.1) and now embed this family in a larger, five parameter family as follows:

$$\Phi(r,\theta,a_i,\lambda_j,\alpha_k,\mu_\ell,\gamma_w) = R_{ij}(r)\Theta_{k\ell w}(\theta,r) \tag{7.1}$$

where now:

$$R_{ij}(r) = \begin{Bmatrix} 1.0, \ r=0 \\ a_i e^{-\lambda_j r}, \ r>0 \end{Bmatrix} \tag{7.2a}$$

$$\Theta_{k\ell w}(\theta,r) = \begin{Bmatrix} 1.0, \ \theta=0 \\ \alpha_k e^{-\mu_\ell \theta} + b\left[1+\gamma_w(r-2.5)\right], \ 0<\theta\leq\pi/2 \\ 0, \ \theta>\pi/2 \end{Bmatrix}^{*} \tag{7.2b}$$

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[*] Observe also that in (7.2b) we have treated the situation at $\theta=\pi/2$ slightly differently. In the December 8 and January 9 testimony, in order to handle the fact that the experimental crash density undergoes a precipitous drop to zero at $\theta=\pi/2$, we regarded ourselves as simply fitting the data in the range $0\leq\theta<\pi/2$, and chose the value b to force the right asymptotic value to the fit as $\theta\longrightarrow\pi/2$. In the present testimony since we are doing the work over again anyway, we take the opportunity to make a slight improvement over this procedure. We now regard the fitting function itself as having a step at $\theta=\pi/2$. The discontinuity at this step results in a delta function for the crash density at $\theta=\pi/2$. This delta function is then included in our likelihood calculation in exactly the same way as the deltas at r=0 and $\theta=0$. This procedure makes little difference numerically over what was done in the December 8 and January 9 testimonies but it is more satisfying conceptually.

Observe that the fifth parameter, γ_w, that we have added is in effect a 'nonseparability index.' For $\gamma_w=0$ (7.1) reduces to the separable case (6.1), so that the family of functions (6.1) is a subset of the family (7.1), i.e.,

$$\phi \subset \Phi \; . \tag{7.3}$$

Observe also of course that we have not considered the entire space of nonseparable functions. This would be much too big a space to work with. We have taken one first step into the nonseparable wilderness, from the safety of (6.1), by allowing the constant term b, in (6.2b), to now be in effect a function of r. We do this in (7.2b) by multiplying b by the r dependent term $[1+\gamma_w(r-2.5)]$. The specific form of this term is chosen so that the average asymptote, b, would obtain at the average r value 2.5 miles.

Thus Θ now becomes a function of r also through the nonseparable, or "coupling" term, and the size of the parameter γ_w determines the degree of nonseparability or coupling of the r, θ variables. We next use the data itself to assign a probability distribution against γ_w as well as against the other four parameters.

We do this of course using Bayes' theorem and the fact that the spatial crash density is, from (7.1):

$$S(r,\theta) = \frac{1}{r}\frac{\partial}{\partial r}\frac{\partial}{\partial \theta}\Phi(r,\theta) \tag{7.4}$$

$$= \left[\frac{1}{r}\frac{\partial}{\partial r}R(r)\right]\left[\frac{\partial}{\partial \theta}\Theta(\theta,r)\right] + \left[\frac{1}{r}R(r)\right]\left[\frac{\partial}{\partial r}\frac{\partial}{\partial \theta}\Theta(\theta,r)\right] \; . \tag{7.5}$$

With this crash density, and the forms (7.2a, b) it follows that the probability of experiencing the set of crash locations B, (6.4), is proportional as follows:

$$p(B|a_i,\lambda_j,\alpha_k,\mu_\ell,\gamma_w) \propto \boldsymbol{r}(a_i,\lambda_j)\,\boldsymbol{a}(\alpha_k,\mu_\ell)\,\boldsymbol{k}(\lambda_j,\alpha_k,\gamma_w)$$

$$\boldsymbol{v}(\lambda_j,\alpha_k,\mu_\ell,\gamma_w) \tag{7.6}$$

where $\boldsymbol{r}$ and $\boldsymbol{a}$ are the same separated radial and angular terms as in (6.6)

$$\boldsymbol{\ell}(a_i, \lambda_j) \equiv \left[(1-a_i)^{\zeta} (a_i \lambda_j)^{M+N+H+V} e^{-\lambda_j \left(\sum_1^M r_m + \sum_1^N r_n + \sum_1^H r_h + \sum_1^V r_v \right)} \right] \tag{7.7}$$

$$\boldsymbol{a}(\alpha_k, \mu_\ell) \equiv \left[(1-\alpha_k - b)^M (\alpha_k \mu_\ell)^N e^{-\mu_\ell \sum_1^N \theta_n} \right] \tag{7.8}$$

$\boldsymbol{k}$ is the correction for nonseparability,

$$\boldsymbol{k}(\lambda_j, \alpha_k, \gamma_w) = \prod_{m=1}^{M} \left\{ 1 + \frac{\frac{b\gamma}{\lambda}\left[1 - \lambda(r_m - 2.5)\right]}{(1-\alpha-b)} \right\} . \tag{7.9}$$

and $\boldsymbol{v}$ is a term accounting for the step function at $\theta = \pi/2$.

$$\boldsymbol{v}(\lambda_j, \alpha_k, \mu_\ell, \gamma_w) = \prod_{v=1}^{V} \left\{ \left[\alpha_k e^{-\mu_\ell \frac{\pi}{2}} + b \right] - \frac{b\gamma_w}{\lambda_j} \left[1 - \lambda_j (r_v - 2.5) \right] \right\} \tag{7.10}$$

The derivation of (7.6) is given in the appendix. It remains only to do the numerical work. For this purpose we choose the same a, λ, α, μ grids as in our January 9 supplemental testimony and get of course the same $\boldsymbol{\ell}$, $\boldsymbol{a}$ tableaus. We therefore do not reproduce them here. The $\boldsymbol{k}$ tableaus are shown in Tables 7.1 through 7.10. It is interesting to note that for both landings and takeoffs the $\boldsymbol{k}$ matrix is the largest for $\gamma = 0$, which seems to say, at least as far as $\boldsymbol{k}$ is concerned, that the data prefers the separable fit to any other.

The probability curves for spatial crash density at the TMI location are shown in Figures 7.1 and 7.2, and compared there with the curves that are obtained using the separable fitting functions of the December 8 and January 9 testimonies. It is seen that the inclusion of nonseparability, by way of the b terms at least, has a fairly small effect on the final probability curves.

TABLE 7.1. k TABLEAU FOR LANDING CRASHES

$\gamma_w = 0.0$

λ \ α	.2000E+00	.3000E+00	.4000E+00	.5000E+00	.6000E+00	.7000E+00
.1333E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.8000E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.6667E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.5714E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.5000E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.4444E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.4000E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.3636E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.3333E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.3077E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01

TABLE 7.2. *k* TABLEAU FOR LANDING CRASHES

$\gamma_w = -0.1$

λ \ α	.2000E+00	.3000E+00	.4000E+00	.5000E+00	.6000E+00	.7000E+00
.1333E+01	.8798E+00	.8620E+00	.8380E+00	.8039E+00	.7518E+00	.6625E+00
.1000E+01	.8530E+00	.8316E+00	.8029E+00	.7626E+00	.7018E+00	.6000E+00
.8000E+00	.8269E+00	.8021E+00	.7692E+00	.7233E+00	.6549E+00	.5430E+00
.6667E+00	.8015E+00	.7737E+00	.7368E+00	.6858E+00	.6109E+00	.4910E+00
.5714E+00	.7769E+00	.7461E+00	.7057E+00	.6502E+00	.5696E+00	.4437E+00
.5000E+00	.7529E+00	.7195E+00	.6758E+00	.6163E+00	.5310E+00	.4007E+00
.4444E+00	.7297E+00	.6938E+00	.6471E+00	.5840E+00	.4948E+00	.3615E+00
.4000E+00	.7071E+00	.6689E+00	.6195E+00	.5533E+00	.4609E+00	.3260E+00
.3636E+00	.6852E+00	.6449E+00	.5930E+00	.5241E+00	.4291E+00	.2937E+00
.3333E+00	.6639E+00	.6216E+00	.5676E+00	.4964E+00	.3995E+00	.2644E+00
.3077E+00	.6432E+00	.5992E+00	.5432E+00	.4700E+00	.3717E+00	.2378E+00

TABLE 7.3. k TABLEAU FOR LANDING CRASHES

$\gamma_w = -0.2$

α \ λ	.2000E+00	.3000E+00	.4000E+00	.5000E+00	.6000E+00	.7000E+00
.1333E+01	.7714E+00	.7396E+00	.6975E+00	.6397E+00	.5553E+00	.4229E+00
.1000E+01	.7245E+00	.6876E+00	.6395E+00	.5744E+00	.4821E+00	.3442E+00
.8000E+00	.6803E+00	.6391E+00	.5860E+00	.5154E+00	.4180E+00	.2792E+00
.6667E+00	.6386E+00	.5937E+00	.5367E+00	.4621E+00	.3619E+00	.2258E+00
.5714E+00	.5993E+00	.5514E+00	.4912E+00	.4139E+00	.3128E+00	.1820E+00
.5000E+00	.5622E+00	.5119E+00	.4494E+00	.3704E+00	.2700E+00	.1462E+00
.4444E+00	.5273E+00	.4750E+00	.4109E+00	.3312E+00	.2326E+00	.1170E+00
.4000E+00	.4944E+00	.4406E+00	.3754E+00	.2959E+00	.2001E+00	.9332E-01
.3636E+00	.4634E+00	.4086E+00	.3428E+00	.2641E+00	.1719E+00	.7415E-01
.3333E+00	.4342E+00	.3787E+00	.3129E+00	.2355E+00	.1474E+00	.5869E-01
.3077E+00	.4068E+00	.3508E+00	.2854E+00	.2098E+00	.1262E+00	.4627E-01

TABLE 7.4. k TABLEAU FOR LANDING CRASHES

$_{w} = -0.3$

λ \ α	.2000E+00	.3000E+00	.4000E+00	.5000E+00	.6000E+00	.7000E+00
.1333E+01	.6738E+00	.6313E+00	.5765E+00	.5034E+00	.4024E+00	.2589E+00
.1000E+01	.6127E+00	.5652E+00	.5050E+00	.4270E+00	.3236E+00	.1874E+00
.8000E+00	.5568E+00	.5055E+00	.4419E+00	.3614E+00	.2593E+00	.1346E+00
.6667E+00	.5056E+00	.4518E+00	.3861E+00	.3054E+00	.2071E+00	.9595E-01
.5714E+00	.4588E+00	.4033E+00	.3369E+00	.2574E+00	.1647E+00	.6779E-01
.5000E+00	.4161E+00	.3598E+00	.2936E+00	.2166E+00	.1305E+00	.4746E-01
.4444E+00	.3771E+00	.3206E+00	.2555E+00	.1818E+00	.1031E+00	.3292E-01
.4000E+00	.3415E+00	.2654E+00	.2221E+00	.1523E+00	.8102E-01	.2260E-01
.3636E+00	.3090E+00	.2539E+00	.1927E+00	.1273E+00	.6342E-01	.1536E-01
.3333E+00	.2794E+00	.2256E+00	.1670E+00	.1061E+00	.4943E-01	.1032E-01
.3077E+00	.2525E+00	.2062E+00	.1445E+00	.8825E-01	.3835E-01	.6849E-02

TABLE 7.5. k TABLEAU FOR LANDING CRASHES

$\gamma_w = -0.4$

λ \ α	.2000E+00	.3000E+00	.4000E+00	.5000E+00	.6000E+00	.7000E+00
.1333E+01	.5864E+00	.5362E+00	.4729E+00	.3916E+00	.2855E+00	.1511E+00
.1000E+01	.5158E+00	.4617E+00	.3952E+00	.3129E+00	.2116E+00	.9605E-01
.8000E+00	.4531E+00	.3969E+00	.3295E+00	.2491E+00	.1558E+00	.6013E-01
.6667E+00	.3976E+00	.3406E+00	.2741E+00	.1975E+00	.1139E+00	.3702E-01
.5714E+00	.3485E+00	.2918E+00	.2274E+00	.1560E+00	.8266E-01	.2238E-01
.5000E+00	.3050E+00	.2496E+00	.1882E+00	.1227E+00	.5954E-01	.1327E-01
.4444E+00	.2666E+00	.2131E+00	.1553E+00	.9615E-01	.4254E-01	.7706E-02
.4000E+00	.2328E+00	.1816E+00	.1279E+00	.7500E-01	.3014E-01	.4373E-02
.3636E+00	.2029E+00	.1545E+00	.1050E+00	.5823E-01	.2117E-01	.2420E-02
.3333E+00	.1767E+00	.1311E+00	.8592E-01	.4500E-01	.1473E-01	.1303E-02
.3077E+00	.1536E+00	.1111E+00	.7013E-01	.3461E-01	.1015E-01	.6810E-03

TABLE 7.6. k TABLEAU FOR TAKEOFF CRASHES

$\gamma_w = 0.0$

λ \ α	.2000E+00	.3000E+00	.4000E+00	.5000E+00	.6000E+00
.1333E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.8000E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.6667E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.5714E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.5000E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.4444E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.4000E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.3636E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.3333E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01
.3077E+00	.1000E+01	.1000E+01	.1000E+01	.1000E+01	.1000E+01

TABLE 7.7. *k* TABLEAU FOR TAKEOFF CRASHES

$\gamma_w = -0.025$

α λ	.2000E+00	.3000E+00	.4000E+00	.5000E+00	.6000E+00
.1333E+01	.9796E+00	.9753E+00	.9666E+00	.9575E+00	.9336E+00
.1000E+01	.9706E+00	.9645E+00	.9553E+00	.9395E+00	.9065E+00
.8000E+00	.9617E+00	.9539E+00	.9420E+00	.9218E+00	.8801E+00
.6667E+00	.9529E+00	.9433E+00	.9288E+00	.9043E+00	.8542E+00
.5714E+00	.9441E+00	.9328E+00	.9157E+00	.8871E+00	.8289E+00
.5000E+00	.9354E+00	.9224E+00	.9028E+00	.8701E+00	.8041E+00
.4444E+00	.9267E+00	.9121E+00	.8901E+00	.8533E+00	.7800E+00
.4000E+00	.9182E+00	.9018E+00	.8774E+00	.8368E+00	.7563E+00
.3636E+00	.9096E+00	.8917E+00	.8649E+00	.8206E+00	.7332E+00
.3333E+00	.9011E+00	.8816E+00	.8525E+00	.8046E+00	.7107E+00
.3077E+00	.8927E+00	.8717E+00	.8403E+00	.7888E+00	.6886E+00

TABLE 7.8. k TABLEAU FOR TAKEOFF CRASHES

$\gamma_w = -0.05$

α λ	.2000E+00	.3000E+00	.4000E+00	.5000E+00	.6000E+00
.1333E+01	.9585E+00	.9497E+00	.9361E+00	.9125E+00	.8614E+00
.1000E+01	.9410E+00	.9287E+00	.9100E+00	.8779E+00	.8109E+00
.8000E+00	.9236E+00	.9080E+00	.8844E+00	.8444E+00	.7626E+00
.6667E+00	.9065E+00	.8877E+00	.8593E+00	.8119E+00	.7165E+00
.5714E+00	.8897E+00	.8677E+00	.8348E+00	.7803E+00	.6724E+00
.5000E+00	.8731E+00	.8481E+00	.8109E+00	.7496E+00	.6305E+00
.4444E+00	.8567E+00	.8288E+00	.7874E+00	.7199E+00	.5905E+00
.4000E+00	.8405E+00	.8098E+00	.7645E+00	.6910E+00	.5525E+00
.3636E+00	.8246E+00	.7912E+00	.7420E+00	.6630E+00	.5163E+00
.3333E+00	.8089E+00	.7728E+00	.7201E+00	.6359E+00	.4819E+00
.3077E+00	.7934E+00	.7548E+00	.6986E+00	.6096E+00	.4493E+00

TABLE 7.9. *k* TABLEAU FOR TAKEOFF CRASHES

$\gamma_w = -0.075$

λ \ α	.2000E+00	.3000E+00	.4000E+00	.5000E+00	.6000E+00
.1333E+01	.9369E+00	.9232E+00	.9021E+00	.8651E+00	.7845E+00
.1000E+01	.9111E+00	.8925E+00	.8641E+00	.8156E+00	.7141E+00
.8000E+00	.8857E+00	.8625E+00	.8273E+00	.7683E+00	.6486E+00
.6667E+00	.8610E+00	.8333E+00	.7918E+00	.7230E+00	.5877E+00
.5714E+00	.8367E+00	.8048E+00	.7573E+00	.6798E+00	.5311E+00
.5000E+00	.8130E+00	.7770E+00	.7240E+00	.6385E+00	.4786E+00
.4444E+00	.7898E+00	.7500E+00	.6919E+00	.5991E+00	.4301E+00
.4000E+00	.7670E+00	.7237E+00	.6608E+00	.5616E+00	.3854E+00
.3636E+00	.7448E+00	.6981E+00	.6307E+00	.5258E+00	.3442E+00
.3333E+00	.7231E+00	.6732E+00	.6017E+00	.4918E+00	.3063E+00
.3077E+00	.7018E+00	.6489E+00	.5737E+00	.4595E+00	.2716E+00

TABLE 7. 10. k TABLEAU FOR TAKEOFF CRASHES

$\gamma_w = -0.10$

α λ	.2000E+00	.3000E+00	.4000E+00	.5000E+00	.6000E+00
.1333E+01	.9147E+00	.8959E+00	.8666E+00	.8157E+00	.7037E+00
.1000E+01	.8809E+00	.8560E+00	.8179E+00	.7528E+00	.6174E+00
.8000E+00	.8481E+00	.8173E+00	.7710E+00	.6935E+00	.5393E+00
.6667E+00	.8162E+00	.7800E+00	.7262E+00	.6379E+00	.4686E+00
.5714E+00	.7852E+00	.7440E+00	.6833E+00	.5856E+00	.4051E+00
.5000E+00	.7552E+00	.7092E+00	.6424E+00	.5366E+00	.3481E+00
.4444E+00	.7259E+00	.6757E+00	.6033E+00	.4907E+00	.2972E+00
.4000E+00	.6976E+00	.6434E+00	.5660E+00	.4478E+00	.2520E+00
.3636E+00	.6701E+00	.6122E+00	.5305E+00	.4077E+00	.2120E+00
.3333E+00	.6434E+00	.5822E+00	.4966E+00	.3704E+00	.1769E+00
.3077E+00	.6175E+00	.5533E+00	.4644E+00	.3357E+00	.1462E+00

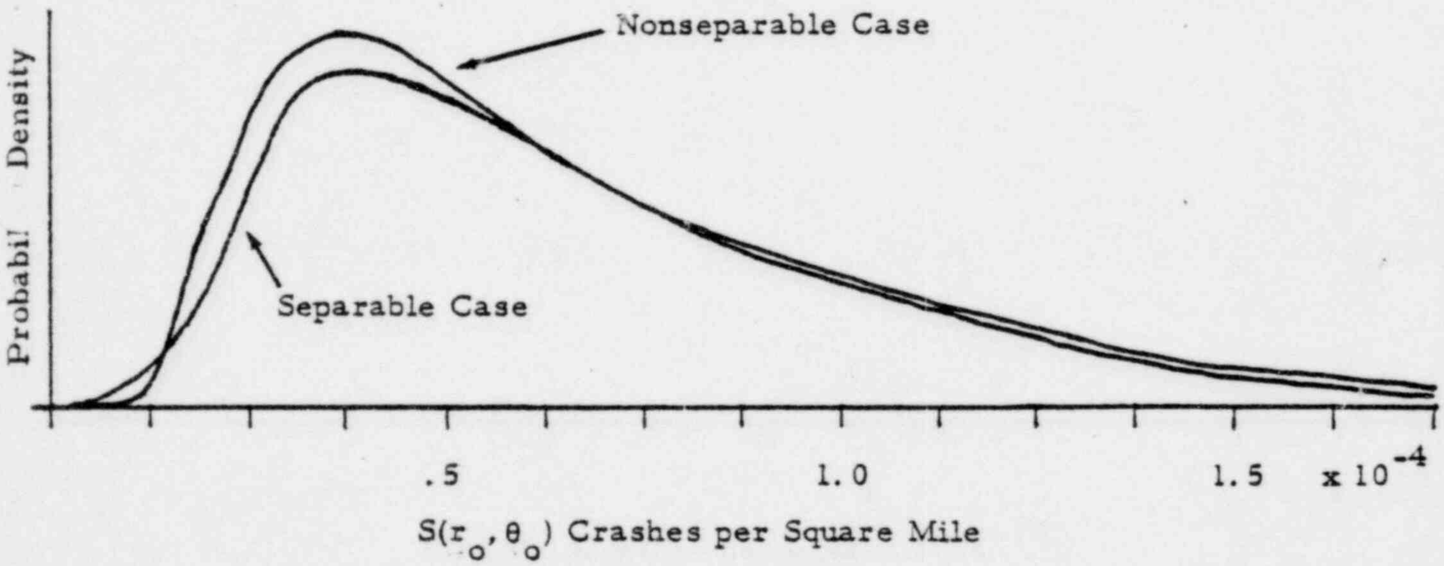

FIGURE 7.1. CRASH DENSITY AT TMI LOCATION
LANDINGS

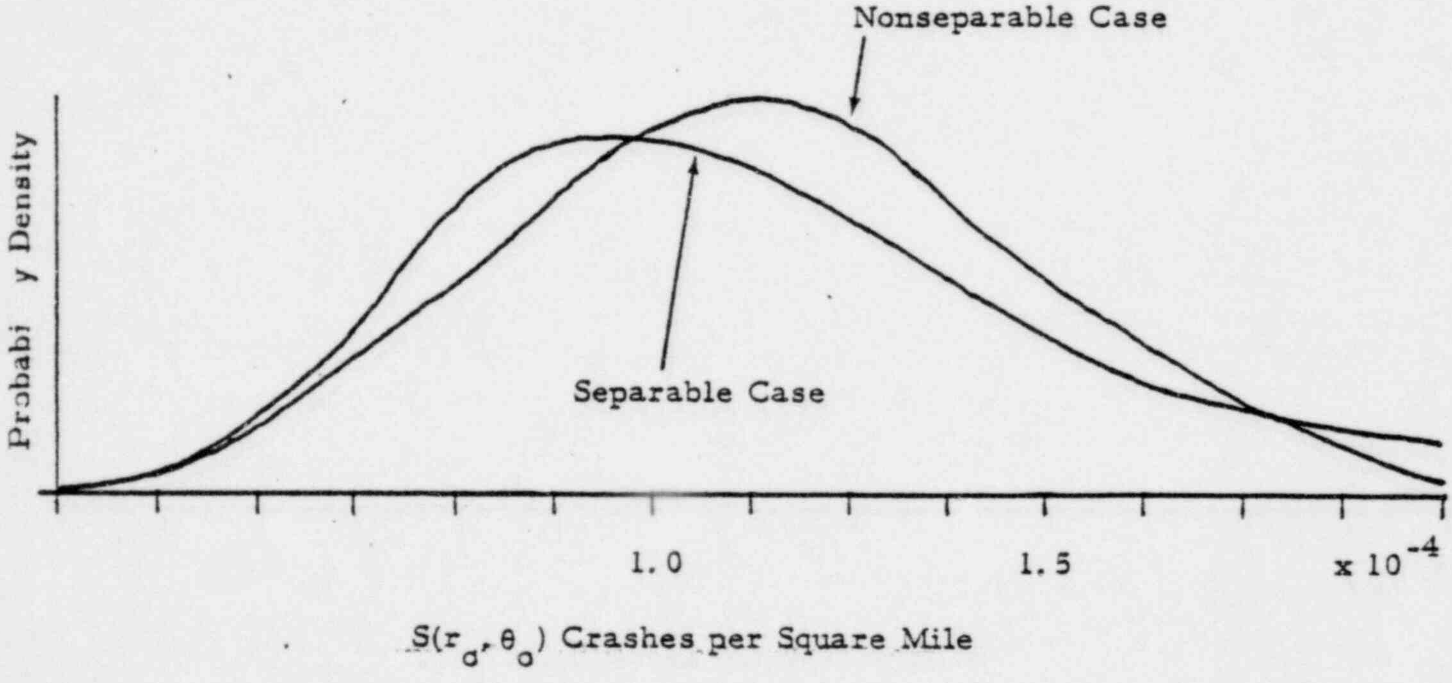

FIGURE 7.2. CRASH DENSITY AT TMI LOCATION
TAKEOFFS

8. SUBQUESTION 3, TIME DEPENDENCE

This question relates to the possibility that the spatial distribution of crashes is itself time dependent, so that we would have nonseparability of space and time. In principle this question can be pursued in the same way as the spatial nonseparability by now allowing R and Θ to be functions of time also. This could be done computationally, for example, by adding terms linear in time to the decay constants λ, μ, and then setting the coefficient of these linear terms by Bayes' theorem using the crash data. The computational work however would now become quite extensive.

More important is the fact that there have been simply too few crashes to allow any meaningful inference to be made on the time dependence of the spatial shape. An attempt to do so would therefore not yield useful results in our opinion, and so we do not pursue this approach any further at this time.

9. CONCLUSION

In summary our answer to the Board's question is as follows:

a. If fitting functions are chosen which are separable in r and θ it follows that our probability curves for the r and θ derivatives can be combined as independent distributions.

b. The actual data on crash location is reasonably in accord with the postulate of separability. This was the conclusion of the NRC statisticians, and is also supported by the Bayesian analysis of the present testimony, as reflected in the final curves of Figures 7.1 and 7.2.

c. Scatter plots of the crash points do not reveal to the eye any obvious time dependence of the spatial crash distribution.

10. REFERENCES

[1] U. S. Nuclear Regulatory Commission, Atomic Safety & Licensing Appeal Board Decision, July 19, 1978, Docket No. 50-320, page 24, Item (3).

[2] Lindley, D. V., "Introduction to Probability & Statistics From a Bayesian Viewpoint," Cambridge University Press, 1970, Part 2, page 15.

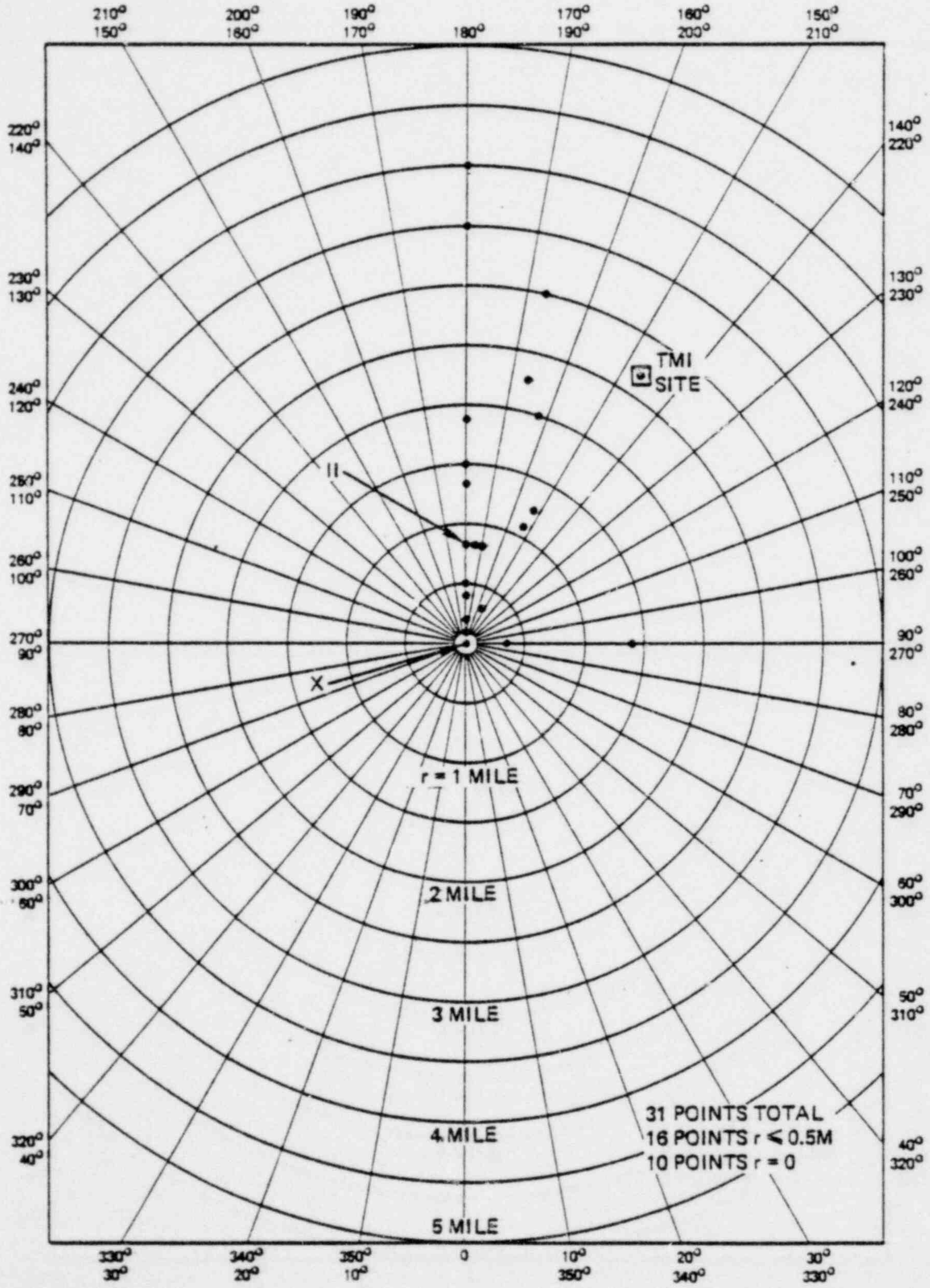

FIGURE 8. 1. SCATTER PATTERN FOR LANDING ACCIDENTS (1956-1964)

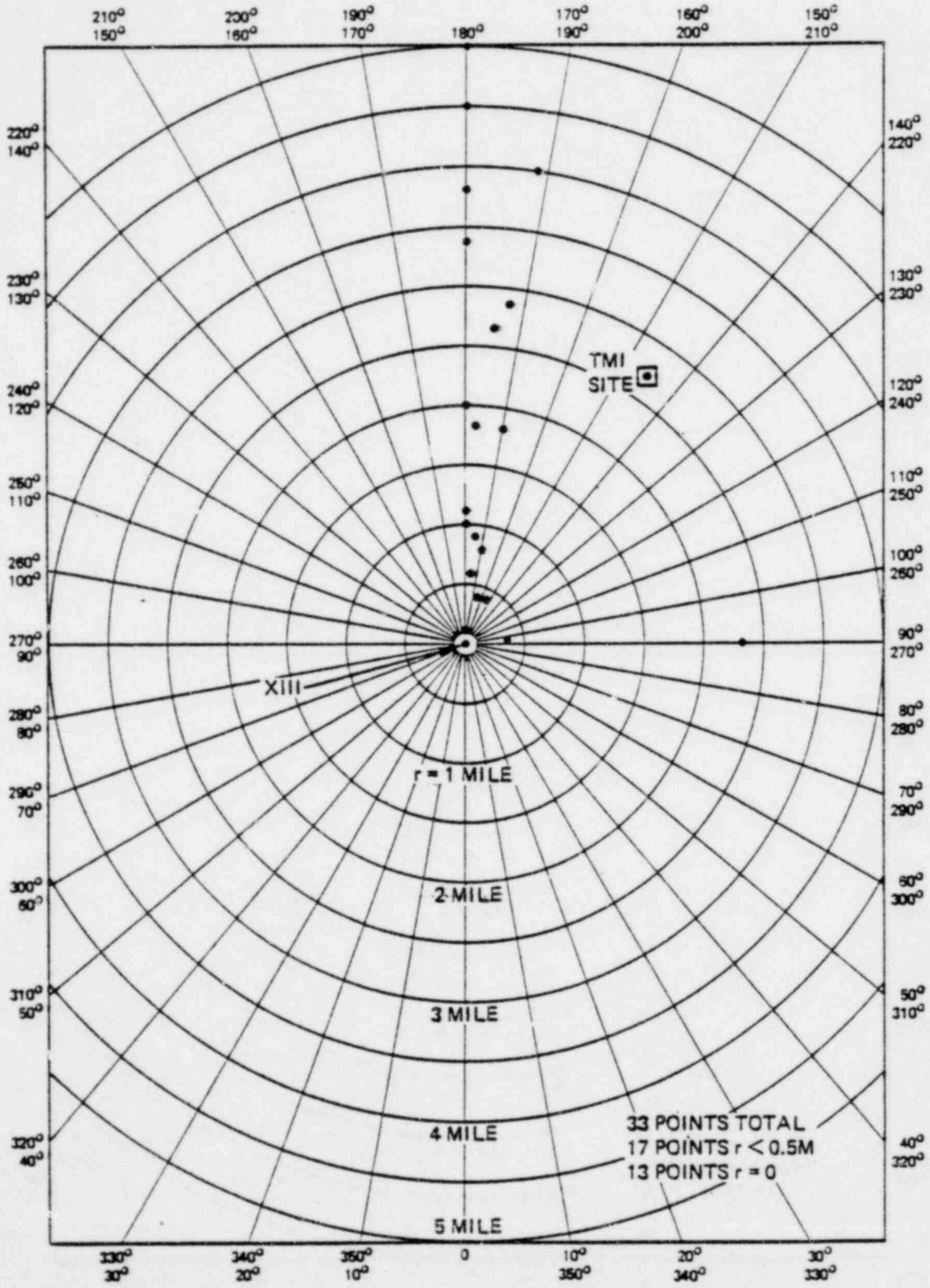

FIGURE 8.2. SCATTER PATTERN FOR LANDING ACCIDENTS (1965-1977)

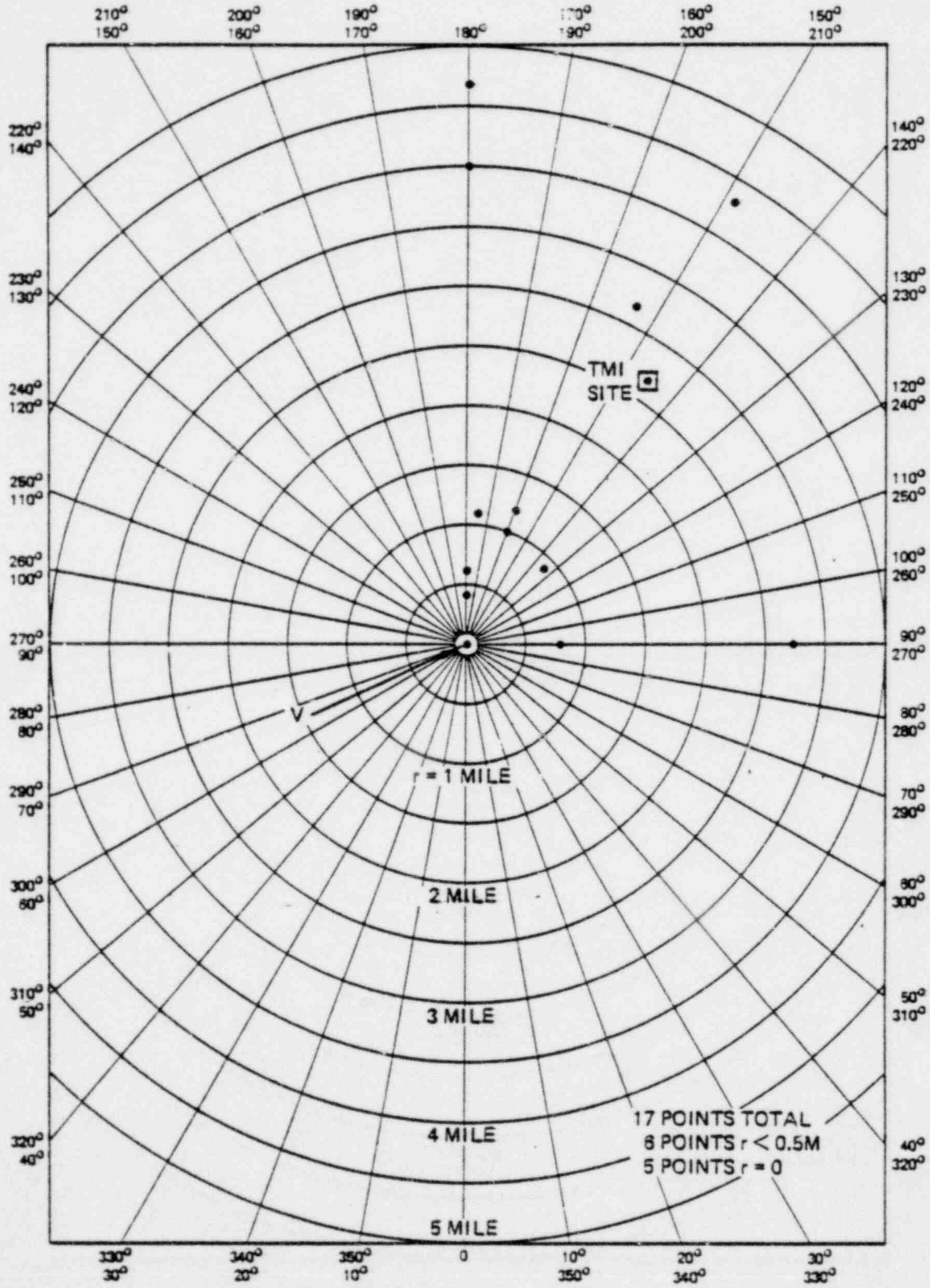

FIGURE 8.3. SCATTER PATTERN FOR TAKEOFF ACCIDENTS (1956-1964)

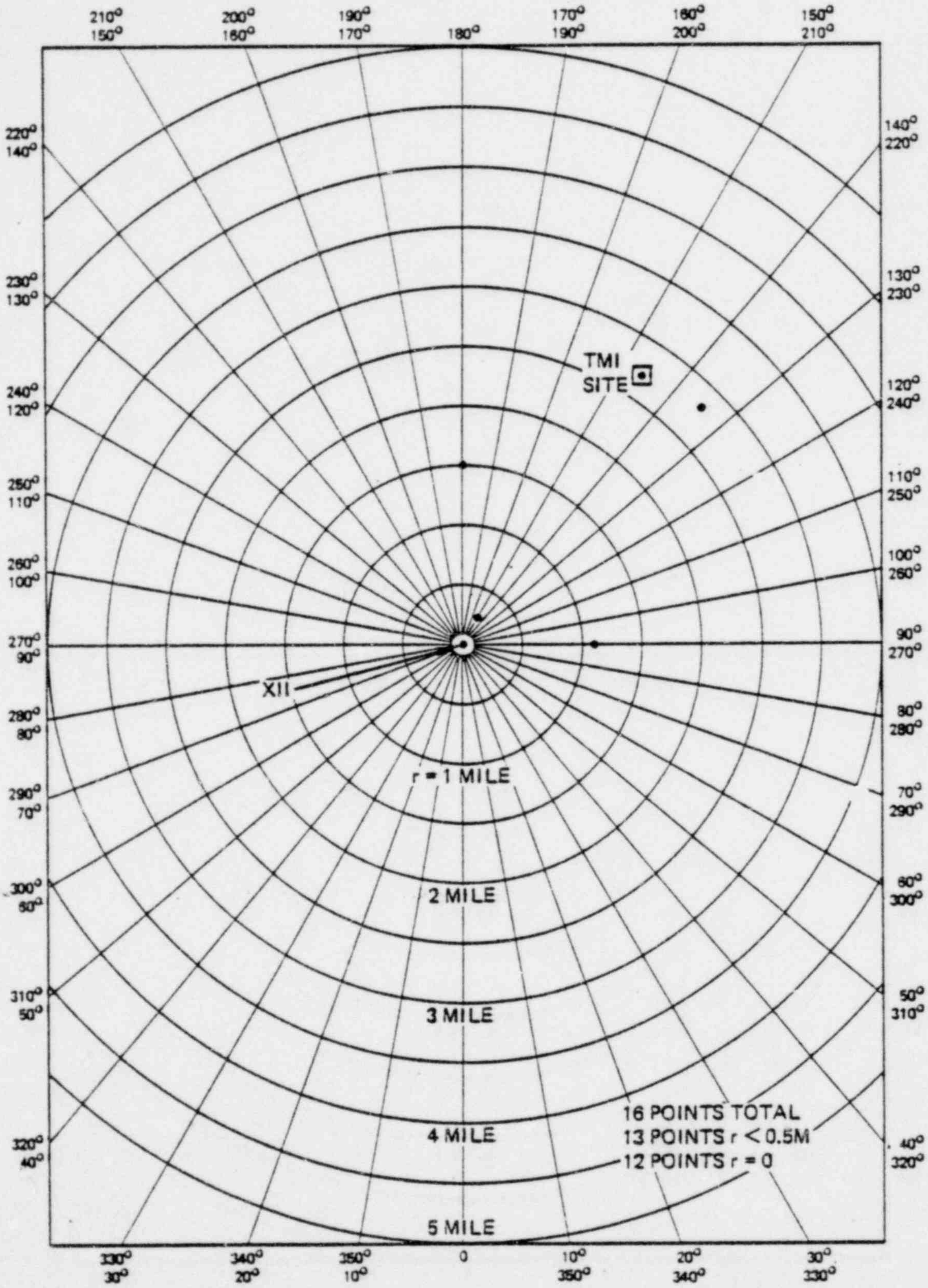

FIGURE 8.4. SCATTER PATTERN FOR TAKEOFF ACCIDENTS (1965-1977)

[3] Benjamin, J. R. and C. A. Cornell, "Probability, Statistics and Decision for Civil Engineers," McGraw-Hill, 1970.

[4] Snedecor, G. W. and W. G. Cochran, "Statistical Methods," Sixth Edition, Iowa State University Press, 1967.

APPENDIX

From (7.2) and (7.5) and dropping subscripts for simplicity we evaluate the likelihood as follows:

A) For $r \geq 0.5$ mile and $\theta > 0$, we have

$$S(r, \theta) = \frac{1}{r}(a\lambda)\, e^{-\lambda r}\, (\alpha\mu)\, e^{-\mu\theta} \quad . \tag{A.1}$$

This is the crash density per square mile and therefore the likelihood of experiencing the set of crash points

$$\left\{\langle r_n, \theta_n \rangle\right\}_{n=1}^{N}$$

is proportional to the product:

$$\prod_{n=1}^{N} \frac{1}{r_n}(a\lambda)\, e^{-\lambda r_n}\, (\alpha\mu)\, e^{-\mu\theta_n}$$

$$= \frac{1}{\left(\prod_{1}^{N} r_n\right)} \left[(a\lambda)^N e^{-\lambda \sum_{1}^{N} r_n}\right] \left[(\alpha\mu)^N e^{-\mu \sum_{1}^{N} \theta_n}\right] \tag{A.2}$$

B) For $r \geq 0.5$ and $\theta = 0$, since

$$\lim_{\theta \to 0+} \Theta(\theta, r) = \alpha + b[1+\gamma(r-2.5)] \tag{B.1}$$

and

$$\Theta(0, r) = 1.0 \tag{B.2}$$

we have

$$\left.\frac{\partial}{\partial\theta}\Theta(\theta, r)\right|_{\theta=0} = -\{1 - \alpha - b[1+\gamma(r-2.5)]\}\delta(\theta) \tag{B.3}$$

where $\delta(\theta)$ is the Dirac delta. Therefore

$$S(r,0) = \frac{1}{r}(a\lambda)\,e^{-\lambda r}\left\{1-\alpha-b[1+\gamma(r-2.5)]\right\}\delta(\theta)$$

$$+\frac{1}{r}ae^{-\lambda r}\,b\gamma\,\delta(\theta)$$

$$= \left[\frac{1}{r}(a\lambda)\,e^{-\lambda r}\right]\left\{(1-\alpha-b)+\frac{b\gamma}{\lambda}[1-\lambda(r-2.5)]\right\}\delta(\theta) \qquad \text{(B. 4)}$$

Therefore the likelihood of experiencing the set of crash points

$$\left\{\langle r_m, 0\rangle\right\}_{m=1}^{M} \qquad \text{(B. 5)}$$

is proportional to the product:

$$\prod_{m=1}^{M}\left[\frac{1}{r_m}(a\lambda)\,e^{-\lambda r_m}\right]\left\{(1-\alpha-b)+\frac{b\gamma}{\lambda}[1-\lambda(r_m-2.5)]\right\}$$

$$=\frac{1}{\left(\prod_{1}^{M} r_m\right)}\left[(a\lambda)^M e^{-\lambda\sum_{1}^{M} r_m}\right](1-\alpha-b)^M \prod_{m=1}^{M}\left\{1+\frac{\frac{b\gamma}{\lambda}[1-\lambda(r_m-2.5)]}{(1-\alpha-b)}\right\}$$

(B. 6)

C) At $r=0$ we similarly have a delta function

$$S(r,\theta) = (1-a)\delta(r) \qquad \text{C. 1)}$$

and therefore the likelihood of experiencing ζ crashes at $r=0$ is

$$(1-a)^{\zeta} \qquad \text{(C. 2)}$$

D) For crashes in the range $0<r<0.5$ mile we regard the angle as not being measured meaningfully. Thus we simply consider that we have no θ values for these points. The probability of a strike at a value r in this range is therefore simply

$$-\frac{d}{dr}R(r) = (a\lambda)\,e^{-\lambda r} \qquad \text{(D. 1)}$$

and therefore the likelihood of experiencing the set of crash radii $\left\{r_h\right\}_{h=1}^{H}$ is proportional to:

$$(a\lambda)^{H}\,e^{-\lambda\sum_{1}^{H} r_n} \qquad \text{(D. 2)}$$

E) For $r \geq 0.5$ and $\theta = \pi/2$, since

$$\lim_{\theta \to \frac{\pi}{2}-} \Theta(\theta, r) = \alpha e^{-\mu\frac{\pi}{2}} + b[1+\alpha(r-2.5)] \qquad \text{(E. 1)}$$

and

$$\lim_{\theta \to \frac{\pi}{2}+} \Theta(\theta, r) = 0.0 \qquad \text{(E. 2)}$$

we have

$$\frac{\partial}{\partial\theta}\Theta(\theta, r)\Bigg|_{\theta=\pi/2} = -\left\{\alpha e^{-\mu\frac{\pi}{2}} + b[1+\gamma(r-2.5)]\right\}\delta(\theta-\frac{\pi}{2}) \qquad \text{(E. 3)}$$

and

$$\begin{aligned} S(r, \pi/2) &= \frac{1}{r}(a\lambda)\,e^{-\lambda r}\left\{\alpha e^{-\mu\frac{\pi}{2}} + b[1+\gamma(r-2.5)]\right\}\delta(\theta-\frac{\pi}{2}) \\ &\quad - \frac{1}{r}\,a e^{-\lambda r}\,b\gamma\,\delta(\theta-\pi/2) \\ &= \left[\frac{(a\lambda)}{r}\,e^{-\lambda r}\right]\left\{\left[\alpha e^{-\mu\frac{\pi}{2}} + b\right] - \frac{\gamma b}{\lambda}\,[1-\lambda(r-2.5)]\right\}\delta(\theta-\frac{\pi}{2}) \; . \end{aligned} \qquad \text{(E. 4)}$$

Therefore the likelihood of experiencing the set of crash points:

$$\left\{\langle r_v, \pi/2 \rangle\right\}_{v=1}^{V} \tag{E. 5}$$

is proportional to:

$$\left[(a\lambda)^V e^{-\lambda \sum_1^V r_v}\right] \prod_{v=1}^{V} \left\{\left[\alpha e^{-\mu \frac{\pi}{2}} + b\right] - \frac{b\gamma}{\lambda}[1-\lambda(r_v-2.5)]\right\} \tag{E. 6}$$

F) Thus, putting (A. 2), (B. 6), (C. 2), (D. 2), and (E. 6) together we see that the likelihood of experiencing the full set of crash data is proportional to

$$\left[(1-a)^{\zeta}(a\lambda)^{N+M+H+V} e^{-\lambda\left(\sum_1^N r_n + \sum_1^M r_m + \sum_1^H r_h + \sum_1^V r_v\right)}\right] \times$$

$$\left[(1-\alpha-b)^M (\alpha\mu)^N e^{-\mu \sum_1^N \theta_n}\right]$$

$$\times \prod_{m=1}^{M} \left\{1 \times \frac{\frac{b\alpha}{\lambda}[1- \ (r_m-2.5)]}{(1- \ -b)}\right\} \times \prod_{v=1}^{V} \left\{\left[\alpha e^{-\mu \frac{\pi}{2}} + b\right] - \frac{b\alpha}{\lambda}[1-\lambda(r_v-2.5)]\right\} \tag{F. 1}$$

which are the four terms given in (7. 6) through (7. 10).

2b

MR. TROWBRIDGE: I have no additional questions.

CHAIRMAN ROSENTHAL: All right.

Now, has there been any agreement reached between the staff and the intervenors and, possibly, the Commonwealth as to the order of cross-examination?

DR. KEPFORD: Isn't it customary for the intervenors to go last?

CHAIRMAN ROSENTHAL: I don't know whether there's any custom. I try to accommodate the wishes of the parties.

DR. KEPFORD: I'm not particular, Mr. Chairman.

CHAIRMAN ROSENTHAL: All right.

Mr. Treby?

MR [illegible]: There, there was no discussion. I don't believe that is the custom, but the staff only has one or two questions; and we'd be happy to go first.

CHAIRMAN ROSENTHAL: Well, okay. Proceed.

CROSS-EXAMINATION

MR. TREBY: Mr. Vallance, I would direct your attention to your March 20th testimony, and particularly page 4 of that testimony. Do you have that before you?

MR. VALLANCE: Yes, I do.

MR. TREBY: On page 4 of that testimony, you have an analysis D-sub theta. This appears to be just for takeoffs, is that correct?

MR. VALLANCE: Yes.

MR. TREBY: Did you perform such an analysis with regard to landings?

MR. VALLANCE: Well, in the course of preparing the January 9th testimony, I of course did prepare such an analysis.

The, the March 10, the March 20th testimony was prepared as an intent to answer some specific questions raised by the hearing board. And the question that raised in ALAB 525 dealt just with takeoffs, I believe.

MR. TREBY: So that you did not physically write down this March 20th testimony, the numerical computations you would go through for landings.

MR. VALLANCE: Yes, that's, that's correct. March 20th was simply was a, a way of clarifying the, the arithmetic that was utilized; and I just did it for takeoffs as, to provide an example.

MR. TREBY: If you did do it for landings, could you indicate what the numerical inputs would be? And I don't expect you to do the math now. But could you just tell us what the inputs would be?

MR. VALLANCE: I, I really couldn't do that off the top of my head. I could certainly do it sometime, but I don't have it in, in, at my fingertips right now.

DR. JOHNSON: Mr. Truby -- I mean Treby; excuse me. Are you on page 4 of Mr. Vallance's March 20?

MR. TREBY: That's correct.

28

Tape 5

Tape 6:

DR. JOHNSON: Okay. Thank you.

MR. TREBY: Those numbers could be determined by looking at your January 9th testimony.

MR. VALLANCE: Yes, that's correct.

MR. TREBY: I have no further questions.

CHAIRMAN ROSENTHAL: Dr. Kepford?

DR. KEPFORD: Mr. Vallance, if I recall your previous testimonies correctly, all your calculations have been based on the assumption that the aircraft gets on the center way, runway centerline extended and follows a straight-in path, is that not correct?

MR. VALLANCE: No, that is not.

DR. KEPFORD: What has been the path that, that --

MR. VALLANCE: The, the analysis we prepared was basically to create a correlation of hit locations for aircraft accidents with respect to the orientation of the runway that was being utilized. There, there is no assumption that the aircraft was or was not on the extended runway centerline.

(Pause.)

DR. KEPFORD: Would your computations be affected at all by the kinds of flight paths that have been discussed this morning whereby planes approximately loop around the island.

MR. TROWBRIDGE: Mr. Chairman, I'm going to have to object. It's just a matter of time. I think Dr. Kepford is entitled to cross-examine it on the supplemental testimony.

He is not entitled to go back and start the process over again that we went through a year ago on Mr. Vallance's basic testimony.

CHAIRMAN ROSENTHAL: I'll allow this question to stand.

But, Dr. Kepford, I think that you should bear in mind that as Mr. Trowbridge indicates, we're not going back to Square 1 here. We are dealing with certain specific matters that were raised essentially in ALAB 525. But the witnesses can answer this question.

MR. VALLANCE: I would say that with respect to the, the probability of a hit at the Three Mile Island location, what I've heard today I don't believe has any effect on the calculations that, that we did. I think our calculations are consistent with what we heard today, for that location.

Now, were the location further out, it might have an effect on it.

(Pause.)

DR. KEPFORD: I have no further questions, Mr. Chairman.

CHAIRMAN ROSENTHAL: All right. I think that --

Ms. Carter, do you have any questions?

MS. CARTER: No, no questions.

CHAIRMAN ROSENTHAL: Well, I think the Board probably does. And maybe --

DR. BUCK: I have some later on, but not right now.

CHAIRMAN ROSENTHAL: Excuse me.

(Pause.)

CHAIRMAN ROSENTHAL: All right, we'll recess at this point for --

DR. KEPFORD: I have just a couple of more questions, which can be answered very quickly.

CHAIRMAN ROSENTHAL: All right. Well, okay.

DR. KEPFORD: Mr. Vallance, have you or the applicant identified any new aircraft flying into Harrisburg International that have not been previously identified?

MR. TROWBRIDGE: Objection. This has nothing to do with Mr. Vallance's testimony.

DR. KEPFORD: Mr. Chairman, a couple of weeks --

CHAIRMAN ROSENTHAL: What does it have to do with his testimony?

DR. KEPFORD: It happens to do with, well, whether or not Boeing 747's land at Harrisburg International Airport.

Now, this is a point, an item we identified over a year ago and has been now so testified by Captain Billie, I believe, that he has landed Boeing 747's here; and I'm wondering whether or not it shows up in their latest tabulations. It was, after all, 1979 that this event took place.

CHAIRMAN ROSENTHAL: Well, I'll allow that question to --

DR. KEPFORD: And would be new data and subject to inclusion in the tabulations.

CHAIRMAN ROSENTHAL: All right, I'll overrule the objection.

MR. VALLANCE: Well, the, the analysis we prepared was more or less independent of exact types of aircraft; so in a sense it includes 747. We lumped heavy aircraft all together into one category and did the analysis on that basis.

Now, whether it was a 747 or a DC-8, we didn't feel we had enough data to distinguish.

(Pause.)

DR. KEPFORD: Do you personally know whether or not 747's have landed at Harrisburg International?

MR. VALLANCE: They occasionally go in there, yes.

DR. KEPFORD: I have no further questions.

CHAIRMAN ROSENTHAL: All right, we'll take our luncheon recess. It's now almost 12:30. I would be hopeful that an hour and 15 minutes would be adequate, so we'll resume at quarter of 2:00.

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(Thereupon, at 12:28 p.m., the luncheon recess was taken.)

DR. JOHNSON: Mr. Vallance, you've marked plenty of testimony; I think I understand everything fairly well, particularly with regard to the normalization. However, on page six and on one of the earlier pages, you discussed why the integration goes from zero to 180 degrees rather than zero to 90 degrees, and indicate that you have a function which is defined from zero to 180 degrees -- is definable from zero to 180 degrees and therefore, you use the full angular range to get your normalization factor.

Don't the data lose validity past an angle of 90 degrees? We were asked -- you were asked to get the data on airplane crashes from zero to 5 miles away from the runway. It would seem to me that a crash at an angle greater than 90 degrees is at a negative radius or some undefined radial position with regard to the ends of runways.

I don't think there is any data in the 90 to 180 degree range and I just don't understand why you would expect your function to be valid in that range.

MR. VALLANCE: Let me try to speak to the point. I did indeed assume that the function applied all the way to 180 degrees. You are quite correct. As it turns out, in our data base, we did not have any accident hits that were at angles greater than 90 degrees, but the rationale was that there could have been.

I don't really look upon that as a negative value of

R. For example, suppose it were out in the 4 to 5 mile range, you could almost equally well have an accident at 100 degrees as you could at say 85 degrees. I would think there would be a continuous probability distribution over that interval.

So, therefore, the rationale I used, and I might add, I used this throughout the analysis, was to try to smooth the data over the total boundaries of the data base that we were working with, and hence, the use of 180 degrees.

Now, I did run a calculation to determine the effect of just going -- using the data and truncating at 90 degrees and I indicated what effect that had in my March 20th testimony, I believe, that it would increase the results by about 15 percent for the angular distribution factor.

Really, I feel that there is a tail on the probability distribution. It is getting very small but there is a finite probability at greater than 90 and the model that we have does, in fact, account for that, even though we didn't have any data there.

Again, I am smoothing data --

DR. JOHNSON: Well, you don't have any data there not because there were no crashes there but because you didn't look for data there. That's one of my problems.

MR. VALLANCE: Oh. No, sir; we did look for data there; I did.

DR. JOHNSON: There were no --

MR. VALLANCE: Early in this analysis, we did have a data point out there, but later it was dropped for some reason. I cannot remember exactly why it is not being applicable.

DR. JOHNSON: Do you have any explanation for the fact that there are three data points at precisely 90 degrees? I think either in the table on Figure 5 in your March 20 testimony, we may have discussed this before.

MR. VALLANCE: I don't believe I have any explanation for that, no, sir.

DR. JOHNSON: In other words, could these possibly have been crashes at angles greater than 90 but put back into the data base at 90 --

MR. VALLANCE: No, no, no. I am quite certain that's not the case. I am quite certain and the NRC could perhaps corroborate this but I believe that our data base did show them as occurring at 90 degrees.

DR. JOHNSON: Of course, your distribution would not predict or does not account for this peaking effect at 90 degrees in any way?

MR. VALLANCE: That's correct.

DR. JOHNSON: I further understand, from your testimony, that the correlation which you have developed is not valid for positions right along the extended runway within zero or within 5 miles?

MR. VALLANCE: It is a special case of the correlation; that's correct. You'd have to use a different -- I mean the correlation, I would say, is valid, but you don't use the negative exponential, you jump to a different correlation.

DR. JOHNSON: Well, you have not shown the value that You would use for that case?

MR. VALLANCE: Well, I think in the March 20 supplement I think I indicated what it would be -- let me look.

DR. JOHNSON: You gave how many if's there were in that --

MR. VALLANCE: Well, like near the bottom of pagefive, the next to the last paragraph, I say, "For hits on the extended runway center line, D of R is as given on page 22 of the referenced testimony D of ceda would have a value of 4 over 14."

The same thing would occur on the runway at R equals zero. There is another discontinuity in the model.

DR. JOHNSON: Okay. I don't have anymore **questions** of you right now, Mr. Vallance. I appreciate your considerable effort in answering the questions in an angle at 5.5. Quite frankly, I will not admit to being totally understanding of what You have done here.

Could you sketch for me the argument and analyses you use to demonstrate that if the variables are expressible or separable and can be expressed in separate functions, that is proof or indication that they are independent, except question one, I believe.

DR. KAPLAN: I have one or two. So the question is if this spacial distribution of factors -- if that spacial shape is separable in Rn Pheta?

DR. JOHNSON: Yes.

DR. KAPLAN: Are the probability distributions that we have for the R derivative and the Pheta derivative at the point in question, are the probability distributions independent?

DR. JOHNSON: Yes.

DR. KAPLAN: Okay, so two independent notions, that's really what needs to be pulled apart here, the notion of separability of the spacial shape and the notion of independence of the probability distributions.

DR. JOHNSON: You say they have to be torn apart --

DR. KAPLAN: Conceptual --

DR. JOHNSON: Conceptually.

DR. KAPLAN: Well, they're two different things.

DR. JOHNSON: I think you say that if -- I thought you said that if they are separable, it implies statistical independence.

DR. KAPLAN: That's right, in effect.

DR. JOHNSON: So they are connected by the --

DR. KAPLAN: They are connected but you have to first Pull them apart conceptually to understand that they are two different things and then one does imply the other, in effect.

DR. JOHNSON: Well, actually what I'm asking is why does one imply the other --

DR. KAPLAN: I understand, I'm just restating the question. Let's go through the item. The argument is given, beginning on page 11. So here we are taking the point of view that what we are trying to find is the shape, the spacial shape, and we have a certain amount of evidence.

So the thing we don't know is a spacial shape. We, therefore, embed that thing we don't know in a space of spacial shape, in a function space. Then we are going to use the evidence at hand to elect a probability distribution over that function space.

In order to permit that, we have to take the discreet approximation to the functions base, some discreet set of functions.

If the particular set we choose then is a separable set, Equation 61, we say how do we erect a probability distribution on this set of functions, this discreet set of functions? The answer is you use base theorem to put a probability on top of each one of those, to assign a probability to each one of those, from the evidence.

If you now go through that process, and that is on pages 12 and 13 --

DR. JOHNSON: Now, let me -- that process has assumed separability opriori --

DR. KAPLAN: Separability, yes. We've assumed separability of the class of functions that we areusing to match. Then we say, with this class of functions, here is the evidence on where the classes actually occur. What does that tell us about the state of confidence we have for each member of that class of functions?

So you go through base theorem which argues effectively this way. It says with respect to each member of this class of functions, if that were the true answer, how likely would it be that we would have experienced the set of crash points that we did, in fact, experience? In light of that, we then get an answer to the reverse question, namely, given that we did experience what we did experience, how likely is it that function is the right one?

Now if you carry out the algebra of that, you come down to Equation 610 -- let's say 608. Notice that the IG terms and the KL terms there are all separate except in the P0 quantity, which is the prior distribution.

So now we say if the prior is separable, as in equation 609, then the whole thing pulls apart as in Equation 610 into two separable pieces. The equation pulls apart into an IG piece and a KL piece, which, in effect, then says that the two probability distributions are independent.

This probability 610 that you get by carrying out this process is the same probability that you would get if you separately calculated the probability distribution for the radial derivative and separately one for the Pheta distribution and then multiply those two using independent multiplication.

So the only -- so that separability implies independence with the little added proviso that the prior is separable, that Your prior state of knowledge on the space of functions is separable.

DR. JOHNSON: When your prior was separable because you set it up that way; wasn't it? In other words, you assumed a prior that was separable?

DR. KAPLAN: In the original testimony?

DR. JOHNSON: Yes?

DR. KAPLAN: I guess you could say, in effect, yes, in the sense that we did the radial part and then we did the Pheta part and multiplied the two together. That's implicitly equivalent to a separable prior, yes.

DR. JOHNSON: Okay. Let me then go on a little further to the second question in which you assumed that the distributions were not separable, on page 15, for instance, and you have a linear connection between the spacial and the radial distribution.

I believe your argument there was that the best probability --

DR. KAPLAN: That the data itself --

DR. JOHNSON: The data itself supported a probability distribution in which the Gamma Sub W was zero; is that -- or the coefficient was zero?

DR. KAPLAN: The data itself showed a preference for a separate function as the fitting function. That was kind of an incidental observation. The real result is that allowing the space of functions to be non-separable gives you pretty much the same final curve.

So in this part of the argument, we are not so much arguing that there is separability anymore, we are saying, allowing non-separability, we get the same result.

DR. JOHNSON: Which of these points -- you obviously think the second part of that is the most important?

DR. KAPLAN: I think that's got the most clout, sure. Nothing is truly separable. The issue of whether something is separable or not is really, in a sense, a semantic or academic argument; nothing is truly separable, nothing in nature.

So the real way to handle the question, or the way to handle the matter, the way to ask the question is, allowing for there to be non-separability, various degrees of non-separability, so broadening our approach to allow that, does our answer change?

The answer to that question is no, essentially no. I think that's got a lot more clout.

DR. JOHNSON: Now, in the ultimate calculation of hit probability, you made a convolution of three factors, the crash rate, the radial and the spacial distribution?

DR. KAPLAN: Yes.

DR. JOHNSON: In your view, would it be possible to create or to formulate this problem as a two function problem as opposed to a three function problem, one of the functions being the radial crash probability per operation -- in other words, normalize the radial function to the per operation crash rate at adding human distance from the end of the runway and to -- which you would then multiply by an angular distribution to get the hit Probability at a particular angle in a particular radial position?

DR. KAPLAN: So, in asking now for a two function formulation, you are lumping the first two together?

DR. JOHNSON: I'm lumping crash rate and radial position. I realize this would have to be done for each of the four classes.

DR. KAPLAN: Oh, yes. So whatever class of aircraft You are talking about, our operations, in principle, yes. Remember in the crash rate question, what we were looking at there was the time variable. That was the crash rate variable of time.

So you are now asking could one regard time and radius as --

DR. JOHNSON: No, I didn't want to get quite that complicated; I was thinking more in terms of things that the staff did in which they did not use a -- they used a fixed crash rate -- I don't think I'll ask you anymore questions on that.

DR. KAPLAN: I feel I haven't satisfied you some how.

DR. JOHNSON: That's not the case on that. You are not the one I should be asking. I have no more questions.

DR. BUCK: I think I should congratulate you on the clarity of your testimony considering the complexity of the subject matter. I don't pretend to say I understand everything you said here but I think I do understand your process very well. I think it was very well written.

CHAIRMAN ROSENTHAL: Are there any further questions of this panel by counsel?

DR. KEPFORD: Mr. Chairman, I have one question which is sort of related and I don't really know how to ask it. It seems to me with the information that's been presented by the pilots this morning, we are faced with a much different situation than we have been previously as far as the computations go because if a plane comes in from the northwest, south of the plant, on the order of a mile and a half south of the plant, then indeed the flight path from the first time it is a mile and a half from the plant, is quite a bit longer than 5 miles as it circles past the plant.

I really wonder how appropriate -- if that kind of situation is taken into account by these models, where, in effect, the plant is a constant distance from the aircraft, more or less, or on the order of 5 or 6 miles, I guess I am asking Mr. Vallance that; do you understand what I am getting at?

MR. VALLANCE: Yes, I believe so. I think there is some effect. I can't just brush it off entirely and say there is absolutely no effect. I said this morning that there was essentially no effect and I'll stick with that. That is in the context -- by a heavy aircraft.

I think the smaller aircraft have a tendency to fly closer in; heavy aircraft, if they are coming in from the west, Perhaps in a number of cases, they fly the pattern shown on the chart that was prepared this morning. If they are coming from the east, they don't fly that pattern. So your question just really deals with planes that are coming in from the west.

The model that we used looks at all airports throughout the U.S. and collects pit location data at all airports. At all airports, the exact details of the flying patterns vary from one airport to another. So in a sense our data collection and our data base reflects the kind of variation that actually exists across the United States as a whole.

If we then try to apply that to a specific landing pattern, if all flights came in the way you are describing, yes, I think there clearly should be some effect and we would have to modify the model to account for it.

I would argue that only a small portion of them come in that way.

DR. KEPFORD: Would, in fact, the fact that a plane is coming in that way,for a significant portion of that distance is banked bias the probability of which direction the plane would go if it were going to crash?

For instance if it were banked to the left, would there be a higher probability that if it were going to crash, it would go left as opposed to leveling off and going right?

MR. VALLANCE: Well, that would depend entirely on the type of event that caused -- that initiated the accident, if it is a control surface failure or something like that. I just really couldn't answer your question unless you are more specific on the type of failure mechanism.

Remember that the centrifugal force of the airplane would be in the direction away from the plant.

DR. KEPFORD: Centrifugal or centripetal?

MR. VALLANCE: I'm not sure. Centrifugal force, I think I mean the outward component; if you are making a circle -- I believe I mean centrifugal.

DR. KEPFORD: If, for those portions of the numbers of heavy aircraft flights that come in from the northwest as diagramed there, would it be appropriate to measure or multiply the area of the plant by, for instance, a distance factor, to represent how long the -- or for what distance the aircraft is close to the plant?

MR. VALLANCE: Well, that would be one possible way of doing it. I'd have to think more about it to know the best way but I guess that's one possibility.

DR. KEPFORD: I have no further questions, Mr. Chairman.

DR. JOHNSON: I'd like to ask some questions related to just what Dr. Kepford has asked. Are you aware of any particular difference between the type of landing patterns which exist at Harrisburg International and the type of landing patterns that exist in other airports?

MR. VALLANCE: Well, as I mentioned earlier, it will differ from one airport to another. It depends on local terrain features and whether other airports are in the vicinity. There are a number of considerations.

I don't have at my fingertips a detailed comparison of whether the Harrisonburg is typical in the approach or not.

DR. JOHNSON: If an airplane comes into an airport, is it not normal for an airplane to enter a landing pattern that includes a downwind leg turn to a base leg, then a turn into an approach at almost any airport?

MR. VALLANCE: Yes; it is, but depending on the terrain features, it may be a series of right turns or left turns.

DR. JOHNSON: Or both, depending --

MR. VALLANCE: Well, it could be both.

DR. JOHNSON: Well, I think one of the pilots this morning indicated that the normal was a series of left turns which would be the west coming -- the plane coming from the west flying south of Harrisburg and then two left turns into the landing or into the bearing of the runway.

Of course if he had to land on runway 13, the same sort of thing would bring him north of the plant with two left turns. Thus, the point I'm trying to ask about is that the data base that you use, the only thing that specifies what happens at the airport is that the plane leader is landing or taking off and that there is nothing in the data base relative to the [illegible] traffic pattern at the airport at all. It is just the spacial distribution of crashing, whatever the pattern is; it does not --

MR. VALLANCE: Yes.

DR. JOHNSON: Does the data for landing crashing illustrate a pattern which reflects these turns into the plane -- I mean into the landing path and the turns from the downwind leg into the base leg and then onto the final leg?

MR. VALLANCE: Well, I would say yes, it reflects it to the extent that actually it occurred at the airport where the event happened that is in our data base now. That's what I referred to earlier and I am unable to take the data base apart and tell you exactly whether they had a right or left hand pattern on every incident.

What we do is compile the entire thing and then we fold it over and make it symmetrical on both sides of the runway, the angular distribution to minimize any bias that might have been in the data base as originally collected.

DR. JOHNSON: What does the data base say in regard to landing crashes?

MR. VALLANCE: With respect to angular distribution?

DR. JOHNSON: Yes.

MR. VALLANCE: Well, the raw data indicated that there were roughly a similar number of data points on both sides of the runway -- of the extended runway center line.

DR. JOHNSON: But were they widely distributed or were they narrowly distributed above the flight path extended?

MR. VALLANCE: Well, they were narrowly distributed about the flight path extended. I mean the quantitative data are in the testimony but they were rather tightly distributed about the extended flight path.

DR. JOHNSON: Does that indicate to you that airplanes had trouble during the maneuvering to get into the flight path or that they had trouble once they got on it?

MR. VALLANCE: I would say that the latter -- the preponderant number of accidents are due to the aircraft, for some reason, flying into the ground while it is on its final approach. Generally speaking, the aircraft has been on or very close to the extended runway center line.

There are, of course, exceptions to that, for example- the 90 degree hits you mentioned earlier. These are planes that were probably out circulating on a base leg or something like that.

DR. JOHNSON: The 90 degree hits that you just referred to, were they the ones that I was referring to earlier?

MR. VALLANCE: Well, you mentioned earlier that a couple of 90 degree hits occurred at Seta equal 90 and I would assume that those were aircraft that might have been --

DR. JOHNSON: Do you recall whether they were landing or takeoff crashes?

MR. VALLANCE: I don't recall but it is in the testimony. We could check it.

DR. JOHNSON: Well, the testimony I was referring to, which is the Figure 5 of your March 20 testimony, which is a plot of takeoff activity, I don't believe there is such a peak at 90 degrees for landing action.

Thank you very much. I have no further questions.

DR. KAPLAN: I have a couple on this same issue. Again, assuming the same flight pattern, if indeed as I think -- I don't remember -- one of the pilots said this morning that TMI serves as a day and night beacon. Is TMI indeed a random point at which accidents might occur or is there some bias introduced by the fact that it is a beacon?

MR. VALLANCE: The message I got from the pilot testimony was that they use it sort of as an offset reference point. It is a visual aide for them to get into the landing pattern and if they try to fly right over it, they, of course, lose it as a visual aide. If they use it as an offset visual aide, then they are able to make benefit of it.

I think that would suggest, in general, that they then fly over the plant at some distance so that they can still see it.

DR. KAPLAN: Of course if they fly right over it, they still know where it is; don't they?

MR. VALLANCE: Well, after they get within a certain distance, they lose sight of it.

DR. KAPLAN: Of course.

MR. VALLANCE: If they are offset, they can see it continuously.

DR. KAPLAN: Sure. If indeed they followed that path in, the one we have been talking about, or indeed RN Theta independent variables?

MR. VALLANCE: Well, I suppose for those particular flights, there may not be as complete an independence as there would be for a number of the other flights that are either coming straight in or flying randomly from the other side of --

DR. JOHNSON: I would like to understand what you mean by RN Theta, Dr. Kepford, in this case. RN Theta in the discussion that I had with Dr. Kaplan referred to the coordinates of a crash. Now you used RN Theta -- I don't understand what you mean by them.

DR. KAPLAN: Well, I am using RN Theta now more as the coordinates of the plane in terms of RN Theta and of course, there is the third one to define at all times, the position of the airplane which is the altitude, Z, H or whatever you want to call.

As the plane would follow a path in there, using TMI as a beacon, my question is, in flying around it, are the variables, RN Theta, in that situation, mathematically independent?

DR. JOHNSON: Well, you are perfectly entitled to ask that question. The only point that I am making is that in this particular case, RN Theta represent the coordinates of an airplane in flight. The previous discussion was relevant to a series of data in which the spacial distribution of crashes were tabulated. That's my only point.

DR. KAPLAN: Well, I guess I am not phrasing my question properly. Would the flight path that we have been talking about cast -- cause to be questioned the assumption of independence of RN Theta for crash data?

MR. VALLANCE: Well, I think there is a factor there and let me speak to it again. If an aircraft is coming in flying in the southeast direction, making a left turn after it passes a plant, Three Mile Island plant, using Three Mile Island as a reference, then those particular aircraft are repetitively flying over that type of a pattern.

I guess you would say if we tried to model that, we would probably come up with a higher probability density of a hit occurring under that exact path than we would in the model that we actually used.

On the other hand, the message again that we got from the pilots is that they do not fly over the plant but rather they stay roughly that mile and a half distance away from it and make a turn around it.

So I think that would mean that the location of the plant, there is a kind of hole; the large aircraft just don't fly over that location. So in that sense, if we try to do this modelling, that would also have an effect on the result out of this additional modelling that we'd show a depressed probability occuring at the Three Mile plant location but an increased probability occurring underneath the flight path of the aircraft.

So you have a couple of opposing factors that would tend to mitigate each other. Of course I can't, just off the top of my head, say exactly how the merits would end up.

DR. KAPLAN: You are assuming that heavy aircraft would not fly over the plant?

MR. VALLANCE: Well, I am assuming that it is extremely rare that heavy aircraft would fly over the plant. I think that is borne out by the testimony we have received.

DR. KAPLAN: No further questions.

CHAIRMAN ROSENTHAL: Any further questions of this panel?

(No response.)

CHAIRMAN ROSENTHAL: Gentlemen, you may be excused. All right, Mr. Chairman or Mr. Treby?

MR. TREBY: Yes. At this time, I would like to call Dr. Moore and Dr. Abramson. While these gentlemen are taking their places, I would indicate that they have been previously sworn on transcript page 373 and their professional qualifications are found at that point.

CHAIRMAN ROSENTHAL: Well, in view of the fact that they testified at the December 1978 hearing, they need not be resworn and of course remain under the oath that you took at that time.

MR. TREBY: Dr. Moore and Dr. Abramson, you each have before you a copy of your -- a document entitled, "Supplemental Testimony of R. Moore and L. Abramson in Response to ALAB 525?

DR. MOORE: Yes.

DR. ABRAMSON: Yes.

CHAIRMAN ROSENTHAL: Mr. Treby, why don't you have them identify themselves individually for the benefit of the reporter?

MR. TREBY: Yes. Starting with Dr. Moore, would you identify yourselves?

DR. ABRAMSON: I am Lee Abramson.

DR. MOORE: I am Roger Moore.

MR. TREBY: And I ask each of you was this 13 page document jointly prepared by you both?

DR. ABRAMSON: It was.

DR. MOORE: Yes, it was.

MR. TREBY: Do either of you have any additions or corrections to make to that document?

DR. ABRAMSON: No.

DR. MOORE: No.

MR. TREBY: Is it true and accurate to the best of your estimation and belief?

DR. ABRAMSON: Yes.

DR. MOORE: Yes, it is.

MR. TREBY: Mr. Chairman, at this time, I'd like to have this document physically incorporated into the record as if read.

CHAIRMAN ROSENTHAL: All right. It will be done.

MR. TREBY: I have a sufficient number of copies for the reporter. I have no further questions for Drs. Moore and Abramson and they are now available for cross-examination.

CHAIRMAN ROSENTHAL: Dr. Kepford?

DR. KEPFORD: I guess my line of questioning would be the same as my questions for Mr. Vallance and Dr. Kaplan. Should I repeat them?

CHAIRMAN ROSENTHAL: Yes.

DR. KEPFORD: Given the fact that a plane might come in on line with 3 miles southwest of the runway and follow approximately a circular path on the order of a mile and a half from the plant, and enter the center line extended, would that kind of a pattern have any effect on the model you used?

DR. ABRAMSON: No. It would have no effect on our model or our calculations.

DR. KEPFORD: Not even the apparent effect that the plant would be approximately a mile and a half from the aircraft for a distance perhaps on the order of 5 miles as opposed to going past it momentarily at a distance of a mile and a half?

DR. ABRAMSON: No; it wouldn't because our model and our calculations were just based on the historical data over the 23, 22 year and then updated the 23 year historical data and hadnothing directly to do with Harrisburg.

DR. KEPFORD: Well then would have such a landing pattern called such into question?

DR. ABRAMSON: It might possibly --

MR. TREBY: I object. I think that these witnesses had a very discreet task to do and that was to develop a model based on certain historical data that they were presented.

CHAIRMAN ROSENTHAL: They can speak for themselves.

DR. ABRAMSON: In answer to your question, it might possibly affect the application of our model and our results.

DR. KEPFORD: Could you describe -- would it be easy to describe what sort of a modification would have been necessary or is it something you'd have to go back --

DR. ABRAMSON: We did not actually directly apply our model but just speaking in general terms, you would have to look at the specific characteristics of the landing and takeoff patterns at Harrisburg and make a determination as to whether the historical data in our model, based on historical data, was relevant to it.

If it was judged not to be completely relevant, you might try to make some adjustment.

DR. KAPLAN: So then what you would need would be to know what percentage of the heavier craft flights then follow the paths indicated; is that not --

DR. ABRAMSON: In doing this, you would have to know what the flight patterns of all the flights, whatever it was, 100 million or 200 million flights in the historical data base were. It would not be sufficient, for example, to know just what the flight patterns of the airlines which crashed were; you'd have to look at the entire data base and make a determination as to their flight paths and then determine whether or not the Harrisburg flight patterns were or were not -- whether or not these represented the Harrisburg flight patterns.

DR. KEPFORD: Would it be possible to make certain assumptions concerning the historical national data base and compare those assumptions with what may be a unique situation here?

DR. AMBRAMSON: One can always make assumptions.

DR. KEPFORD: Would that be a place to start?

DR. ABRAMSON: If I were to do it, I would want to talk with peopleand investigate instead of making assumptions about it.

DR. KEPFORD: Does that particular type of landing pattern indicate that there might be a need for such an analysis?

MR. TREBY: Mr. Chairman, again I object. This is way beyond the scope of the direct testimony. These witnesses merely did some analysis of the probability based on historical data.

CHAIRMAN ROSENTHAL: All right, but they are expert witnesses inthis area. They are being asked questions which seem to me to be within the bounds of their area of confidence and also have some application to their area of testimony. The objection is overruled.

MR. TREBY: Mr. Chairman, I would point out to you that actually the application of their model was done by a different witness. It was done by Mr. Isenhuten. He is the one who made the various assumptions as to the--

CHAIRMAN ROSENTHAL: Well, Mr. Treby, if this is beyond their particular area of expertise, all they have to do is indicate that. I'd frankly state that I'd rather hear it come from the witnesses than from counsel.

Anytime any witness here is perfectly equipped to say that this is not within his area of competence as applied to this proceeding, let them say that if that is the case.

DR. ABRAMSON: Could you repeat the question.

DR. KEPFORD: Do the kind of landing patterns shown here, the ones coming in from the northwest -- would the existenceof such patterns indicate a need for a different analysis for this particular situation, if indeed some reasonable percentage of heavy aircraft come in on that path?

DR. ABRAMSON: Well, insofar as this may be determined to be a rather unusual pattern, and I don't know whether it is or not, then this might indicate the need for some analysis.

DR. KEPFORD: I am not suggesting that it is necessarily an unusual problem, but the subject of the proceeding has to do with the probability of an aircraft crash into Three Mile Island, Unit Two, in particular.

It seems to me that is what might make those patterns unique; not the patterns themselves, but the fact that we are worried about aircraft crashing into Three Mile Island, which is sort of at the center of what can be approximated to be a semi-circle there.

DR. ABRAMSON: As I understand your question, I think you are asking about landing patterns and takeoff patterns, flight patterns, and if they are in fact unique to Three Mile Island or rather unusual. If they are not, then as I understand the application of our model, it is reasonable to suppose that the historical data base is typical of Three Mile Island or of Harrisburg and if you can apply it without any modification.

However, if it should turn out, upon further analysis that the flight patterns at Harrisburg were rather unusual, then thismight call for additional analysis but you would have to make this determination in some way first that these flight patterns weren't taken in their entirety rather atypical as compared with the historical flight patterns on which our model was based?

DR. KEPFORD: I guess the point I'm trying to ask you is given those flight patterns,does the position of TMI 2 make the situation unique?

DR. ABRAMSON: I can't say because I don't know the relation between the flight patterns and the point of impacts of the planes that crashed.

DR. KEPFORD: I have no further questions, Mr. Chairman.

CHAIRMAN ROSENTHAL: Dr. Buck?

DR. BUCK: I have a few because I am little confused by some of your testimony. On page one, this is your testimony -- supplemental testimony of March 16, 1979 -- down near the bottom of the page, beginning about six lines up, in commenting on the Applicant's approach, you say, "This can be a useful approach provided that the assumptional, functional form is correct, since it makes use of all the data to estimate the unknown parameters.

"However, if the assumed functional formula is incorrect, then using it can lead to significant estimation errors." Are you implying here that the function used by the applicants is somehow incorrect?

DR. ABRAMSON: No. I'm just raising the possibility that it might be incorrect.

DR. BUCK: Do you think it is and what do you mean by incorrect in a function of this sort?

DR. ABRAMSON: Well, by incorrect, would be that it does not represent what the actual state of affairs is; it is not a correct mathematical abstraction or theoretical model for the state of affairs --

DR. BUCK: Do you believe it is correct or incorrect?

DR. ABRAMSON: I don't know. I think the problem is that there is relatively little data and I think it would be extremely difficult to determine whether it is correct or not and I certainly don't know whether it is correct.

DR. BUCK: Well, have they used all the data that is available essentially?

DR. ABRAMSON: They've used more of the data than we have, yes.

DR. BUCK: Well, then how do you determine that by using more data, and their's is likely to be more incorrect than yours is, using a small amount of data?

DR.ABRAMSON: Well, it isn't so much the amount of data as it is a question of the assumptions. In using all of the data, they are making an assumption that they have an additional assumption, that they have a known functional form.

Now, we don't make this assumption; we don't make the assumption of a fixedfunctional form. Therefore, we are not vulnerable -- our model is not vulnerable to the possibility the assumption might be wrong.

DR. BUCK: All right, but what assumptions do you make on your data?

DR. ABRAMSON: Well, we assume that the accidents were independently distributed in time.

DR. BUCK: Is that different from what the Applicant does?

DR. ABRAMSON: No. They make the same assumption.

DR. BUCK: So that's the same assumption?

DR. ABRAMSON: That's the same assumption. Another assumption that we make is that the point of impact, the R and the Theta coordinates are statistically independent and we confirm that with the data.

DR. BUCK: Does the Applicant make that assumption also?

DR. ABRAMSON: The Applicant also makes that assumption. We have the same assumptions.

DR. BUCK: All right. What other assumptions does he make that you don't.or vice versa?

DR. ABRAMSON: That he makes that we don't? He assumes the fixed functional form. He also assumes a prior distribution. He's using a different approach --

DR. BUCK: You also assume a prior distribution?

DR. ABRAMSON: No. We do not assume a prior distribution. In this particular approach, the basing approach requires you assume a prior distribution and the approach we use does not require this. So we don't assume it.

DR. BUCK: What data exactly do you use. Thisis what confused me.

DR. ABRAMSON: We used the historical crash data, that is, the locations of the landing and takeoff accidents over the past 22 and 23 years in our updated testimony.

DR. BUCK: All right. What does the Applicant use?

DR. ABRAMSON: He used, I believe, the crash data for the 22 year period.

DR. BUCK: And you used for how long?

DR. ABRAMSON: Also -- well, 22 and we updated the 23, basically the same period of time.

DR. BUCK: So you are using the same data then?

DR. ABRAMSON: Yes.

DR. BUCK: Well go ahead. I'm getting more and more confused about your statements that you used different data but go ahead.

DR. ABRAMSON: I don't believe I said we used different data. We used -- we start with the same data base; we use it in different ways.

DR. BUCK: Would you try to explain to me how you use it in different ways, please?

DR. ABRAMSON: We had a perhaps the easiest way would be to refer to our original testimony where we had -- I guess the original testimony, staff testimony, Tables 9-A and 9-B, where there was a rectangular array of the crash locations.

DR. BUCK: Yes. I remember the rectangular array but I am still not sure as to why you are saying that is a different usage than what the Applicant really comes up with.

DR. ABRAMSON: Well, because the way we use that was in order to estimate the crash densities in the vicinity of Three Mile Island, we basically use the data only that -- the crashes that occurred in the vicinity of Three Mile Island.

DR. BUCK: Have there been crashes occurring in the vicinity of Three Miles Island?

DR. ABRAMSON: When I say in the vicinity of Three Mile Island, I mean in the coordinates of Three Mile Island.

DR. BUCK: You mean you are taking the total data and picking out the few accidents that have occurred in the -- close to the coordinates that would apply to Three Mile Island?

DR. ABRAMSON: Yes, except we do this in each coordinate, R and Theta separately, so we have a band in R and a band inTheta and we look at those separately. R, for example, we look at all those crashes which occured between 2.0 and 3.5 miles from the end of the runway.

DR. BUCK: Well, how many crashes in the total data that You have have occurred in the area of 1 mile, say around the coordinates of Three Mile Island?

MR. TREBY: Excuse me, may I interrupt for one second to find out if the witness needs his earlier testimony?

DR. ABRAMSON: Yes, I think --

MR. TREBY: Do you have it up there?

DR. ABRAMSON: Yes, I have it. I'll have to find it. Could you repeat the question, please?

REPORTER: In the data that you have in the area of 1 mile around the coordinates of Three Mile Island -- I don't think you really finished your question.

DR. BUCK: Yes, it's the 9 mile coordinate that I am talking about here, the three mile square.

DR. ABRAMSON: I can't answer that directly because that is not in the polar coordinates. In the polar coordinates, you would have a distance and then you would have the angle, so that would have to be translated.

DR. BUCK: Well, can you give me approximately -- you must be able to give me an approximate answer.

DR. ABRAMSON: Actually, I would say that in the circle say of the 1 mile radius around Three Mile Island, I would say there were no crashes in the historical data base.

DR. BUCK: How far out do you have to go --

DR. ABRAMSON: No landing crashes.

DR. BUCK: How far out do you have to go?

DR. ABRAMSON: Oh, you might have to go out to maybe about -- maybe about a mile a mile and a half. There is one possible one in the corner; there might be one in that circle or a little further out.

DR. BUCK: How much farther out do you have to go to get two?

DR. ABRAMSON: Maybe another half a mile or 2 miles.

DR. BUCK: What I'm getting at is really how many data points are you relying on here?

DR. ABRAMSON: Well, you see it isn't the advantage of treating R and Theta separately, which is you don't look at the circles around Three Mile Island. What you do is look and see, for example, if you are interested in R, Three Mile is 2.7 miles. So we looked at a region between 2 and 3.5 miles.

What the data indicates is that it is relevant for that to look at all crashes, regardless of the angle that they took place between 2 and 3.5 miles. If you plotted these, you would get a cone out front -- excuse me, you would get an angular region which could be quite far from the position of Three Mile Island, but that all of these, by the assumption we made, would be relevant as far as indicating the probability of a crash in this angular region, in this radial region.

In that, I can answer that for the landing data, we had a total of, for the 23 year period, 10 crashes. I'm not sure; I don't have the take off data here. It was a little bit less.

DR. BUCK: So you are using the historical data within that section to give you a probability of the crash right at Three Mile Island?

DR. ABRAMSON: In the vicinity, that's right.

DR. BUCK: And that you think is a milder assumption than taking all of the crashes and analyzing a function of those?

DR. ABRAMSON: Yes, because see we make no functional assumption -- we do make one additional assumption, namely that the crash density at Three Mile -- the crash density in the vicinity of Three Mile Island is approximately constant.

What we have done by using the data in this region, 1 1/2 mile region, 15 degree wide region, in effect, we have estimated the average crash density over that region and the assumption, in using this is that the actual crash density at the point of Three Mile Island, whatever it is, is approximated by this average. So that is an additional assumption that we make.

I think it is a significantly weaker assumption and assuming that you have a functional form ranging over the whole R Theta plane.

DR. BUCK: What do you mean by weaker assumption now?

DR. ABRAMSON: Weaker, it is a less -- it is less restrictive an assumption. In effect, all it says is that the crash density has not changed very rapidly in R and Theta. It is approximately constant over the region of interest. That is 1 1/2 miles, 15 degrees --

DR. BUCK: And you think that is a more restrictive assumption than the Applicant's assumption?

DR. ABRAMSON: Less restrictive. Yes, I think it is much less restrictive. As a matter of fact, the Applicant's model does satisfy this reasonable -- does satisfy this assumption.

DR. BUCK: I am sorry, it does what?

DR. ABRAMSON: I said the Applicant's model would approximately satisfy this assumption too but the Applicant's goes considerably further than this in its mathematical form, mathematical implications.

DR. BUCK: So in other words, what you are doing is trying to narrow down your analysis to only the region around Three Mile Island?

DR. ABRAMSON: That's right. The mathematical region around it, I should say. This is done separately for R and separately for Theta so it is not restricted to the geographic location around Three Mile Island.

DR. BUCK: Apparently you had a change of mind from your original testimony until this one on your calculation of competence level. Was this a new theory that came up or did you guys just learn something new?

DR. ABRAMSON: We learned something new and we realized --

DR. BUCK: Wasn't this rather common knowledge before this, that this sort of thing was applicable?

DR. ABRAMSON: It certainly was not common to us and I think it was not very commonly noted in the statistical area, I would guess. It was just something that we discovered -- an assumption that we had previously made, namely that there might be dependents between our estimates was not true and that in fact they are statistically independent.

This assumption then allowed us to use a paper in the existing statistical literature and to considerably sharpen our competence limits.

DR. BUCK: I think that is all I have.

CHAIRMAN ROSENTHAL: Dr. Johnson?

DR. JOHNSON: The assumption that you were describing to Dr. Buck with regard to your use of the word, "in the vicinity of TMI," the assumption that you actually make is that there is a crash rate in an angular region which is uniform over all angles between the two and three-and-a-half-mile radii and a crash rate that is uniform then at all radii in the angular region that you used? Is that not true?

DR. ABRAMSON: We really don't have to make quite that assumption. You can make a little weaker assumption, namely that the average crash rate, which is really what we estimate, is approximately the true value in -- at TMI. Or you could even go further and say that if you have a convex -- if the true crash rate density is a convex function, that it overestimates or that you have a conservative estimate.

DR. JOHNSON: I don't understand your answer at all. Let me ask my question again. You calculate a radial distribution and an angular distribution; in order to get the radial distribution, you take all of the crashes that occur within a 2 to 3 1/2 mile radius and assume that there is an average crash rate which is constant within this angular region? Is that not true?

At any angle within that region, you would have the same radial crashes?

DR. ABRAMSON: No, that is a possible assumption that could be made in order to be able to apply our results. It is not necessary to make that assumption.

I don't recall that we make that explicitly -- see, We don't explicitly make that assumption.

DR. JOHNSON: Well, if you follow the arithmetic that You used, you make that assumption. Your arithmetic is displayed and that assumption is inherent in that arithmetic as I see it.

DR. ABRAMSON: No, that's -- on page two of our supplemental testimony, it says the estimates are based on the mild assumption that the conditional crash densities are approximately constant, but then we go on to say that the conditional crash densities are not approximately constant and it is plausible to assume that they would be concave decreasing. So that a core joining any two points on the curve would like wholly above the curve.

In such a case, an estimate may, with our methodology, be conservatively biased. That is it would tend to overestimate the density. So I guess I could answer your question by saying that if we make the assumption of uniformity, then our estimate tends to be an unbiased estimate.

If we make this assumption --

DR. BUCK: Density of what, sir?

DR. ABRAMSON: If we make the assumption of uniformity, then our estimate would tend to be an unbiased estimate. It neither tend to be too high or too low, conservative or non-conservative.

If, on the other hand, you want to make an assumption that the density is not uniform, but is decreasing in a concave manner, then our estimate would tend to be conservative, that is it would tend to overestimate the true value at TMI.

DR. JOHNSON: But the assumption that you did make in making your calculations was that it was uniform; is that not true?

DR. ABRAMSON: Well, we don't really have to make any assumption in making our calculations. The assumption is made when you take our calculations and want to apply them and say that our calculations are really relevant to the point of application.

Perhaps there is a fine point here but we can carry through --

DR. BUCK: No, I think it is not a fine point. I think it is something which we should understand as to what you are doing with Theta and R because I was under the same impression.

DR. ABRAMSON: In effect, we -- what our arithemetic does, our estimates, are an estimate of the averagedensity over the region. That's true without any assumptions whatsoever. Then the question is --

DR. JOHNSON: When you say over the region, what is the region?

DR. ABRAMSON: The region is the region that we used in the vicinity of Three Mile Island, specifically 2 to 3.5 miles in radius and 20 to 35 -- 25 to 40 degrees in angle. Those are the regions I'm talking about. These are the regions in the vicinity of Three Mile Island.

DR. JOHNSON: Did you not just say that you assumed that the crash density was constant within those regions?

DR. ABRAMSON: No. What I meant to say is that if you just look at our arithmetic, what we have done, regardless of what we might havesaid about the assumptions we have made, what we did was in effect estimate the average density in those regions.

DR. BUCK: Both in Theta and R?

DR. ABRAMSON: Correct. Because we used the data over those regions and we didn't subdivide those regions in any way. We estimated the average. If you make the additional assumptions that the density is uniform in those regions, then we are estimating the -- the average is the constant value.

DR. JOHNSON: I cannot, for the life of me, see how you could take the average density in those regions and make -- for sure you didn't make any of the assumptions. In other words, the way you utilized them, there is no implication and there is -- from the inside to the outside or from the low angle to the higher angle. You make no such assumptions and in fact, thewway you apply the data, you -- there is no distinction made between the crash rates -- for instance, you did not try to determine whether Three Mile Island fell in the middle of that roughly square defined by these two regions or at the outer boundary, to the right or to the left.

So you did indeed assume an average uniform crash density within those two regions; did you not? That's the only thing we are asking.

DR. ABRAMSON: The way in which our results were applied assumed that the average, which was what we had actually estimated, was, in fact, an estimate of what happens at Three Mile Island.

There were various mathematical models for which this is true. One of them is you have a uniform density. Another one could be that you have a linearly decreasing density in which case, the average would again be with TMI approximately in the middle, the average would again be a good estimate of TMI.

It is possible to make the assumption of uniformity. It is not absolutely necessary to do so.

DR. JOHNSON: Okay. Do you recall the first order that this Board issued with regard to the crash probability situation -- I don't remember the number of it - 480 or something of that nature --

DR. ABRAMSON: Well, I read it. I am not sure --

DR. JOHNSON: Do you recall that the Board asked that the Applicant and staff prepare generic models, models which took crash rate data and all airports and established a -- from this data, create an analytical model that would predict crash probability at a point within the 5 mile radius of the end of the airport?

DR. ABRAMSON: Yes.

DR. JOHNSON: Is ityour belief that the model that the staff has come up with meets the criteria that we established?

DR. ABRAMSON: I believe that the calculations the model is based on and our supplemental testimony does meet that requirement, yes, insofar as the aerial crash density is concerned.

DR. JOHNSON: As I understand the way you eliminate non-zero predictions from your certain regions of the area, is by hypothesizing crashes in certain locations, would you say that this was a mild or strong assumption?

DR. ABRAMSON: It is true that we eliminated zero estimates because zero estimates make a lot of people uncomfortable. The way we did it was it is a mathematical device of postulating a crash in the area where there was none and what this leads to is a conservative value of the estimate. It leads to an overestimate. No assumptions are necessary in order for this to be true.

DR. JOHNSON: You say no assumption is necessary?

DR. ABRAMSON: No, it is just a mathematical device. In effect, what you are doing is you are taking a fraction and you increase the numerator and denominator by 1 and this must increase the value of the fraction.

DR. BUCK: It has a practical effect,does it not?

DR. ABRAMSON: Well, its practical effect is to yield a conservative estimate of the true density at that particular location.

DR. BUCK: But if you only have a very few things to begin with, that makes quite a difference in the fraction.

DR. ABRAMSON: Not really because -- well, for the particular case at hand,I don't think so because the denominator of this fraction -- well, in one case, it was about 40 and in the other case it was about 15. So instead of having 0 over 15, for example, you have 1 over 16, it is about .06.

Whether this is a significant increase, I don't know. You would have to plug this into the formula and see what effect it would have.

DR. BUCK: You only find one area in there which had no crash density?

DR. ABRAMSON: We found one or two places in here in which this did have an effect, I believe. I'm speaking from memory now. It was just about one or two places; that's all. It was not in -- it was intended to be for the larger values of R and larger values of Theta where, of course, there was no historical crash data.

DR. BUCK: No,but you used it in the region of TMI, did you not?

DR. ABRAMSON: No, because in the vicinity of TMI, we did have positive number of crashes in all instances. This adjustment was not made for our original testimony on TMI and does not effect the estimates at TMI.

DR. BUCK: __

DR. JOHNSON: That was largely fortuitous, so at Three Mile Island had been displaced by small amount, then the original analysis would not have been applicable there; is that not true?

DR. ABRAMSON: Well, we would have used the analysis similar to the one that was done in our supplement. We might have used an analysis that was similar to what was done in our supplemental testimony; that's right.

DR. BUCK: Well, that still depends upon the angle that You happen to take to begin with. You could move this angle one way or theother and in some cases, you would have had zero and in some cases, you would have had perhaps a larger number. It depends so much on the assumption of the angle,of the radius that you take.

DR. ABRAMSON: That's true. I'd like to add that what You wind up with here is a point estimate and I think this point estimate must be taken in context with an uncertainty analysis which we did with confidence intervals.

The point estimate by itself really doesn't mean very much unless you have some notion, intuitive or quantitative at best -- some notion of the uncertainty of this point estimate and whether you have zero or one crashes, the uncertainty would certainly cover this.

DR. BUCK: Let me go back again and ask your for your statement of do you or do you not believe that the applicant has used a reasonably correct function in their estimates?

DR. ABRAMSON: I really can't say whether they've used a reasonably correct function or not.

DR. BUCK: You haven't really analyzed their approach?

DR. ABRAMSON: Mathematically, the function looks like a reasonable function. In order to really answer this question, I would have to look at the sensitivity of their answer to using other functions which might also look plausible and reasonably fit the data well and see if you come out with roughly about the same answers.

Also, you'd have to compare their function with say the approach that we took without assuming the function. That could be another way to say whether or not --

DR. BUCK: In other words, you are saying it is not obviously, incorrect?

DR. ABRAMSON: No, I can't say that.

DR. JOHNSON: You were willing to accept the concept of a linearly decreasing or at least a piecewise linearly decreasing probability as a modification of your method, I believe, to estimation of crash density between the bounds of your different regions.

DR. ABRAMSON: What I am saying is that our method would apply if in fact this were the case. I said that there are many mathematical functions, many mathematical densities for which our method would yield approximately the correct answer or a conservative answer and a linerally decreasing one is one of them..

DR. JOHNSON: Did the Applicant make any claim to the uniqueness of the functional form that he used other than they seemed to fit the data?

DR. MOORE: I think there is another point to be made: so far as I can recall, there was no goodness of fit of the function that the applicant assumed, based upon the quality of the data.

It was, indeed, apparently a good fit; but no quantitative or statistical assessment of the quality of that fit was made.

That's my recollection.

And, for example, you may remember that at the 90 degree point, there is some discombobulation of the function in the data when it is plotted, for example.

DR. JOHNSON: Did you make an estimate of the goodness of fit for the method that the Staff utilized?

DR. MOORE: In a couple of ways: number one, the question of the independence of R and Theta for the crash events were still up in the air, you may recall, the last time we met. That has now been at least -- the assumption of the independence of R and Theta has now been tested, and the data do not deny the appropriateness of that assumption; that is, the hypothesis is not rejected; that they are independent. That's one assessment of quality of assumptions.

The other one; namely, the binomial behavior of the crash occurring either in the region of interest or not, is basically a follow-through of the beginning of the discussion that Dr. Abramson brought on. Namely, we look at thos occurances that are of interest by the nature of their being close to the point of interest and compare that frequency to all such occurances. And, that, conventionally follows the Bernoulli or the binomial assumption.

You either get a hit of interest of you don't.

DR. JOHNSON: Well, I would feel rather more comfortable with that approach if the region of interests were more directly associated with the area in which you are trying -- with the mathematical region of interest were more indirectly associated with the physical region of interest that we try to find the crash rate in.

Dr. Buck mentioned circles centered on Three Mile Island and the plant. And, to me, that approach would appear to be more valid than the region that your approach expected which extended over all angles for a given -- all radii for a given angle, so that the, for instance, in the landing crash data, have small angles; your radial average included the high crash rate near zero angle and smeared that crash rate over the entire region. That does not necessarily seem plausible to me.

DR. ABRAMSON: I would agree that it would seem more plausible on the surface just to concentrate on those crashes in the vicinity of Three Mile Island.

But, this was a mathematical analysis and we were trying to use everything that we felt was reasonable to use.

And, as Dr. Moore indicated and as was shown in our original testimony, the date indicated that an assumption of independence between R and Theta was a very plausible assumption and this allowed us to make more use of the data then would have been possible had we just concentrated on those crashes in the vicinity of Three Mile Island.

DR. JOHNSON: Well, let me get to competence --

CHAIRMAN ROSENTHAL: I think at this point, we will take our afternoon recess and give Dr. Moore and Dr. Abramson an opportunity to take a deep breath before the onslaught resumes. We will commence again at 3:30.

(Whereupon, the hearing was recessed at 3:15 p.m. for a break and resumed again at 3:30 p.m.)

end of tape 9

tape 10

CHAIRMAN ROSENTHAL: I think we will resume. You look refreshed, gentlemen.

DR. MOORE: May I risk throwing some kerosene on this fire?

CHAIRMAN ROSENTHAL: Kerosene?

DR. MOORE: To come back to the question of what -- I hesitate to say we -- let me be very personal -- what I think of the applicant's models.

I don't know what to think is my answer. The plots that are given in the testimony of 9 January, Figure 2, for example, for landing accidents for the distribution for R; that plot looks pretty good. But, if you will notice, the points at the left-hand end of the curve are below the straight line; in the middle, they are above the straight line; and at the bottom, they are below the straight line again.

Now, my physics teachers would have thrown me out if I tried to put that one over on them; not my stat teacher. Point number one.

That leads me to the ask the question, is this model tested in terms of the data that it purports to represent?

DR. JOHNSON: Well, if that --

DR. MOORE: And, I have not seen that in terms of any goodness of fit [illegible]ement. Now, perhaps, it has been done, I simply haven't seen it.

DR. JOHNSON: The Figure 2 is the figure which, to my understanding, is an eyeball fit for that data. The applicant's Theta model is described in the Appendix to this testimony and the uncertainty estimates are based on that method of determination -- well, the analytic forms to these that are used to fit the data in the Theta model are not -- this model, as I understand it, or the Figure 2 displays simply an eyeball fitting of the data.

As a matter of fact, at the hearing before, I helped Mr. Vallance on this very same point; this is the wrong line to draw through that data, but I think to discuss the applicant's model, you should look at the Figure B1 or B11 which illusrates the type of fit that would be obtained using the Theta technology.

DR. MOORE: It was my understanding, that the function written down; namely, .72 x E^{-R} over 1.51, forms an input for the Basian (?) analysis.

Have I misunderstood something?

DR. JOHNSON: In my opinion, you have. However, I'm probably not the one who would make that statement.

DR. MOORE: I don't know what the point of doing Figure 2 would have been if it wasn't going to be used --

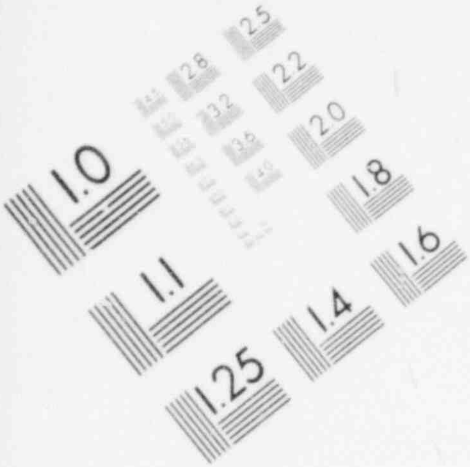
DR. JOHNSON: Yes, the point of Figure 2 is the applicant made two estimates. They made a point estimate and a probability function estimate of the hit frequencey.

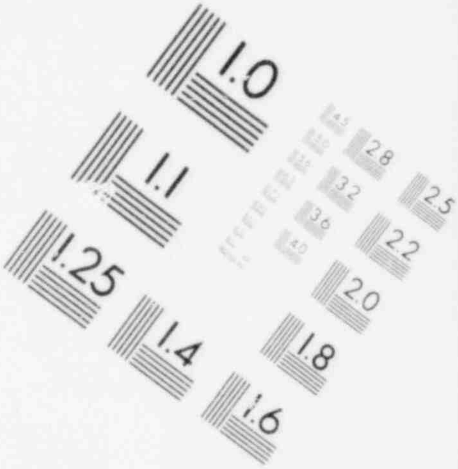
And, the one that you are looking at on Figure 2, is the figure that provided the basis for the point estimate.

DR. MOORE: Well, in Table 9, it does tell me that the hit location and probability density functions for the landings, for radials, includes these constants; especially the constant 1.51. Then it says, during probability density, it has the constant 1.51; that's on Page 22 of the applicant January 9 testimony.

And, if that figure was only used for the purposes of plotting points and drawing a straight, I'm hardput to understand why it is in the testimony at all.

DR. JOHNSON: Well, I think I see that that phase is for the single value calculation; hit location probability density function, and under that in parenthesises, the single value calculation.





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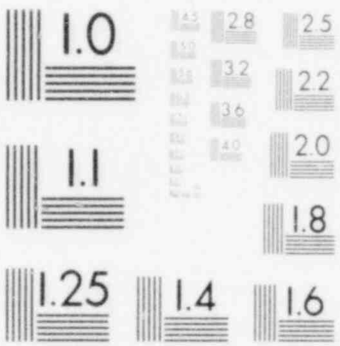
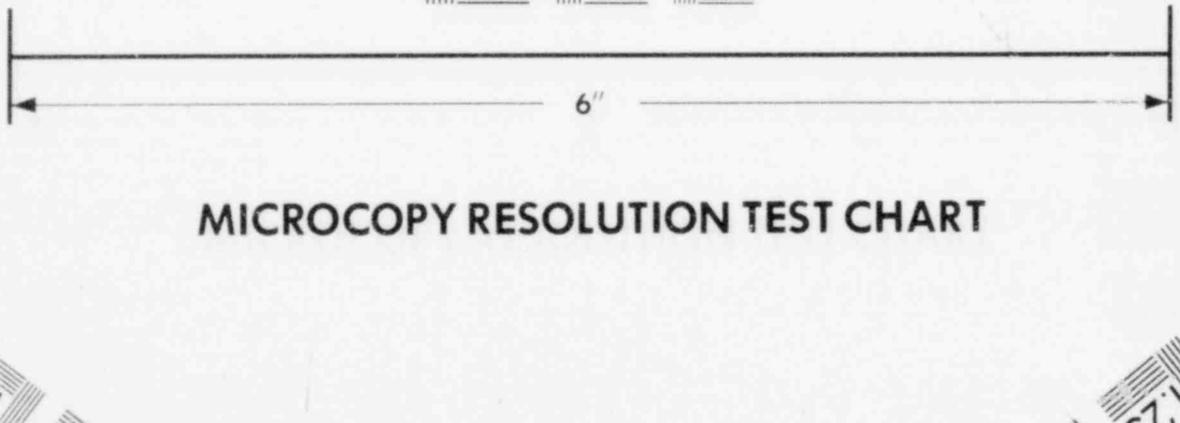
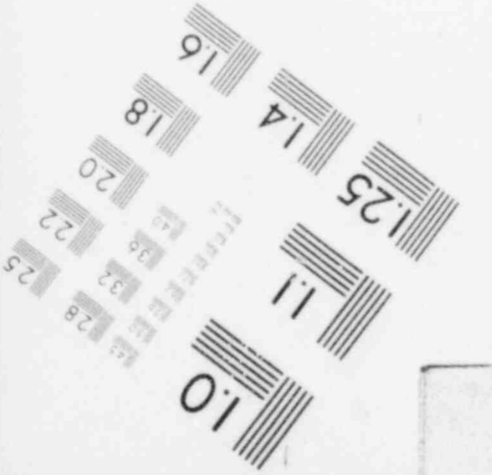
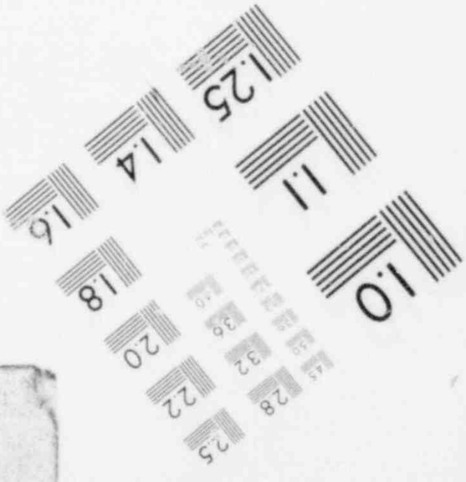




MICROCOPY RESOLUTION TEST CHART





Now, you are aware that they made the probability distribution function estimate on the history conceived at which the frequency -- the various frequencies and their associated probabilities, for instance, Table 3C, Page 15, shows the density for non-scheduled take-offs.

DR. MOORE: I realize that there is an answer that comes out, but you need a prior distribution to start the process. I think all that we are trying to determine is what were the numbers that constituted the prior distribution?

DR. JOHNSON: The prior distribution was simply the assumption that the data on the probablilty distribution would be plotted in an exponential form; that's the prior --

DR. MOORE: Without any parameter evaluation?

CHAIRMAN ROSENTHAL: I think maybe at this point, if you don't mind -- I'm addressing this to the applicant's witnesses -- you can even do it from where you are, would you like to respond to this?

DR. KAPLAN: Yes, maybe to just clarify the nomenclature a little bit.

There is a class of functions being used to fit the data, if you speak of it that way, is a class of exponential functions.

What we are calling the prior, in other words, we are saying the, quotes, distribution -- if we were to have millions and millions of crashes and if we operated for a long,

long and had millions and millions of crashes, there would be a spacial distribution of the crash frequency.

Okay, that's what we are talking about.

Now, the question is, what is the distribution? In order to -- we don't know it, of course -- so we have to express our answer to the question of probabibilistics, then, probabilistically. We have to say, this unknown distribution, how do you express a state of knowledge about a spacial shape? Well, you inbed that unknown spacial shape in a family of spacial shapes. Then you erect the probability distribution on the family to express where, within that family, you think the true answer lies with what degree of confidence you have.

Okay. Now, the family of distributions that we are using is a family of exponentials. Now, with respect to the prior, in the Basian sense, what we call the prior distribution and not the family itself, is having chosen the family, the approximating set, if you will. Now, you have to say, where, within that set, is the -- or, what's our degree of confidence on where the true answer lies within that set?

Now, that's a question of inference, right? We have to infer from the data where, within the set, the true answer lies, okay? Or, the data justifies, or what degree of confidence does the data justify on where, within that set, the true answer lies, okay? That's the question of inference.

Now, in order to make an inference, you have to have a prior. Okay. You have to say, well, before you had the data, what was your state of knowledge of about where, within that family, the true answer lies. That's what we call the prior in the Basian sense.

Now, all this business about having to assume a prior, in my view, that's kind of silliness, because you cannot avoid assuming a prior; you can't do inference without assuming a prior. How could you possibly make an inference by whatever -- any method, right? Because there is two aspects to your knowledge: there is the specific evidence of the crashes that we are treating explicity, right, with base theorem. And, then there is everything else that you know; that's your other state of knowledge. If you don't know anything else, that's a state of knowledge.

Now, when you say you avoid choosing a prior, what that really means is that you are choosing a uniform prior which says you don't know anything else. And, so, all this business of banging on the Basian approach by saying it has to assume a prior, in my view, is silliness, because you can't avoid choosing a prior. All you can do is bury the fact.

DR. MOORE: I didn't think I would be critized for assuming a prior; I don't appreciate that.

CHAIRMAN ROSENTHAL: No, we are not. Let's -- I think, Dr. Kaplan, you were a little argumentative. All that we wanted to get from you -- I don't want this to degenerate into a debate --

DR. KAPLAN: Yes; I'm sorry.

CHAIRMAN ROSENTHAL: -- between applicant and Staff witnesses. What we were calling upon you to do was simply to clarify what you had done, and so I'm not -- you can -- I don't want a response, Dr. Moore, in kind.

You have got now what Dr. Kaplan has said was done, and I hope that, perhaps, clarifies it. You can make a response to questions that are addressed to you, you know, any kind of response you wish.

DR. JOHNSON: I would like now to get to the specific question with regard to the estimates of precision on the Staff hit --

DR. BUCK: Dr. Johnson, may I ask a question before you get into that?

DR. JOHNSON: Sure.

DR. BUCK: Has the Staff -- I ask this question because of this last interchange here -- has the Staff gone to the applicant and asked for an explanation of what the applicant is doing or had discussions with the applicant's witnesses as to what they have been doing? Has the Staff really investigated what the applicant's approach was on this?

DR. MOORE: When we first got into this problem, something like a year and a half ago, we spend quite a bit of time studying the applicant material and we did spend quite a bit of time in, at least, thinking about the problem. And, I believe we had one meeting prior to the December '78 hearing.

We did not come to a complete understanding at that time. It remains the same. Mostly revolving around this question of the quality of the assumption relative to the data.

DR. BUCK: Thank you. Sorry, Reed; go ahead.

DR. JOHNSON: With regard to the estimates of precision , I believe your supplemental testimony of March the 16th varifies my belief that the Bonferoni (?) method of calculating a competence limit for three factors which are multiplied together does, in fact, represent the simultaneous confidence limit that all three of the factors would be at their upper or at the confidence limit associated with the level that we are talking about.

So, that a 70 percent confidence level would be associated with the three factors being at their 90 percent confidence limit; is that --

DR. ABRAMSOM: Yes, that's a correct interpretation of the Bonferoni method.

DR. JOHNSON: And, is it -- to me, it is intuitively unpleasing to force the three factors to be at that 90 percent limit simultaneously. It does not appear to represent any sort of reality in the probabilistic sense.

DR. ABRAMSON: The Bonferoni method is a bounding method; it gives you a conservative result, as was pointed out in the reference and as you pointed out in your comments on our tesimony.

DR. JOHNSON: But, it has, albeit conservative, it has associated with it the difficulty and that is, we are trying to establish some sort of a validity on the point estimate as to how good it is; and, for the -- for a method which then just says, well, conservatively, we know that it cannot be less than some very large number; that doesn't help us, nor does it help the public in trying to understand what we are dealing with here.

And, the that extent, we are representing the public; we are trying to establish a level of understanding of what's going on.

Now, in your most recent or in the March 16 testimony, there is -- it is somewhat more helpful, but again, as I understand it, using the fact that the radial and angluar distributions are independent, you can calculate a 90 percent confidence limit on the factors -- the radial and angular factors -- using binomial methods; is that correct?

DR. ABRAMSON: If I may correct you, we assume throughout that the model -- we have model independence between R and Theta.. The point in question, is whether we had statistical independence in the estimates of the densities.

And, that we showed subsequent to our original testimony in December, 1978. And, this additional verification demonstration of statistical independence, then, allowed us to use the Bewler (?) reference to get improved confidence limits.

DR. JOHNSON: All right.

Then, in your Table on Page 9, the estimates for the combined factor is then at the 90 percent limit and you multiply by the crash rate data, under the Bonferoni method, and you get the upper bound revised, 80 and 90 percent.

Is that correct?

DR. ABRAMSON: That's correct.

DR. JOHNSON: And, with one you can use 90 percent and the others you used 95 percent.

DR. ABRAMSON: That's right. We used two 95 percents and they wind up in a 90 percent via the Bonferoni method.

DR. JOHNSON: Would you still characterize these are conservative?

DR. ABRAMSON: Yes, the upper bounds are conservative.

DR. JOHNSON: Because you were, indeed, requiring that both the product was radial and angular at the 90 percent limit and the crash rate is at its 90 percent limit --

DR. ABRAMSON: 95 percent.

DR. JOHNSON: 95 percent.

Now, explain to me what you have done to calculate the lower bounds.

DR. ABRAMSON: Okay. What we did there, is that we started with a 90 percent confidence limit on the aerial crash densitiy; that is the product of our D-R and D-Theta, which we got from this Bewler reference. And, that is an approximately exact 90 percent confidence limit.

Then what we did, we took the observed rate, observed crash rate, and just multiplied the two. Treating that observed rate as the correct rate and it is possible to show that if you do this, you wind up with a lower bound on the exact 90 percent confidence limit.

DR. JOHNSON: That bothers me. Why --

DR. ABRAMSON: I can explain that a little more if you like.

DR. JOHNSON: Well, I'd like to know what -- for instance, let us assume that the point estimates for the crash rate is 5. We will assume also that the 90 percent limit is 80.

Presumably, also there is a number like 2 which would be the 10 percent limit on that crash rate; in other words, the crash rate -- the median value is 5, the 90 percent is 80, the 10 percent maybe 2.

I don't see why multiplying the 5 times the 90 percent aerial densitiy gives you a lower bound. It would seem to me that the 2 multiplied by the aerial 90 percent limit would give you a lower number, whether is it a lower bound or not.

So, I would like you to explain that.

DR. ABRAMSON: Okay. Well, intuitively, I think you can explain it as follows: suppose that the observed crash rate was the exact pressure; it was the correct one.

Then, I think it is clear that all you are doing is by taking the original 90 percent limit and multiplying by that , you are going to wind up with a 90 percent limit; you have simply multiplied by a known constant.

All right. Now the actual estimated observed crash rate is not the correct value; it's just an estimate of it. So, therefore, if we should multiply our 90 percent by this observed value, the question remains as what the relation of this product is to the correct 90 percent of the product; the correct 90 percent, the one that we are looking for.

And, it turns out that it is not difficult to see, but I have indicated it in this paper, that in order to adjust for the uncertainty in this observed value, that it turns out that you really have under-estimated the overall confidence limit.

If you would like, I could submit as a supplement an additional mathmematical demonstration of this, but I don't feel that I can explain it in words any more clearly than I have now.

DR. JOHNSON: I'm not sure at this point whether that will be necessary. I think this Board will have to consider -- I more or less understand what has been done.

DR. ABRAMSON: Perhaps, I could say that it is not obvious that this should be a lower bound. I think I would agree with what I sense as your hesitation in accepting my statement about this. All I can claim now is that I believe --

I proved that it turns out that it really is a lower bound in all cases.

DR. JOHNSON: I have not further questions.

CHAIRMAN ROSENTHAL: Any further questions of these witnesses?

Okay; gentlemen, you may be excused.

Now, Mr. Treby, I gather, for a very limited purpose you have agreed to produce Dr. Read?

MR. TREBY: That's correct.

CHAIRMAN ROSENTHAL: I guess he's really coming up here as a Board witness, isn't he.

You know, of course, what the limited inquiry is and you can either pursue it, or we will have the Board do it.

Dr. Read, my recollection is that you testified at the December 1978, hearing and were sworn in at that time, so you need not be sworn in again. You are under that same oath.

MR. TREBY: Mr. Chandler will present Dr. Read.

MR. CHANDLER: I think that since the sole inquiry was by, I believe, Dr. Johnson; perhaps, if he would care to ask the questions.

DR. JOHNSON: You caught me in the middle of an ear change.

MR. CHANDLER: I'm sorry.

DR. JOHNSON: Dr. Read, the main purpose of having you here is to ask, with regard to the crash in San Diego, Calif nia on 9/25/1978. It appears on , I guess, the addition Table 4 in the February 4 testimony.

That crash was listed as a non-scheduled plane crash and the reason that it is non-scheduled is given that even though it is a scheduled airline, that that airline was not certified at the time of the crash; is that correct?

DR. READ: Yes, sir.

DR. JOHNSON: I would like to know; relative to the discussion that we had in the earlier hearing about what is the difference between the crash rate of scheduled and non-scheduled aircraft operations, and it was pretty much related to the fact that the unfamiliarity factor was the separation of -- in this particular instance, we have specifically, the Southwest Airlines which is, as far as I know, a regularly scheduled airline, albeit only within the State of California, so that all of the criteria for scheduled airline operations were filled by that -- the operation of that carrier.

I just don't understand the rationale behind the setting this down as a non-scheduled crash.

DR. READ: During the 10 years I was in California, I always thought of it as a scheduled airline, too.

And, indeed, the accident record itself is filled with clues that this was a scheduled type of accident. In fact, a significant aspect of the cause of the accident was blase attitude of the crew, having done it so often.

I originally had, when I first started putting this down, listed it as a scheduled air crash. However, during the prior 22 years, there were quite a few crashes that were also by airlines or aircarriers that had the only piece of paper was th   cident brief that said that they were a commercial operator of a large aircraft. And, when a commercial operator of a large aircraft pauses at Harrisburg, we count it as non-schedule. So, to be completely consistent with the prior 22 years, it had to be called non-scheduled because the aspect that we were looking at in these old crashes was how the CAB viewed the airplane.

I agree with you that the airplane is an inanimate object and doesn't really know whether it is supposed to be scheduled or not and choose how it crashes that way.

This was just done on a description of the operator that was in the accident brief.

DR. JOHNSON: Well, the difficulty is the demoninators are Pacific Southwest Airlines flights included in the operations of scheduled airlines or unscheduled airlines?

And, the same question goes for these other cases that you are talking about.

DR. READ: In the earlier years, they would not be, nor would other commercial operators be, because the way of tabulating the data was different.

In the last few years, it is quite likely that they have been included as scheduled airliners --

DR. BUCK: Excuse me, Dr. Read, I didn't quite understand that answer; was the operations would have been included in the scheduled?

DR. READ: I believe so, in the last few years.

CHAIRMAN ROSENTHAL: But, not prior to that?

DR. READ: No. Certainly not during the '50's and early '60's, and I am uncertain about those 10 years inbetween there.

DR. BUCK: But, the accidents that occurred on those airlines were included in the non-scheduled?

DR. READ: Yes. We have always included in non-scheduled, commercial operators of large aircraft and it is quite possible that, although PSA was none of our actual accidents in the past, it is quite possible that other regional aircarriers that did not cross the stateline in the '50's and '60's appear in our long list of accidents.

CHAIRMAN ROSENTHAL: As non-sched's?

DR. READ: Yes, sir.

CHAIRMAN ROSENTHAL: Even though, in point of fact, they operated on schedules.

DR. READ: Yes, sir. Of course, in those days, they need not have to say they were on a certified route air carrier; if you hold a ticket for a scheduled flight --

DR. BUCK: But, where were the operations included?

DR. READ: The operations on most of those for the early years, or most of the early years, would be under non-scheduled.

DR. BUCK: But, in the later years, where has Pacific, for example, been included? It's been included in scheduled or non-scheduled?

DR. READ: I don't know for sure.

DR. JOHNSON: Well, it still raises the problem, that there is obviously a great disparity in the accident rate between scheduled and non-scheduled airlines.

And, we were lead to believe that this was because the non-scheduled personnel were not as familiar as the scheduled personnel with the airports that they were operating at.

So, you seem to be saying, particularly to this crash, artifical criterion or nomonclature criterion that has no basis in the factual situation. And, of course, it obviously makes a large difference in the resulting answers, being one crash with an emunerator and a very small demoninator that you have in the non-sched situation. It makes the non-scheduled crash rate increase significantly, whereas if it were added to the scheduled operations crash rate, it would not make a very big difference.

But, whichever one it upsets or changes, it would seem to me that the way of setting these things out would be according to the factual situation, and not according to an artifical criteria.

DR. READ: I would agree with you, actually, on most grounds.

DR. JOHNSON: The Chairman has given me need to ask you one question that I am reminded that is this is outside of what you receive to be your area of expertise, for heaven sakes, tell me that you don't know or you do not wish to answer.

The flight patterns of airplanes that has followed as they come in for landings. We have had described to us this morning, the flight patterns on approaches primarily to Three Mile Island, runway 31 from the west. And, that particular patterns seems to circle the Three Mile Island plant.

In your opinion, are the flight patterns followed by incoming aircraft at Three Mile Island similiar to those flown by planes coming into typical airports throughout the United States, or do you have any basis?

DR. READ: I have a small basis; it's a non-random sampling of airports near nuclear power plants, or nuclear power plant proposed sites.

And, I would say that given the fact that it's a single runway, that they are, indeed, quite comparable. There is a slight tendency for left-handed turns to be more prevalent. I think like 60 percent -- 55 or 60 percent of the patterns in the United States are left-handed patterns, rather then right-handed patterns.

But, in recent years -- I mean recent in the last 30 years -- the traditional use of left-handed turns has been over-dictated or countermanned by local terrain features and so this particular pattern would be quite comparable to all that I have seen.

DR. JOHNSON: Well, a plan coming into Harrisburg from the east, having to land at runway 13, following the left-hand rule would flight north of the airport and then turn south and then east into the runway; is that correct?

DR. READ: Yes, it is.

CHAIRMAN ROSENTHAL: Before you go on, Reed, just so that we are clear on the dimensions of the sample that was involved in that prior answer, as to whether the Harrisburg patterns were typical or not.

You indicated that this was based on your study of airports in the vicinity of nuclear plants or sites, proposed sites for nuclear plants; is that correct?

DR. READ: Yes, sir.

CHAIRMAN ROSENTHAL: Would you like to give some estimate as to what we are talking about -- 3, 4, 5 -- so we know how large this non-random sample, what might be a non-random sample is?

DR. READ: It would be of the order of 4 or 5 commercial airports; however, we have looked at the crash distribution for all military aircraft and which the left-handed rule is more dominate; it's more like 60/40. And, there you can actually see the effect of the traffic pattern on the crash density. That is to say, there are more crashes on one side of the runway then to the other.

So, my knowledge of the military bases would be somewhat more extensive then of civilian airports.

DR. JOHNSON: I don't have any further questions.

DR. BUCK: Let me just ask one thing: is the primarily because the pilot sits on the left side of the plane?

DR. READ: No, sir. In the 1910's and the 1920's, they adopted the right-hand turn roll for the props and so when a plane turns, it looses its lift to drag ratio and he has to rev up the engines, so it is easier to turn left.

DR. BUCK: Okay.

CHAIRMAN ROSENTHAL: Do any of the parties have questions of Dr. Read, obviously those questions would have to be within the outer bounds of the subjects which were covered by Dr. Johnson's questions.

Staff?

MR. CHANDLER: No, sir.

CHAIRMAN ROSENTHAL: Mr. Trowbridge?

MR. TROWBRIDGE: No questions.

CHAIRMAN ROSENTHAL: Dr. Kepford?

DR. KEPFORD: One question concerning the crashes of the military planes, where there was -- they came in from one side. Which side -- were the crashes on the same side that they were coming in, or --

DR. READ: Yes, sir.

DR. KEPFORD: No further questions. Thank you.

CHAIRMAN ROSENTHAL: Ms. Carter?

MS. CARTER: No questions.

CHAIRMAN ROSENTHAL: All right, Dr. Read, we thank you and you may be excused.

Insofar as I am aware, that terminates the evidentiary hearing. The question that remains before we recess is the establishment of a new schedule for proposed findings of fact and conclusions of law.

As I indicated at the conclusion of our hearing in December a year ago and as those of you who have followed the Appeal Board decisions in cases where the Appeal Board itself have taken evidence, we do not follow the Licensing Board format of paragraph findings; we issue what are, from the Federal Distric Court parlance would be known as memorandum, opinions. And, for that reason, we do not call upon the parties as to the Licensing Boards to submit their proposed findings of fact and conclusions of law in the form of an initial decision as Licensing Boards issue them.

Any form that the parties wish is permissible; all that we are interested in insuring is that the parties provide us, with one form or another, all of the findings of fact which in their judgment based upon the record that has been adduced in the proceeding should be included in our decision.

All right. Now, I am hopeful that each party has given some thought to scheduling and I'll start, I think, on the right and go around to the left.

Before I do that, Ms. Carter, is it your contemplation that the Commonwealth is going to file proposed findings?

MS. CARTER: I suspect not.

CHAIRMAN ROSENTHAL: You suspect not. All right.

Well, let's start with Staff; what's your thought?

MR. CHANDLER: Mr. Chairman, two things: one, I do have a final wrap-up item regarding Dr. Read's affidavit. During one of our recesses, the Staff and applicants had a chance to briefly discuss proposed scheduling. I had started a conversation with Dr. Kepford regarding scheduling, but I was unable to complete it because we resumed the hearing. If I coulg suggest a, perhaps, 10 minute recess, then we could continue that and perhaps come up with agreement.

Prior to doing that, if that would be agreeable, I would like to renew my offer of Dr. Read's affidavit and attached analysis, which were submitted on February 4, 1980, and the affidavit of Dr. Read which was provided to the Board and parties this morning, as well as the joint affidavit of Dr.'s Moore and Abramson. Each of these documents has been attested to and sworn to by the respective affiant as to the truth and correctiveness of the statements made therein.

At this time, I would, once again, offer them and ask that they be incorporated in the transcript as if read.

CHAIRMAN ROSENTHAL: Is there any objection?

MR. TROWBRIDGE: Excuse me, Mr. Chairman. I think I have not objection, but I would like to repeat the subject of a conversation that I have had before with Mr. Chandler.

We did not, obviously, come prepared to extend our date for a year; in fact, we read ALAB 570 as encouraging us to rest on the 20 or so years of data.

Therefore, in preparing findings, I have no reason to take any exception to any of the up-dated data; we simply have not checked it. Nor, have we factored it into our own calculations. Therefore, we would like to accept the supplemental data and analysis of it as evidence in this proceeding, but solely for the purpose of indicating that it does not significantly affect the data and analysis on which we have been working under in the past. And, for our part, when we file proposed findings, we will file them based on that earlier -- last year's data and we will compare our results and the Staff's results over a comparable period.

CHAIRMAN ROSENTHAL: That's acceptable.

Hearing no objection, documents to which Mr. Chandler referred will be admitted into evidence and incorporated into the record as if read.

All right. I think, in Mr. Chandler's suggestion, we will call for a 10 minute recess and let the parties -- that should be sufficient time -- see if they can work out some agreement as to a proposed briefing schedule or schedule for findings of fact and conclusions of law.

So, we will resume at 25 after.

(Whereupon, the hearing was recessed at 4:15 p.m. and resumed again at 4:25 p.m.)

CHAIRMAN ROSENTHAL: Mr. Chandler, would you like this report, the results of the conference in the hall?

MR. CHANDLER: Yes, sir.

As usual we promptly came to agreement:

The parties would propose to file simultaneously on April 15th an initial post-hearing memorandum, followed by responsive simultaneous filings on May 9th.

By saying "simultaneous," I think the parties would reserve to themselves the right to file earlier than that, so that they could not necessarily be simultaneously.

But rather than follow the format provided by 10-C of part 2.75 for having an applicant file followed by intervenors, followed some days later by staff, essentially set a final date of the 15th of April for the initial; and responses due by May 9th.

MR. TROWBRIDGE: If I could possibly manage it, consistent with other interferences in life, I'm going to file somewhat earlier than 40 days, not for the purpose of stealing a margin, because I don't want to wait 40 days and have to come up to speed again on this arithmetic.

CHAIRMAN ROSENTHAL: Well, as I understand it, Mr. Trowbridge, April 15th is the deadline; and every party, each party is perfectly free to file earlier than that. But the, if there is an earlier filing on the part of one or more of the parties, that does not affect the May 9 response date.

That will hold in all events.

All right. Is there any further matters?

(No response.)

Well, on behalf of the entire membership of the Board, I wish to thank counsel as representatives of the parties, as well as the witnesses for their helpful presentations. And this matter now stands once again submitted -- I hope for the last time.

I understand that, with the exception of Dr. Kepford, we will be seeing a new cast of characters tomorrow, both in terms of counsel and in terms of witnesses.

We will adjourn until 9:00 o'clock tomorrow morning, at which time we will commence hearing the radon issues that are before us in, for consolidated proceedings.

The hearing is adjourned.

End rcp (Thereupon, at 4:30 p.m., the hearing was adjourned.)