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Simulator Project

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11. Supplementary Notes

12. Abstract
In the continuing effort to improve runway acceptance rate, a study was conducted of crew
performance in the B-727 during an ILS approach and missed approach. Reaction time, straight
segment distance requirements, the minimum height for initiation of the missed approach, time
and distance values, and flight parameters were measured. Pilot acceptance of directed turns
at low altitude was also evaluated.

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workload
missed approach
crew performance

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1.0 INTRODUCTION

The Missed Approach Crew Performance Boeing 727 (B-727) Simulator Project was conducted by the Federal Aviation Administration (FAA) to support the major air carrier airport capacity enhancement program for operations in instrument meteorological conditions. The FAA Standards Development Branch, AVN-540 conducted the simulator project and the FAA Aviation Standards Branch, AAC-950, was responsible for providing engineering support of the B-727 simulator.

1.1 STATEMENT OF PROBLEM

One method of improving airport capacity at several airports would be to operate simultaneous instrument approaches to parallel runways with distances less than 4,300 feet between centerlines. According to criteria in the U. S. Standard for Terminal Instrument Procedures (TERPS) Manual, paragraph 992, "RUNWAY SEPARATION", if separation between parallel runway centerlines where simultaneous operations are less than 4,300 feet are approved, separation must be provided by Air Traffic Control (ATC). A possible conflict can occur when aircraft on final approach penetrates the "No Transgression Zone (NTZ)" when another aircraft is on the parallel approach. If the aircraft is not configured properly to safely execute an immediate missed approach (MA), the result could be an "adverse condition." (NOTE: The NTZ is 2,000 feet wide equidistant between runway centerlines extended).

2.0 PROJECT OBJECTIVES

The purpose of the test was to evaluate the crews' performance, both in response time and space requirements, when executing a missed approach where specific crucial maneuvers are required. This test essentially studied the missed approach phase of flight emanating from a simulated Instrument Meteorological Conditions (IMC) approach on an Instrument Landing System (ILS). The scenarios were designed based on these objectives:

a. Evaluate the pilot performance/reaction time when faced with normal and adverse operational conditions.

b. Evaluate straight segment distance requirements from decision height (DH) point where a missed approach turn can be acceptably executed.

c. Determine the minimum height above field elevation at which the aircraft is operationally capable of successfully initiating a MA turn under normal operating conditions and when aircraft is faced with an adverse condition.
d. Evaluate the distance and time required from the decision to execute a MA to the missed approach turn in normal operation and when the aircrew is confronted with mechanical distractions.

e. Evaluate parameters such as bank angle, lowest altitude in the MA segment, descent rate, and rate of turn associated with ATC directed maneuvering and normal MA turn.

f. Determine the pilots acceptability of ATC directed turns during the low altitude transition from approach to MA.

3.0 RELATED PROJECTS

Demonstration projects have been initiated at Raleigh-Durham (RDU) and Memphis (MEM) International Airports to evaluate distances less than the presently required 4,300 feet between parallel runway centerlines for independent simultaneous ILS/MLS approaches.

4.0 TEST LOCATION

The B-727 Simulator Test was conducted at the FAA Mike Monroney Aeronautical Center located in Oklahoma City, Oklahoma.

5.0 TEST DESCRIPTION

5.1 Method. Twenty pilots from the FAA and various airlines participated in this test. The approach scenarios were designed for dual-pilot and flight engineer with a test director and ATC in the cab to operate the test. The pilots flew simulated straight-in approaches to 100 and 200 foot decision height (DH) to either a; (1) crew oriented MA; (2) ATC directed MA; and (3) landing, under varying wind and instrument meteorological conditions. A total of 387 approaches were flown during this test. The airport selected for this test was Memphis International Airport with parallel runways 36R and 36L having 3,400 feet of separation between centerlines. The elevation for Memphis International Airport was 332 feet. The ILS approaches for this test were flown to runway 36L. The published MA for this runway's ILS approach is "CLIMB TO 1000 FEET, THEN CLIMBING LEFT TURN TO 1800 FEET DIRECT ME LOM AND HOLD." (See Appendix A).

5.2 Flight Procedures. By test design, the simulator maintained a gross weight of 154,000 lbs. representing a nominal heavy landing weight of a B-727, landing gear down, and flaps set at 30° for each approach. The simulator was set to intercept altitude just prior to the outer marker. The captain and first officer flew the approaches with flight director. Approaches started at the glide slope intercept and terminated in a landing or a MA. All runs included ATC normal routine phraseology except as noted. At DH, the pilot made the decision to land or execute a MA, except on scenarios where the ATC directed the pilot to turn. Prior to each run, the pilots were given information needed to accomplish each test run. The scenarios were:
a. Use company policy along with the published MA. (Scenarios 102, 105, 110 and 113).

b. Turn the aircraft as soon as pilot was satisfied with the aircraft reconfiguration and follow the published MA. (Scenarios 101, 104, 108 (fog model), 109 and 112).

c. Follow the direction of the controller when pilot is able. The ATC started the message at height of 580 feet mean sea level (MSL) prior to DH of 100 feet and 680 feet MSL prior to DH of 200 feet (scenarios 103, 106, 107 (engine out), 111, and 114). For the scenario with the turn occurring six miles from threshold, the height was 2400 feet MSL (scenario 115).

The ATC phraseology used in item "c" above was taken from FAA Directive 7110.65F, paragraph 5-126, "SIMULTANEOUS ILS/MLS APPROACHES." This form of phraseology is used when an aircraft is observed penetrating the NTZ. The ATC instructs the aircraft on the adjacent final approach course to alter course to avoid the deviating aircraft. The phraseology is "TURN (left/right) HEADING (degrees) IMMEDIATELY, CLIMB AND MAINTAIN (altitude)."

The simulator personnel recorded the system parameters listed in Table 1. Digital tape recordings and data listing were provided for postflight analysis. Observer logs were utilized to record equipment problems, subject pilot comments and special factors such as the length of time taken for the ATC message, crew procedures, etc., to assist in the final analysis.

5.3 Test Simulator. The B-727 flight simulator has a six-axis motion base and the simulator provided a computer generated visual image which simulates a twilight visual display. This gives the flight crew a realistic visual approach segment with a ±45 degree field of vision.

5.4 Subject Pilots. Twenty subject pilots from the Airline Pilots Association (ALPA), Allied Pilots Association (APA), and Air Transport Association (ATA) represented four air carrier operators. Also, FAA participated in this simulator test. Upon arriving at the test site, the pilots were briefed on the purpose of the test and test procedures. Each pilot completed and returned a pilot experience form and questionnaire. Table 2 depicts a range of total flying time from 6,000 to 25,000 hours with a mean of 10,660 hours. The pilots' range of flying time on a B-727 is from 200 to 12,000 hours with a mean of 5,327.

5.5 Approach/Missed Approach Scenarios. Prior to the simulator tests, coordination with AVN-540, Lincoln Laboratory, ALPA, APA, ATA, Flight Standards and other FAA personnel was conducted to
Table 1

<table>
<thead>
<tr>
<th>DATA COLLECTION SYSTEM PARAMETERS</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parameter</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Seconds</td>
</tr>
<tr>
<td>Indicated Airspeed</td>
<td>Knots</td>
</tr>
<tr>
<td>Radio Altitude</td>
<td>Feet</td>
</tr>
<tr>
<td>Rate of Climb</td>
<td>Feet/Minute</td>
</tr>
<tr>
<td>Pitch Angle</td>
<td>Degrees</td>
</tr>
<tr>
<td>Roll Angle (Bank)</td>
<td>Degrees</td>
</tr>
<tr>
<td>Ground Distance (0 = Threshold)</td>
<td>Feet</td>
</tr>
<tr>
<td>Air Traffic Control Event Marker</td>
<td>Discrete</td>
</tr>
<tr>
<td>Flap angle</td>
<td>Degrees</td>
</tr>
<tr>
<td>Gear Position</td>
<td>Discrete</td>
</tr>
<tr>
<td>Heading</td>
<td>Degrees</td>
</tr>
<tr>
<td>Localizer Deviation</td>
<td>Feet</td>
</tr>
<tr>
<td>Exhaust Pressure Ratio (EPR)</td>
<td>Ratio</td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>PILOT BACKGROUND</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Pilot</td>
<td>B-727 Hours</td>
<td>Instrument Hours</td>
</tr>
<tr>
<td>1</td>
<td>5,000</td>
<td>2,500</td>
</tr>
<tr>
<td>2</td>
<td>3,500</td>
<td>6,000</td>
</tr>
<tr>
<td>3</td>
<td>6,000</td>
<td>3,000</td>
</tr>
<tr>
<td>4</td>
<td>1,030</td>
<td>2,500</td>
</tr>
<tr>
<td>5</td>
<td>12,000</td>
<td>5,000</td>
</tr>
<tr>
<td>6</td>
<td>9,500</td>
<td>2,000</td>
</tr>
<tr>
<td>7</td>
<td>1,200</td>
<td>2,000</td>
</tr>
<tr>
<td>9</td>
<td>9,000</td>
<td>1,500</td>
</tr>
<tr>
<td>10</td>
<td>12,000</td>
<td>6,000</td>
</tr>
<tr>
<td>11</td>
<td>10,000</td>
<td>3,500</td>
</tr>
<tr>
<td>12</td>
<td>11,000</td>
<td>2,000</td>
</tr>
<tr>
<td>13</td>
<td>3,000</td>
<td>2,000</td>
</tr>
<tr>
<td>14</td>
<td>2,200</td>
<td>700</td>
</tr>
<tr>
<td>15</td>
<td>10,000</td>
<td>18,000</td>
</tr>
<tr>
<td>16</td>
<td>4,000</td>
<td>10,000</td>
</tr>
<tr>
<td>17</td>
<td>4,600</td>
<td>8,000</td>
</tr>
<tr>
<td>18</td>
<td>1,300</td>
<td>600</td>
</tr>
<tr>
<td>19</td>
<td>1,000</td>
<td>300</td>
</tr>
<tr>
<td>20</td>
<td>200</td>
<td>2,000</td>
</tr>
<tr>
<td>AVG</td>
<td>5,327</td>
<td>3,880</td>
</tr>
</tbody>
</table>
define appropriate approach and MA scenarios. FAA test pilots, under the direction of AVN-540, evaluated and verified various approaches and MA's. There were two scenarios with special conditions. Scenario 107 sustained an engine failure near DH, and scenario 108 was the fog model. For the fog model, the runway was visible to the pilot at DH; after DH, fog penetrated the runway environment. Table 3 lists the description of each scenario.

6.0 PILOT QUESTIONNAIRE SUMMARY

This section provides analyses of pilot ratings, comments, and recommendations from the pilot questionnaires. The questionnaires were evaluated and analyzed to examine the pilot responses under the conditions identified in the project objectives. The analysis consists of mean, mode (count in parentheses), minimum and maximum values, and comments. T-test results will be used when applicable. If significance at the .05 probability level is present, the "t" value is indicated by an asterisk.

6.1 Questions and Responses.

Question 1. Using the scales below, circle the number that represents your estimate of the overall acceleration segment performance/safety when asked to turn the aircraft immediately after reaching DH. (1 = below average, 4 = average, 7 = above average). Results are listed in table 4.

The T-test results showed an increase in pilot workload and an unacceptability to passenger comfort as determined by pilots' comments.

Question 2a. On the MA, when you were directed to climb and turn when able, what did you use as a basis for your decision?

Nine pilots indicated that they based their turn on altitude. Eight pilots based their turn on both altitude and aircraft configuration to begin a turn.

Question 2b. Pilots were asked to 'please elaborate' on what influenced their turn. Their comments are given below:

Have safe flying speed for configuration and angle of bank for turn.

Basis for the decision was safety and comfortable situation awareness.
<table>
<thead>
<tr>
<th>Scenario Number</th>
<th>Description of Conditions</th>
<th>ATC Phraseology</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>300' Ceiling / 4000 RVR 200' DH</td>
<td>None -- Crew lands.</td>
</tr>
<tr>
<td>101</td>
<td>Zero Zero / 100' DH Winds 270° at 15 kts</td>
<td>None -- Crew turns when able.</td>
</tr>
<tr>
<td>102</td>
<td>Zero Zero / 100' DH Winds 270° at 15 kts</td>
<td>None -- Crew will turn at company policy, if any.</td>
</tr>
<tr>
<td>103</td>
<td>Zero Zero / 100' DH Winds 270° at 15 kts</td>
<td>Turn left heading 280 immediately. Climb and maintain 2500.</td>
</tr>
<tr>
<td>104</td>
<td>Zero Zero / 100' DH Winds 350° at 5 kts</td>
<td>None -- Crew turns when able.</td>
</tr>
<tr>
<td>105</td>
<td>Zero Zero / 100' DH Winds 350° at 5 kts</td>
<td>None -- Crew will turn at company policy, if any.</td>
</tr>
<tr>
<td>106</td>
<td>Zero Zero / 100' DH Winds 350° at 5 kts</td>
<td>Turn left heading 280 immediately. Climb and maintain 2500.</td>
</tr>
<tr>
<td>107</td>
<td>Zero Zero / 100' DH Engine Failure (Mechanical distraction)</td>
<td>Turn left immediately heading 290. Climb and maintain 2000. Traffic two o'clock one mile crossing.</td>
</tr>
<tr>
<td>108</td>
<td>At DH -- Runway in sight After DH -- Fog obscures runway</td>
<td>Fog Model -- Crew turns when able.</td>
</tr>
<tr>
<td>109</td>
<td>Zero Zero / 200' DH Winds 350° at 5 kts</td>
<td>None -- Crew turns when able.</td>
</tr>
<tr>
<td>110</td>
<td>Zero Zero / 200' DH Winds 270° at 15 kts</td>
<td>None -- Crew will turn at company policy, if any.</td>
</tr>
<tr>
<td>111</td>
<td>Zero Zero / 200' DH Winds 270° at 15 kts</td>
<td>Turn left heading 270 immediately. Climb and maintain 3000.</td>
</tr>
<tr>
<td>112</td>
<td>Zero Zero / 200' DH Winds 270° at 15 kts</td>
<td>None -- Crew turns when able.</td>
</tr>
<tr>
<td>113</td>
<td>Zero Zero / 100' DH Winds 350° at 5 kts</td>
<td>None -- Crew will turn at company policy, if any.</td>
</tr>
<tr>
<td>114</td>
<td>Zero Zero / 200' DH Winds 350° at 5 kts</td>
<td>Turn left heading 270 immediately. Climb and maintain 3000.</td>
</tr>
<tr>
<td>115</td>
<td>Early Turn - Turn occurring six miles from threshold</td>
<td>Turn left heading 270 immediately. Climb and maintain 4000.</td>
</tr>
</tbody>
</table>
Table 4

Pilot Questionnaire Response Statistics

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>Mode</th>
<th>Maximum</th>
<th>Minimum</th>
<th>T-test</th>
<th>E</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>WORKLOAD</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Demanding</td>
<td>3.00</td>
<td>3 (7)</td>
<td></td>
<td></td>
<td>-3.25*</td>
<td></td>
</tr>
<tr>
<td>Undemanding</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

| **SPEED**            |      |      |         |         |        |    |
| Demanding            | 4.70 | 6 (7)|         |         | 1.93   |    |
| Undemanding          | 1    | 2    | 3       | 4       | 5      | 6  |

| **ALTITUDE**         |      |      |         |         |        |    |
| Demanding            | 4.15 | 6 (6)|         |         | 0.37   |    |
| Undemanding          | 1    | 2    | 3       | 4       | 5      | 6  |

| **PASSENGER COMFORT**|      |      |         |         |        |    |
| Demanding            | 3.10 | 2 (8)|         |         | -2.59* |    |
| Undemanding          | 1    | 2    | 3       | 4       | 5      | 6  |

* Significant at the .05 level.

The pilots, using altitude as a reason for their turns, stated the following heights as the lowest altitudes they would initiate a turn:

<table>
<thead>
<tr>
<th>No. of Pilots</th>
<th>Altitude (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>100</td>
</tr>
<tr>
<td>6</td>
<td>200</td>
</tr>
<tr>
<td>4</td>
<td>300</td>
</tr>
<tr>
<td>3</td>
<td>400 or greater*</td>
</tr>
</tbody>
</table>

* The maximum altitude given was 1000 feet.

Our policy is that turns should not be made below 300 feet unless directed by SIDs, noise abatement, or ATC. Bank angle limited to 15° at V₂ + 10. The turn, when able, is a bit misleading. The urgency of a controller's voice is a good basis for beginning a turn.
Flaps generally 5°, retracting to 2°.

Controllability of aircraft.

Initial turn not started until positive rate of climb established and then turn rate was slower than normal until well established in climb.

Less than 200 feet, limit 15° bank; above 200 feet, less than bug + 10, limit 15° bank; greater than bug + 10, limit 30°.

Below 200 feet, 15° bank above full 30°. Also, depending on flaps. First thing done though is pull the nose up, by this time I was high enough to go into the 30° bank.

Safe altitude primary flap configuration follows all MAes the same.

Obstacle clearance altitude provided by ATC.

Obtain positive rate, then maintain airspeed and configuration.

Flaps not a factor as long as minimum maneuver speed for the particular flap setting is maintained.

Not a good thing to start turn while going from flaps 30 to 15° and until into the MA far enough to have safe altitude.

---

Question 3. Does your company direct an altitude (minimum) that all turns must be made above?

Sixty-five percent of the pilots stated there was a policy for minimum altitudes where turns are executed. Listed below are these altitudes:

<table>
<thead>
<tr>
<th>No. of Pilots</th>
<th>Altitude (Feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>100</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
</tr>
<tr>
<td>8</td>
<td>400</td>
</tr>
<tr>
<td>1</td>
<td>1000</td>
</tr>
</tbody>
</table>

The pilots, answering with 100 feet, stipulated that turns starting at this altitude would only be initiated if requested by ATC.

Also, two pilots responded with 'minimum safe altitude'.

---

Question 4. On the controller-directed MA, were you able to follow the directions immediately? If not, why not?
Eighty-four percent (16 out of 19) of the pilots stated they were able to immediately follow the ATC directions, but only if some conditions were met. Under the pilot comments these requirements are so stated.

6.2 Pilot Comments.

If I heard then yes, if other crew members had to tell me, then no. Seventy-five percent of the time I heard the direction, which got better as the number of approaches were made and I became more familiar with flight instruments.

Pilots who could not immediately follow the directions, gave these reasons: (1) Because of speed for flap configuration; (2) Were able to turn and climb, but needed the ATC to repeat the heading and altitude; and (3) Too low for safe maneuvering.

Pilots who answered "yes" to reacting immediately, made these comments: (1) Could respond quickly, but not if the rate of turn was less than normal. A better climb rate had to be established: (2) Could follow directions immediately. however, sometimes the crew had to ask again for the directions. The main concern was getting away climbing and turning.

Question 5. Given the fact that another aircraft was on a simultaneous parallel instrument approach in instrument meteorological conditions, would that have made any difference in your reaction to an immediate MA turn when directed by ATC at low altitude?

Seventy percent (14 out of 20) of the pilots said instrument meteorological conditions would make a difference in their reaction to an immediate MA turn instructed by ATC. The pilots giving this response, gave these remarks:

Knowing that another aircraft is on simultaneous parallel approach when given a turn, your reaction would be quicker knowing aircraft is there.

I would probably be ready to turn in a certain direction if I know another aircraft was on a simultaneous approach to a nearby runway. Specifically, if this runway were less than normal separation standards.

If immediate turn was directed, a concern about the other aircraft.

I would consider the direction from ATC to be more urgent in this scenario.

Instrument meteorological conditions should not make a difference, but probably would in actuality.
If controller directs turn in direction of reported parallel or simultaneous approaching aircraft, I would definitely hesitate and question instructions while proceeding straight ahead to go around.

Instruction when immediate is used, needs to include terminology for "MA" or "climb" especially being low. With parallel approaches in progress, I would be very aware of the location and would probably be ready for MA.

Avoid mid-air.

Intellectually no, however from a psychological stand point, it probably would increase the sense of urgency.

Might influence me to start turn at unsafe altitude, and aircraft not configured to safely turn which could result in an inflight collision.

Pilots with "no" responses, gave these remarks:

I always comply with ATC request, whenever possible and to whatever extent possible.

Even in visual conditions, if an immediate turn is needed, I am going to comply due to the possibility of a mid-air.

In an actual instrument approach, other aircraft are not my concern if under the control of ATC.

Have to brief crew as to that possibility.

7.0 SIMULATOR TEST ANALYSIS SUMMARY

This section provides statistical analyses and results from the Project Objectives in Section 2.0. The analyses are focused on crew performance and reaction time when executing a MA under varying conditions. These conditions were: (1) Pilots using their airline policy when executing a MA under normal conditions; (2) Pilots turning when able; (3) Pilots being confronted with the decision to land or execute a MA in fog-like conditions (fog model); and (4) Pilots being directed by the ATC to execute a MA "immediately" while the pilots are being distracted by an engine-out situation.

7.1 STATISTICAL ANALYSIS. The analyses are displayed in tables listing the mean, standard deviation, minimum and maximum values, and frequency charts in Appendix B through H.
Table 5 gives the statistics for segment distance between DH and the MA turn under normal conditions.

Table 5

**Segment Distance From DH to Turn Initiation Statistics**

**Crew Turns When Able**

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (feet)</th>
<th>Minimum (feet)</th>
<th>Maximum (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>20</td>
<td>3794</td>
<td>1744</td>
<td>7648</td>
</tr>
<tr>
<td>104</td>
<td>19</td>
<td>3052</td>
<td>1006</td>
<td>7156</td>
</tr>
<tr>
<td><strong>Combined Mean</strong></td>
<td><strong>3432</strong></td>
<td><strong>Standard Deviation</strong> = <strong>1859</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (feet)</th>
<th>Minimum (feet)</th>
<th>Maximum (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>109</td>
<td>15</td>
<td>3821</td>
<td>536</td>
<td>6768</td>
</tr>
<tr>
<td>112</td>
<td>20</td>
<td>3160</td>
<td>700</td>
<td>10868</td>
</tr>
<tr>
<td><strong>Combined Mean</strong></td>
<td><strong>3443</strong></td>
<td><strong>Standard Deviation</strong> = <strong>2072</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Crew Turns Using Company Policy**

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (feet)</th>
<th>Minimum (feet)</th>
<th>Maximum (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>102</td>
<td>17</td>
<td>7373</td>
<td>4286</td>
<td>11174</td>
</tr>
<tr>
<td>105</td>
<td>20</td>
<td>7861</td>
<td>5352</td>
<td>12896</td>
</tr>
<tr>
<td><strong>Combined Mean</strong></td>
<td><strong>7637</strong></td>
<td><strong>Standard Deviation</strong> = <strong>1769</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (feet)</th>
<th>Minimum (feet)</th>
<th>Maximum (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>18</td>
<td>7069</td>
<td>1602</td>
<td>13328</td>
</tr>
<tr>
<td>113</td>
<td>20</td>
<td>6260</td>
<td>3488</td>
<td>8080</td>
</tr>
<tr>
<td><strong>Combined Mean</strong></td>
<td><strong>6643</strong></td>
<td><strong>Standard Deviation</strong> = <strong>1901</strong></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

According to table 5, although, the average distances between DH to turn initiation were less than the prescribed length of 1.5 NM or 9114 feet, one pilot for scenario 112, two pilots for scenario 102, five pilots for scenario 105, and two pilots for scenario 110 did exceed the 1.5 NM segment. See frequency charts in Appendix B.
Table 6 provides the time difference between ATC request and turn initiation statistics.

Table 6

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (sec)</th>
<th>Minimum (sec)</th>
<th>Maximum (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>103</td>
<td>20</td>
<td>7.2</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>106</td>
<td>19</td>
<td>7.4</td>
<td>3</td>
<td>20</td>
</tr>
</tbody>
</table>

Combined Mean = 7.3

Standard Deviation = 4.5

* Engine Failure

DH = 200 Feet

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (sec)</th>
<th>Minimum (sec)</th>
<th>Maximum (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>111</td>
<td>19</td>
<td>5.4</td>
<td>2</td>
<td>13</td>
</tr>
<tr>
<td>114</td>
<td>15</td>
<td>4.3</td>
<td>2</td>
<td>12</td>
</tr>
</tbody>
</table>

Combined Mean = 4.9

Standard Deviation = 2.8

Early Turn (Six Miles Out)

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (sec)</th>
<th>Minimum (sec)</th>
<th>Maximum (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>115</td>
<td>33</td>
<td>4.5</td>
<td>2</td>
<td>16</td>
</tr>
</tbody>
</table>

Table 7 provides the distance between ATC request and MA turn initiation statistics.

From tables 6 and 7, the average times and distances from the moment ATC gave the request for a turn and the initiation of a turn was 7.3 seconds at 1909 feet for a DH of 100 feet, and 4.9 seconds at 1270 feet for a DH of 200 feet. The six-mile out scenario average time and distance was 4.5 seconds at 1256 feet. See frequency charts in Appendix C and D.
Table 7

Range Difference Between ATC Request and Turn Initiation Statistics

**DH = 100 Feet**

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (feet)</th>
<th>Minimum (feet)</th>
<th>Hgt At Turn (feet)</th>
<th>Maximum (feet)</th>
<th>Hgt At Turn (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>103</td>
<td>20</td>
<td>1886</td>
<td>524</td>
<td>284</td>
<td>5913</td>
<td>785</td>
</tr>
<tr>
<td>106</td>
<td>19</td>
<td>1932</td>
<td>788</td>
<td>168</td>
<td>5525</td>
<td>130</td>
</tr>
<tr>
<td><strong>Combined Mean = 1909</strong></td>
<td><strong>Standard Deviation = 1217</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*107*          | 18           | 1986        | 794            | 156               | 4374           | 245               |

* Engine Failure

**DH = 200 Feet**

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (feet)</th>
<th>Minimum (feet)</th>
<th>Hgt At Turn (feet)</th>
<th>Maximum (feet)</th>
<th>Hgt At Turn (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>111</td>
<td>19</td>
<td>1410</td>
<td>527</td>
<td>257</td>
<td>3304</td>
<td>365</td>
</tr>
<tr>
<td>114</td>
<td>15</td>
<td>1092</td>
<td>500</td>
<td>256</td>
<td>3037</td>
<td>345</td>
</tr>
<tr>
<td><strong>Combined Mean = 1270</strong></td>
<td><strong>Standard Deviation = 714</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Early Turn (Six Miles Out)**

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (feet)</th>
<th>Minimum (feet)</th>
<th>Hgt At Turn (feet)</th>
<th>Maximum (feet)</th>
<th>Hgt At Turn (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>115</td>
<td>33</td>
<td>1256</td>
<td>544</td>
<td>1811</td>
<td>7009</td>
<td>1691</td>
</tr>
</tbody>
</table>

Once the decision was made to execute the MA, an increase in the exhaust pressure ratio (EPR) value was used to determine when the pilot actually started the MA. Table 8 provides the time between the EPR increase and the execution of the MA turn in normal conditions.
<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (sec)</th>
<th>Minimum (sec)</th>
<th>Maximum (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>20</td>
<td>15</td>
<td>5</td>
<td>33</td>
</tr>
<tr>
<td>104</td>
<td>20</td>
<td>12</td>
<td>4</td>
<td>24</td>
</tr>
<tr>
<td><strong>Combined Mean = 13</strong></td>
<td><strong>Standard Deviation = 7</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DH = 200 Feet</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>109</td>
<td>19</td>
<td>12</td>
<td>2</td>
<td>22</td>
</tr>
<tr>
<td>112</td>
<td>19</td>
<td>10</td>
<td>3</td>
<td>38</td>
</tr>
<tr>
<td><strong>Combined Mean = 11</strong></td>
<td><strong>Standard Deviation = 7</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Crew Turns Using Company Policy**

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (sec)</th>
<th>Minimum (sec)</th>
<th>Maximum (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>102</td>
<td>18</td>
<td>25</td>
<td>14</td>
<td>37</td>
</tr>
<tr>
<td>105</td>
<td>20</td>
<td>29</td>
<td>19</td>
<td>52</td>
</tr>
<tr>
<td><strong>Combined Mean = 28</strong></td>
<td><strong>Standard Deviation = 7</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DH = 200 Feet</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>17</td>
<td>24</td>
<td>13</td>
<td>44</td>
</tr>
<tr>
<td>113</td>
<td>20</td>
<td>22</td>
<td>11</td>
<td>32</td>
</tr>
<tr>
<td><strong>Combined Mean = 24</strong></td>
<td><strong>Standard Deviation = 7</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 9 provides the distance between EPR increase and the initiation of the MA turn "in normal conditions."
### Table 9

**Range Difference Between EPR Increase and Turn Initiation**  
**In Normal Operations Statistics**

**Crew Turns When Able**

\[
\text{DH} = 100 \text{ Feet}
\]

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (feet)</th>
<th>Minimum (feet)</th>
<th>Hgt At Turn (feet)</th>
<th>Maximum (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>20</td>
<td>3977</td>
<td>1318</td>
<td>121</td>
<td>8805</td>
</tr>
<tr>
<td>104</td>
<td>20</td>
<td>3187</td>
<td>944</td>
<td>58</td>
<td>6513</td>
</tr>
</tbody>
</table>

Combined Mean = 3582  
Standard Deviation = 2022

\[
\text{DH} = 200 \text{ Feet}
\]

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (feet)</th>
<th>Minimum (feet)</th>
<th>Hgt At Turn (feet)</th>
<th>Maximum (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>109</td>
<td>19</td>
<td>3212</td>
<td>519</td>
<td>196</td>
<td>6245</td>
</tr>
<tr>
<td>112</td>
<td>19</td>
<td>2731</td>
<td>769</td>
<td>162</td>
<td>11219</td>
</tr>
</tbody>
</table>

Combined Mean = 2971  
Standard Deviation = 2061

**Crew Turns Using Company Policy**

\[
\text{DH} = 100 \text{ Feet}
\]

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (feet)</th>
<th>Minimum (feet)</th>
<th>Hgt At Turn (feet)</th>
<th>Maximum (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>102</td>
<td>18</td>
<td>7216</td>
<td>3632</td>
<td>393</td>
<td>10650</td>
</tr>
<tr>
<td>105</td>
<td>20</td>
<td>7843</td>
<td>5159</td>
<td>714</td>
<td>14645</td>
</tr>
</tbody>
</table>

Combined Mean = 7546  
Standard Deviation = 1972

\[
\text{DH} = 200 \text{ Feet}
\]

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (feet)</th>
<th>Minimum (feet)</th>
<th>Hgt At Turn (feet)</th>
<th>Maximum (feet)</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>17</td>
<td>6870</td>
<td>3494</td>
<td>590</td>
<td>13536</td>
</tr>
<tr>
<td>113</td>
<td>20</td>
<td>5814</td>
<td>3014</td>
<td>212</td>
<td>8326</td>
</tr>
</tbody>
</table>

Combined Mean = 6299  
Standard Deviation = 1755

As shown in tables 8 and 9, the average time and distance the pilots used to turn when able, was less than them basing their turns using their company policy. See frequency charts in Appendix E and F.
Table 10 provides the statistics on the maximum bank angle in the MA turn. All turns were made to the left.

Table 10

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (deg)</th>
<th>Minimum (deg)</th>
<th>Maximum (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>20</td>
<td>-29.3</td>
<td>-23.0</td>
<td>-33.2</td>
</tr>
<tr>
<td>104</td>
<td>20</td>
<td>-29.2</td>
<td>-19.2</td>
<td>-35.9</td>
</tr>
</tbody>
</table>

Combined Mean = -29.2  
Standard Deviation = 3.6

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (deg)</th>
<th>Minimum (deg)</th>
<th>Maximum (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>108**</td>
<td>22</td>
<td>-29.9</td>
<td>-23.2</td>
<td>-35.0</td>
</tr>
<tr>
<td>109</td>
<td>19</td>
<td>-29.6</td>
<td>-20.6</td>
<td>-35.7</td>
</tr>
<tr>
<td>112</td>
<td>20</td>
<td>-28.8</td>
<td>-20.9</td>
<td>-41.9</td>
</tr>
</tbody>
</table>

** Fog Model
Combined Mean = -29.2  
Standard Deviation = 4.4

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (deg)</th>
<th>Minimum (deg)</th>
<th>Maximum (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>102</td>
<td>18</td>
<td>-30.6</td>
<td>-20.0</td>
<td>-38.8</td>
</tr>
<tr>
<td>105</td>
<td>20</td>
<td>-30.5</td>
<td>-11.1</td>
<td>-40.5</td>
</tr>
</tbody>
</table>

Combined Mean = -30.5  
Standard Deviation = 5.4

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (deg)</th>
<th>Minimum (deg)</th>
<th>Maximum (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>18</td>
<td>-30.4</td>
<td>-15.0</td>
<td>-37.3</td>
</tr>
<tr>
<td>113</td>
<td>20</td>
<td>-31.4</td>
<td>-22.7</td>
<td>-41.8</td>
</tr>
</tbody>
</table>

Combined Mean = -30.9  
Standard Deviation = 5.3
Table 10 Continued

Maximum Bank Angle In the MA Turn Statistics
(Negative Values Indicate Left Turns)

Crew Turns Under ATC Direction

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (deg)</th>
<th>Minimum (deg)</th>
<th>Maximum (deg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>103</td>
<td>20</td>
<td>-28.3</td>
<td>-19.2</td>
<td>-36.5</td>
</tr>
<tr>
<td>106</td>
<td>20</td>
<td>-28.2</td>
<td>-20.2</td>
<td>-32.7</td>
</tr>
<tr>
<td><strong>Combined Mean</strong> = -28.3</td>
<td><strong>Standard Deviation</strong> = 3.8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| 107*          | 18           | -23.4      | -7.3   | -33.4 D |

* Engine Failure

<table>
<thead>
<tr>
<th>DH = 200 Feet</th>
</tr>
</thead>
<tbody>
<tr>
<td>111</td>
</tr>
<tr>
<td>114</td>
</tr>
<tr>
<td><strong>Combined Mean</strong> = -29.2</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Early Turn (Six Miles Out)</th>
</tr>
</thead>
<tbody>
<tr>
<td>115</td>
</tr>
</tbody>
</table>

The average bank angles, from table 10, ranges from -28.2° (scenario 106) to -32.3° (scenario 115). See frequency charts in Appendix G.

Table 11 provides the statistics on "turn rates."

The average turn rates in Table 11 ranges from 3.09 (scenario 107) to 4.18 degrees/second (scenario 115). See frequency charts in Appendix H.
Table 11

Maximum Turn Rate In The MA Turn Statistics

Crew Turns When Able

DH = 100 Feet

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (deg/sec)</th>
<th>Minimum (deg/sec)</th>
<th>Maximum (deg/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>101</td>
<td>20</td>
<td>3.6</td>
<td>2.8</td>
<td>4.4</td>
</tr>
<tr>
<td>104</td>
<td>20</td>
<td>3.7</td>
<td>2.4</td>
<td>4.7</td>
</tr>
<tr>
<td>Combined Mean = 3.6</td>
<td>Standard Deviation = 0.6</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Crew Turns When Able

DH = 200 Feet

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (deg/sec)</th>
<th>Minimum (deg/sec)</th>
<th>Maximum (deg/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>108**</td>
<td>22</td>
<td>3.7</td>
<td>2.7</td>
<td>4.9</td>
</tr>
<tr>
<td>109</td>
<td>19</td>
<td>3.6</td>
<td>2.3</td>
<td>4.6</td>
</tr>
<tr>
<td>112</td>
<td>20</td>
<td>3.6</td>
<td>2.2</td>
<td>5.4</td>
</tr>
<tr>
<td>** Fog Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combined Mean = 3.6</td>
<td>Standard Deviation = 0.7</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Crew Turns Using Company Policy

DH = 100 Feet

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (deg/sec)</th>
<th>Minimum (deg/sec)</th>
<th>Maximum (deg/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>102</td>
<td>18</td>
<td>3.7</td>
<td>2.4</td>
<td>5.2</td>
</tr>
<tr>
<td>105</td>
<td>20</td>
<td>3.6</td>
<td>1.4</td>
<td>5.1</td>
</tr>
<tr>
<td>Combined Mean = 3.7</td>
<td>Standard Deviation = 0.8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

DH = 200 Feet

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (deg/sec)</th>
<th>Minimum (deg/sec)</th>
<th>Maximum (deg/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>110</td>
<td>18</td>
<td>3.7</td>
<td>2.1</td>
<td>5.0</td>
</tr>
<tr>
<td>113</td>
<td>20</td>
<td>3.8</td>
<td>2.5</td>
<td>5.7</td>
</tr>
<tr>
<td>Combined Mean = 3.8</td>
<td>Standard Deviation = 0.8</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 11 Continued

Maximum Turn Rate In The MA Turn Statistics
Crew Turns Under ATC Direction

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (deg/sec)</th>
<th>Minimum (deg/sec)</th>
<th>Maximum (deg/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>103</td>
<td>20</td>
<td>3.6</td>
<td>2.2</td>
<td>4.7</td>
</tr>
<tr>
<td>106</td>
<td>19</td>
<td>3.6</td>
<td>2.5</td>
<td>4.5</td>
</tr>
</tbody>
</table>

Combined Mean = 3.6  Standard Deviation = 0.6

107* 18 3.1 1.0 4.4
* Engine Failure

DH = 200 Feet

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (deg/sec)</th>
<th>Minimum (deg/sec)</th>
<th>Maximum (deg/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>111</td>
<td>19</td>
<td>3.8</td>
<td>2.1</td>
<td>5.2</td>
</tr>
<tr>
<td>114</td>
<td>20</td>
<td>3.7</td>
<td>2.1</td>
<td>5.0</td>
</tr>
</tbody>
</table>

Combined Mean = 3.8  Standard Deviation = 0.7

Early Turn (Six Miles Out)

<table>
<thead>
<tr>
<th>Scenario No.</th>
<th>No. of Cases</th>
<th>Mean (deg/sec)</th>
<th>Minimum (deg/sec)</th>
<th>Maximum (deg/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>115</td>
<td>38</td>
<td>4.2</td>
<td>2.7</td>
<td>6.4</td>
</tr>
</tbody>
</table>

8.0 CONCLUSIONS

The following conclusions are in response to the stated objectives a through f.

a. Combining the 100 feet and 200 feet DH scenarios the average time to respond to the ATC directed turn was 6.2 seconds. If the two longest times to respond (20 and 22 seconds) are removed, the average time to respond to the ATC directed turn was only 5.8 seconds. The long response time on some of the ATC directed turns may be the result of the subject pilots not being briefed on the meaning of the word 'immediately.' As with any seldom used specialized vocabulary, without periodic retraining there may be excessive variability in meaning conveyed by these words and a pilot's ultimate response to them.

b. and d. Combining the 100 feet and 200 feet DH scenarios the average distance to the turn after executing a missed approach following company policy was 7133 feet. When the pilots were
briefed to ignore company policy and turn when able, this distance was reduced to 3438 feet. Finally, when the pilots were directed by ATC to execute an immediate turn, the mean distance to turn was only 1611 feet. If the two longest distances to the turn (5913 and 5525 feet) are removed, the mean distance to turn was only 1495 feet.

In a similar fashion the combined standard deviation for distance to turn after ATC intervention was 1057 feet including the two longest distances and only 808 feet excluding those distances. The standard deviation for time to turn after ATC intervention was 4.0 seconds including the two longest times and only 3.1 seconds excluding those times.

c., e. and f. Even though the results of the pilot questionnaire indicated a statistically significant degradation to passenger comfort, no excessive height loss, bank angles, rate of turns or speed variations were observed in the data or by the safety pilot during any of the normal or adverse maneuvers throughout the test.

It was generally agreed upon by the subject pilots, the controllers involved in the test and AVN-540 that the phraseology used by ATC be revised to more clearly reflect the intent of the urgent situation brought about by any close flying aircraft. The word 'immediately' should be moved forward in the communication so that pilots can initiate turns a little sooner, thus reducing response time and increasing safety. The suggested phraseology for an ATC directed missed approach which is the result of NTZ intrusion or similar incident is "TURN (left/right) IMMEDIATELY, HEADING (degrees), CLIMB AND MAINTAIN (altitude)."
APPENDIX A

SAMPLE APPROACH PLATES
MISSING APPROACH
Chairs to 1000 then climbing
left turn to 1800 direct ME
LOM and hold.

CATEGORIES II ILS—SPECIAL AIRCREW
& AIRCRAFT CERTIFICATION REQUIRED

Figure A-1
APPENDIX B

SEGMENT DISTANCE FROM DH TO TURN INITIATION

FREQUENCY CHARTS
Segment Between DH and Turn Initiation
Scenario 101 - Crew Turns When Able

DH = 100 Feet
Segment Between DH and Turn Initiation
Scenario 104 - Crew Turns When Able

DH = 100 Feet

Figure B-2
Segment Between DH and Turn Initiation
Scenario 101 and 104 Combined
Crew Turns When Able

DH = 100 Feet

Figure B-3
Segment Between DH and Turn Initiation
Scenario 109 - Crew Turns When Able

DH = 200 Feet

Figure B-4
Segment Between DH and Turn Initiation
Scenario 112 - Crew Turns When Able

DH = 200 Feet

Figure B-5
Segment Between DH and Turn Initiation
Scenario 109 and 112 Combined
Crew Turns When Able

DH = 200 Feet

Figure B-6
Segment Between DH and Turn Initiation
Scenario 102 - Crew Turns Using Company Policy

DH = 100 Feet
Segment Between DH and Turn Initiation
Scenario 105 - Crew Turns Using Company Policy

DH = 100 Feet

Figure B-8
Segment Between DH and Turn Initiation
Scenario 102 and 105 Combined
Crew Turns Using Company Policy

DH = 100 Feet

Figure B-9
Segment Between DH and Turn Initiation
Scenario 110 - Crew Turns Using Company Policy

DH = 200 Feet

Figure B-10
Segment Between DH and Turn Initiation
Scenario 113 - Crew Turns Using Company Policy

DH = 200 Feet

Figure B-11
Segment Between DH and Turn Initiation
Scenario 110 and 113 Combined
Crew Turns Using Company Policy

DH = 200 Feet

Figure B-12
APPENDIX C

TIME DIFFERENCE BETWEEN ATC REQUEST AND TURN INITIATION

FREQUENCY CHARTS
Time Difference Between ATC Request and Turn Initiation
Scenario 103

DH = 100 Feet
Time Difference Between ATC Request and Turn Initiation
Scenario 106

DH = 100 Feet

Figure C-2
Time Difference Between ATC Request and Turn Initiation
Scenario 103 and 106 Combined

DH = 100 Feet

Figure C-3
Time Difference Between ATC Request and Turn Initiation
Scenario 107 (Engine Failure)

DH = 100 Feet

Figure C-4
Time Difference Between ATC Request and Turn Initiation
Scenario 111

DH = 200 Feet

Figure C-5
Time Difference Between ATC Request and Turn Initiation
Scenario 114

DH = 200 Feet

Figure C-6
Time Difference Between ATC Request and Turn Initiation
Scenario 111 and 114 Combined

DH = 200 Feet

Figure C-7
Time Difference Between ATC Request and Turn Initiation
Scenario 115 (Six Mile-Out Turn)
APPENDIX D

RANGE DIFFERENCE BETWEEN ATC REQUEST AND TURN INITIATION

FREQUENCY CHARTS
Range Difference Between ATC Request and Turn Initiation
Scenario 103

DH = 100 Feet

Figure D-1
Range Difference Between ATC Request and Turn Initiation
Scenario 106

DH = 100 Feet

Figure D-2
Range Difference Between ATC Request and Turn Initiation
Scenario 103 and 106 Combined

DH = 100 Feet

Figure D-3
Range Difference Between ATC Request and Turn Initiation
Scenario 107 (Engine Failure)

DH = 100 Feet

Figure D-4
Range Difference Between ATC Request and Turn Initiation
Scenario 111

DH = 200 Feet

Figure D-5
Range Difference Between ATC Request and Turn Initiation
Scenario 114

DH = 200 Feet

Figure D-6
Range Difference Between ATC Request and Turn Initiation
Scenario 111 and 114 Combined

DH = 200 Feet
Range Difference Between ATC Request and
Turn Initiation
Scenario 115 (Six-Mile Out Turn)

DH = 200 Feet

Figure D-8
APPENDIX E

TIME DIFFERENCE TO RECONFIGURE AIRCRAFT IN NORMAL OPERATION

FREQUENCY CHARTS
Time Difference to Reconfigure Aircraft
In Normal Operation
Scenario 101 - Crew Turns When Able

DH = 100 Feet

Figure E-1
Time Difference to Reconfigure Aircraft

In Normal Operation

Scenario 104 – Crew Turns When Able

DH = 100 Feet

Figure E-2
Time Difference to Reconfigure Aircraft
In Normal Operation
Scenario 101 and 104 Combined

DH = 100 Feet

Figure E-3
Time Difference to Reconfigure Aircraft
In Normal Operation
Scenario 109 - Crew Turns When Able

DH = 200 Feet

Figure E-4
Time Difference to Reconfigure Aircraft
In Normal Operation
Scenario 112 - Crew Turns When Able

DH = 200 Feet

Figure E-5
Time Difference to Reconfigure Aircraft
In Normal Operation
Scenario 109 and 112 Combined

DH = 200 Feet

Figure E-6
Time Difference to Reconfigure Aircraft
In Normal Operation – Scenario 102
Crew Turns Using Company Policy

DH = 100 Feet

Figure E-7
Time Difference to Reconfigure Aircraft
In Normal Operation – Scenario 105
Crew Turns Using Company Policy

DH = 100 Feet

Figure E-8
Time Difference to Reconfigure Aircraft
In Normal Operation
Scenario 102 and 105 Combined

DH = 100 Feet

Figure E-9
Time Difference to Reconfigure Aircraft
In Normal Operation - Scenario 110
Crew Turns Using Company Policy

DH = 200 Feet

Figure E-10
Time Difference to Reconfigure Aircraft in Normal Operation — Scenario 113
Crew Turns Using Company Policy

DH = 200 Feet

Figure E-11
Time Difference to Reconfigure Aircraft
In Normal Operation
Scenario 110 and 113 Combined

DH = 200 Feet

Figure E-12
APPENDIX F

RANGE DIFFERENCE TO RECONFIGURE AIRCRAFT IN NORMAL OPERATION

FREQUENCY CHARTS
Range Difference to Reconfigure Aircraft
In Normal Operation
Scenario 101 - Crew Turns When Able

DH = 100 Feet

Figure F-1
Range Difference to Reconfigure Aircraft
In Normal Operation
Scenario 104 — Crew Turns When Able

DH = 100 Feet

Figure F-2
Range Difference to Reconfigure Aircraft
In Normal Operation
Scenario 101 and 104 Combined

DH = 100 Feet

Figure F-3
Range Difference to Reconfigure Aircraft
In Normal Operation
Scenario 109 - Crew Turns When Able

DH = 200 Feet

Figure F-4
Range Difference to Reconfigure Aircraft
In Normal Operation
Scenario 112 – Crew Turns When Able

DH = 200 Feet

Figure F-5
Range Difference to Reconfigure Aircraft
In Normal Operation
Scenario 109 and 112 Combined

DH = 200 Feet
Range Difference to Reconfigure Aircraft
In Normal Operation - Scenario 102
Crew Turns Using Company Policy

DH = 100 Feet

Figure F-7
Range Difference to Reconfigure Aircraft
In Normal Operation - Scenario 105
Crew Turns Using Company Policy

DH = 100 Feet

Figure F-8
Range Difference to Reconfigure Aircraft
In Normal Operation
Scenario 102 and 105 Combined

DH = 100 Feet

Figure F-9
Range Difference to Reconfigure Aircraft
In Normal Operation – Scenario 110
Crew Turns Using Company Policy

DH = 200 Feet

Figure F-10
Range Difference to Reconfigure Aircraft
In Normal Operation - Scenario 113
Crew Turns Using Company Policy

DH = 200 Feet
Range Difference to Reconfigure Aircraft
In Normal Operation
Scenario 110 and 113 Combined

DH = 200 Feet

Figure F-12
APPENDIX G

MAXIMUM BANK ANGLE IN THE MISSED APPROACH TURN

FREQUENCY CHARTS
Maximum Bank Angle In The MA Turn
Scenario 101 - Crew Turns When Able

DH = 100 Feet

Figure G-1
Maximum Bank Angle In The MA Turn 
Scenario 104 - Crew Turns When Able 

DH = 200 Feet 

Figure G-2
Maximum Bank Angle In The MA Turn
Scenario 101 and 104 Combined
Crew Turns When Able

DH = 100 Feet

Figure G-3
Maximum Bank Angle In The MA Turn
Scenario 108 – Crew Turns When Able
Fog Model

DH = 200 Feet

Figure G-4
Maximum Bank Angle In The MA Turn
Scenario 109 - Crew Turns When Able

DH = 200 Feet

Figure G-5
Maximum Bank Angle In The MA Turn
Scenario 112 - Crew Turns When Able

DH = 200 Feet

Figure G-6
Maximum Bank Angle In The MA Turn
Scenario 109 and 112 Combined
Crew Turns When Able

DH = 200 Feet

Figure G-7
Maximum Bank Angle in the MA Turn
Scenario 102 - Crew Turns Using Company Policy

DH = 100 Feet

Figure G-8
Maximum Bank Angle In The MA Turn
Scenario 105 - Crew Turns Using Company Policy

DH = 100 Feet

Figure G-9
Maximum Bank Angle In The MA Turn
Scenario 102 and 105 Combined
Crew Turns Using Company Policy

DH = 100 Feet

Figure G-10
Maximum Bank Angle In The MA Turn
Scenario 110 – Crew Turns Using Company Policy

DH = 200 Feet

Figure G-11
Maximum Bank Angle In The MA Turn
Scenario 113 - Crew Turns Using Company Policy

DH = 200 Feet

Figure G-12
Maximum Bank Angle In The MA Turn
Scenario 110 and 113 Combined
Crew Turns Using Company Policy

DH = 200 Feet

Figure G-13
Maximum Bank Angle In The MA Turn
Scenario 103 - Crew Turns Under ATC Direction

DH = 100 Feet

Figure G-14
Maximum Bank Angle In The MA Turn
Scenario 106 - Crew Turns Under ATC Direction

DH = 100 Feet

Figure G-15
Maximum Bank Angle In The MA Turn
Scenario 103 and 106 Combined
Crew Turns Under ATC Direction

DH = 100 Feet

Figure G-16
Maximum Bank Angle In The MA Turn
Scenario 107 - Crew Turns Under ATC
Direction (Engine Failure)

DH = 100 Feet

Figure G-17
Maximum Bank Angle In The MA Turn
Scenario 111 - Crew Turns Under ATC Direction

DH = 200 Feet

Figure G-18
Maximum Bank Angle In The MA Turn
Scenario 114 – Crew Turns Under ATC Direction

DH = 200 Feet

Figure G-19
Maximum Bank Angle In The MA Trun
Scenario 111 and 114 Combined
Crew Turns Under ATC Direction

DH = 200 Feet

Figure G-20
Maximum Bank Angle In TheMA Turn
Scenario 115 - (Six-Mile Out Turn)

Figure G-21
Maximum Turn Rate In The MA Turn
Scenario 101 - Crew Turns When Able

DH = 100 Feet
Maximum Turn Rate In The MA Turn
Scenario 104 - Crew Turns When Able

![Bar Chart]

DH = 100 Feet

Figure H-2
Maximum Turn Rate In The MA Turn
Scenario 101 and 104 Combined
Crew Turns When Able

DH = 100 Feet

Figure H-3
Maximum Turn Rate In The MA Turn
Scenario 108 – Crew Turns When Able
Fog Model

DH = 200 Feet

Figure H-4
Maximum Turn Rate In The MA Turn
Scenario 109 - Crew Turns When Able

DH = 200 Feet

Figure H-5
Maximum Turn Rate In The MA Turn
Scenario 112 - Crew Turns When Able

DH = 200 Feet

Figure H-6
Maximum Turn Rate In The MA Turn
Scenario 109 and 112 Combined
Crew Turns When Able

DH = 200 Feet

Figure H-7
Maximum Turn Rate In The MA Turn
Scenario 102 - Crew Turns Using Company Policy

DH = 100 Feet

Figure H-8
Maximum Turn Rate In The MA Turn
Scenario 105 - Crew Turns Using Company Policy

DH = 100 Feet

Figure H-9
Maximum Turn Rate In The MA Turn
Scenario 102 and 105 Combined
Crew Turns Using Company Policy

Figure H-10

DH = 100 Feet
Maximum Turn Rate In The MA Turn
Scenario 110 – Crew Turns Using Company

DH = 200 Feet

Figure H-11
Maximum Turn Rate In The MA Turn
Scenario 113 - Crew Turns Using Company Policy

DH = 200 Feet

Figure H-12
Maximum Turn Rate In The MA Turn
Scenario 110 and 113 Combined
Crew Turns Using Company Policy

DH = 200 Feet

Figure H-13
Maximum Turn Rate In The MA Turns
Scenario 103 - Crew Turns Under ATC
Direction

DH = 100 Feet

Figure H-14
Maximum Turn Rate In The MA Turn
Scenario 106 - Crew Turns Under ATC Direction

DH = 100 Feet

Figure H-15
Maximum Turn Rate In The MA Turn
Scenario 103 and 106 Combined
Crew Turns Under ATC Direction

DH = 100 Feet

Figure H-16
Maximum Turn Rate In The MA Turn
Scenario 107 - Crew Turns Under ATC
Direction (Engine Failure)

DH = 100 Feet

Figure H-17
Maximum Turn Rate In The MA Turn
Scenario 111 - Crew Turns Under ATC
Direction

DH = 200 Feet

Figure H-18
Maximum Turn Rate In The MA Turn
Scenario 114 – Crew Turns Under ATC
Direction

\[ \text{DH} = 200 \text{ Feet} \]

Figure H-19
Maximum Turn Rate In The MA Turn
Scenario 111 and 114 Combined
Crew Turns Under ATC Direction

DH = 200 Feet

Figure H-20
Maximum Turn Rate In The MA Turn
Scenario 115 — (Six-Mile Out Turn)

Figure H-21
APPENDIX I

COMPOSITE PLOTS OF ALL SCENARIOS
Scenario 101
Crew Turns When Able
Category II - 100 Ft DH
Lateral Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 270 Deg at 15 kts

o -- START OF ATC MESSAGE
Scenario 101
Crew Turns When Able
Category II - 100 Ft DH
Vertical Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 270 Deg at 15 kts

B727 MISSED APPROACH CREW PERFORMANCE SIMULATOR PROJECT
FAA MIKE MONRONEY AERONAUTICAL CENTER
OKLAHOMA CITY, OKLAHOMA

-2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0
0.5 NM/INCH

200 FT/INCH

-2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0

0.5 NM/INCH

o -- START OF ATC MESSAGE
Scenario 102
Crew Turns Using Company Policy
Category II - 100 Ft DH
Lateral Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 270 Deg at 15 kts

0 -- START OF ATC MESSAGE
Scenario 102
Crew Turns Using Company Policy
Category II - 100 Ft DH
Vertical Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 270 Deg at 15 kts

o -- START OF ATC MESSAGE
Scenario 103
ATC Directed Turn
Category II - 100 Ft DH
Lateral Composite Plot

CONDITIONS: Ceiling — Zero
Visibility — Zero
Winds — 270 Deg at 15 kts

o -- START OF ATC MESSAGE
Scenario 103
ATC Directed Turn
Category II - 100 Ft DH
Vertical Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 270 Deg at 15 kts

o -- START OF ATC MESSAGE
Scenario 104
Crew Turns When Able
Category II - 100 Ft DH
Lateral Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 350 Deg at 5 kts

o -- START OF ATC MESSAGE
Scenario 104
Crew Turns When Able
Category II - 100 Ft DH
Vertical Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 350 Deg at 5 kts

0 -- START OF ATC MESSAGE
Scenario 105
Crew Turns Using Company Policy
Category II - 100 Ft DH
Lateral Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 350 Deg at 5 kts

o -- START OF ATC MESSAGE
Scenario 105
Crew Turns Using Company Policy
Category II - 100 Ft DH
Vertical Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 350 Deg at 5 kts

-2.5 -2.0 -1.5 -1.0 -0.5 0.5 1.0 1.5 2.0
0.5 NM/INCH

o -- START OF ATC MESSAGE
Scenario 106
ATC Directed Turn
Category II - 100 Ft DH
Lateral Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 350 Deg at 5 kts

o -- START OF ATC MESSAGE
Scenario 106
ATC Directed Turn
Category II - 100 Ft DH
Vertical Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 350 Deg at 5 kts
Scenario 107
ATC Directed Turn
Category II - 100 Ft DH
Lateral Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- None
**Engine Failure

0 -- START OF ATC MESSAGE
Scenario 107
ATC Directed Turn
Category II - 100 Ft DH
Vertical Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- None
**Engine Failure

o -- START OF ATC MESSAGE
Scenario 108
Crew Turns When Able
Category I - 200 Ft DH
Vertical Composite Plot

CONDITIONS: **Fog Model
At DH - Runway in sight
After DH - Fog clouded runway

o -- START OF ATC MESSAGE
Scenario 108
Crew Turns When Able
Category I - 200 Ft DH
Lateral Composite Plot

CONDITIONS: **Fog Model
    At DH - Runway in sight
    After DH - Fog clouded runway

o -- START OF ATC MESSAGE
Scenario 109
Crew Turns When Able
Category I - 200 Ft DH
Lateral Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 270 Deg at 15 kts

---

START OF ATC MESSAGE
Scenario 109
Crew Turns When Able
Category I - 200 Ft DH
Vertical Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 270 Deg at 15 kts

o -- START OF ATC MESSAGE
Scenario 110  
Crew Turns Using Company Policy  
Category I - 200 Ft DH  
Lateral Composite Plot

CONDITIONS: Ceiling -- Zero  
Visibility -- Zero  
Winds -- 270 Deg at 15 kts

o -- START OF ATC MESSAGE
Scenario 110
Crew Turns Using Company Policy
Category I -- 200 Ft DH
Vertical Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 270 Deg at 15 kts
Scenario 111
ATC Directed Turn
Category I - 200 Ft DH
Lateral Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 270 Deg at 15 kts

0 -- START OF ATC MESSAGE
Scenario 111
ATC Directed Turn
Category I - 200 Ft DH
Vertical Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 270 Deg at 15 kts
Scenario 112
Crew Turns When Able
Category I - 200 Ft DH
Lateral Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 350 Deg at 5 kts

º -- START OF ATC MESSAGE
Scenario 112
Crew Turns When Able
Category I - 200 Ft DH
Vertical Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 350 Deg at 5 kts

-2.5 -2.0 -1.5 -1.0 -0.5 0.0 0.5 1.0 1.5 2.0
0.5 NM/INCH

o -- START OF ATC MESSAGE
Scenario 113
Crew Turns Using Company Policy
Category I - 200 Ft DH
Lateral Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 350 Deg at 5 kts

o -- START OF ATC MESSAGE
Scenario 113
Crew Turns Using Company Policy
Category I - 200 Ft DH
Vertical Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 350 Deg at 5 kts

o -- START OF ATC MESSAGE
Scenario 114
ATC Directed Turn
Category I - 200 Ft DH
Lateral Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 350 Deg at 5 kts

-- START OF ATC MESSAGE
Scenario 114
ATC Directed Turn
Category I - 200 Ft DH
Vertical Composite Plot

CONDITIONS: Ceiling -- Zero
Visibility -- Zero
Winds -- 350 Deg at 5 kts

---

0 -- START OF ATC MESSAGE
Scenario 115
ATC Directed Turn
Six Miles From Threshold
Lateral Composite Plot

0.5 NM/HALF-INCH