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Flight Systems Laboratory
Flight Technologies and Procedures Division
Flight Standards Service

Safety Study Report on Simultaneous Parallel Instrument Landing System (ILS) and Area Navigation (RNAV)/Required Navigation Performance (RNP) Approaches—Phases 1B and 2B

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| 12. Abstract | This report presents the results of a safety study conducted on Navigation System Error (NSE), autopilot use, and pilot workload during a Required Navigation Performance (RNP) Parallel Approach Transition (RPAT) operation. The primary purpose of this study was to assess RPAT operational and human factor issues. Three main areas were evaluated: (1) A 0.10 nautical mile (NM) NSE was used to simulate a 99% Global Positioning System (GPS) accuracy by offsetting the Area Navigation (RNAV) nominal approach 607 feet left and right of the runway. This NSE offset was not detectible to the aircrew on the aircraft’s navigational display. (2) Current approval guidance for RNP Procedures with Special Aircraft and Aircrew Authorization Required (SAAAR) dictates that the autopilot or flight director be used to conduct these types of operations. Currently, there is no guidance concerning use of the autopilot for RPAT operations. (3) Finally, closely spaced parallel operations such as RPAT create inherent pilot workload and crew coordination issues. Airspeed changes, checklist usage, and Pilot Flying/Pilot Monitoring duties can increase pilot workloads during RPAT operations. This safety evaluation report was conducted by the FAA Flight Operations Simulation and Analysis Branch (AFS-440) using a B737-800 Level D Full Fight Simulator located at the Mike Monroney Aeronautical Center in Oklahoma City, Oklahoma. |
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Executive Summary

This report presents the results of a safety study conducted on Navigation System Error (NSE), autopilot use, and pilot workload during a Required Navigation Performance (RNP) Parallel Approach Transition (RPAT) operation. NSE is defined as an error in the ground based or satellite navigation system’s estimation of the aircraft’s true position. The primary purpose of this study was to assess RPAT operational and human factor issues. This safety evaluation report was conducted by the FAA Flight Operations Simulation and Analysis Branch (AFS-440) using a B737-800 Level D Full Flight Simulator located at the Mike Monroney Aeronautical Center in Oklahoma City, Oklahoma.

A 2005 RPAT simulator study introduced industry pilots to NSEs that equaled the RNP value specified for the approach [1]. Thus, if the RNP value of the approach was RNP 0.30 nautical miles (NM), the Area Navigation (RNAV) approach was offset 1,800 feet left or right of the nominal approach track to simulate an NSE at the maximum allowed for the approach. With this level of offset, pilots experienced a very unexpected “sight picture” when flying the programmed offset RNAV procedure while attempting to maintain visual contact with the Instrument Landing System (ILS) aircraft and the landing runway.

As RPAT operations require use of the Global Positioning System (GPS), this 0.30 NM NSE was later considered excessive for this type of evaluation. Therefore, after the 2005 study, the FAA decided to conduct RPAT testing with a more realistic value for simulated NSE. Generally, the GPS NSE as documented in a Memorandum of Agreement between the FAA Flight Technologies and Procedures Division, AFS-400, Avionics Certification System Branch, AIR-130 and the RNAV/RNP Program Group, AJR-37, is 100 meters based on a Gaussian distribution at the 95% probability level.[3] It was decided that 0.10 NM would more closely reflect a GPS NSE at the 99% probability level associated with the equipage and capability of RNP-approved aircraft. This safety study evaluates pilot actions in recognition, resolution, and maintenance of stabilized flight during an RNAV approach with an NSE of 0.10 NM (607 feet).

RPAT operations typically use Radius-to-Fix (RF) leg segments to provide course guidance to the final approach course. FAA Advisory Circular 90-101, “Approval Guidance for RNP Procedures with Special Aircraft and Aircrew Authorization Required (SAAAR),” Appendix 4, 2.b requires that an autopilot or a flight director driven by the RNAV system must be used when RF legs are present. The previous 2005 RPAT simulator study provided a limited snapshot of the effects of flight director only (autopilot OFF) flight operations. The previous study indicated pilots had difficulty manually maintaining course and airspeed control while monitoring ILS traffic [1]. This also noticeably impacted crew coordination, situational awareness, and pilot

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1 AC 120-29A, Criteria for Approval of Category I and Category II Weather minima for Approach, page 43, paragraph 4.5 (h)
workload. This safety study collects additional flight director only data which allows a more thorough comparison of autopilot ON or flight director only during RPAT operations.

To increase airport approach capacity, Air Traffic Control (ATC) routinely requests that pilots maintain 170 knots or greater to Final Approach Fixes (FAFs). As such, to maximize the capacity increase benefits of an RPAT operation, it is expected at this time that 170 knots or greater will be used for both the ILS and RNAV aircraft. Additionally, capacity and visual acquisition is also enhanced when the two aircraft are paired within close in-trail spacing. The draft RPAT Operations Plan states that ATC’s goal is to vector and make speed adjustments so the two aircraft are in-trail spaced 1 NM or less as the two aircraft cross their respective thresholds.[4]. This will also aid multiple RPAT streams. As a lead-in to future RPAT testing, this safety study looks at pilot workload and crew coordination issues while both the ILS and RNAV aircraft are at 170 knots to the Final Approach Fix (FAF) and Precision Final Approach Fix (PFAF), respectively, then slowing to final approach speed and completing the required checklists.

The following recommendations are made as a result of this RPAT operation safety study:

1. Develop an RPAT training program to address crew coordination, aircrew workload, and checklist management. This is a repeat of the 2005 RPAT simulator test recommendation.

2. Mandate the use of autopilot for RPAT operations to mitigate pilot workload and ensure RNAV course guidance is maintained for closely spaced runway operations. This is a repeat of the 2005 RPAT simulator test recommendation.

3. Conduct a study to validate Pilot Flying versus Pilot Monitoring issues and cross track bias found in this test with the ILS aircraft on the right side of the RNAV aircraft. (All previous studies have been conducted with the ILS aircraft to the left side of the RNAV aircraft).

4. Conduct a study to determine the pilot’s ability to visually maintain proper in-trail spacing.

5. Conduct a study to evaluate night RPAT operations.

6. Conduct further studies to determine Flight Technical Errors (FTEs) in RNAV approaches with RF legs.

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1.0 Introduction

This report presents the results of a safety study conducted on Navigation System Error (NSE), autopilot use, and pilot workload during a Required Navigation Performance (RNP) Parallel Approach Transition (RPAT) operation. NSE is defined as an error in the ground-based or satellite navigation system’s estimation of the aircraft’s true position.\(^1\) This safety evaluation report was conducted by the FAA Flight Operations Simulation and Analysis Branch (AFS-440) using a B737-800 Level D Full Flight Simulator located at the Mike Monroney Aeronautical Center in Oklahoma City, Oklahoma.

1.1 Purpose and Structure of the Report

The primary purpose of the study was to assess RPAT operational and human factors issues. This report provides background information about NSEs, describes the evaluation used, explains the methods used to analyze the data, and presents conclusions and recommendations based on the study.

1.2 Navigation System Error

A 2005 RPAT simulator study introduced industry pilots to NSEs that equaled the RNP value specified for the approach [1]. Thus, if the RNP value of the approach was RNP 0.30 nautical miles (NM), the Area Navigation (RNAV) approach was offset 1,800 feet left or right of the nominal approach track to simulate NSEs at the maximum allowed for the approach. With this level of offset, pilots experienced a very unexpected “sight picture” when flying the programmed offset RNAV procedure while attempting to maintain visual contact with the Instrument Landing System (ILS) aircraft and the landing runway.

As RPAT operations require use of the Global Positioning System (GPS), the 0.30 NM NSE was considered to be excessive for this type of evaluation. Therefore, after the 2005 study, the FAA decided to conduct RPAT testing with a more realistic value for simulated NSEs. Generally, the GPS NSE as documented in a Memorandum of Agreement between the FAA Flight Technologies and Procedures Division, AFS-400, Avionics Certification System Branch, AIR-130 and the RNAV/RNP Program Group, AJR-37, is 100 meters based on a Gaussian distribution at the 95% probability level.[3] It was decided that 0.10 NM would more closely reflect a GPS NSE at the 99% probability level associated with the equipage and capability of RNP-approved aircraft. This safety study evaluates pilot actions in recognition, resolution, and maintenance of stabilized flight during an RNAV approach with an NSE of 0.10 NM (607 feet).

\(^2\) AC 120-29A, Criteria for Approval of Category I and Category II Weather minima for Approach, page 43, paragraph 4.5 (h)
1.3 Autopilot Use

RPAT operations use Radius-to-Fix (RF) leg segments to provide course guidance to the final approach course. FAA Advisory Circular 90-101, “Approval Guidance for RNP Procedures with Special Aircraft and Aircrew Authorization Required (SAAAR),” Appendix 4, 2.b requires that an autopilot or flight director driven by the RNAV system must be used when RNP 0.3 or when RF legs are present.

The previous 2005 RPAT simulator study provided a limited snapshot of flight director only (autopilot OFF) flight operations. The previous study indicated pilots had an increased level of difficulty manually maintaining course and airspeed control while monitoring ILS traffic. This also noticeably impacted crew coordination, situational awareness, and pilot workload. This safety study collects additional flight director only data, which allows a more thorough comparison of autopilot ON or flight director only during RPAT operations.

1.4 Pilot Workload

To increase airport approach arrival rate and capacity, Air Traffic Control (ATC) routinely requests that pilots maintain 170 knots or greater to FAFs. As such, to maximize the capacity of an RPAT operation, it is expected at this time that both ILS and RNAV aircraft will maintain 170 knots or greater. Additionally, capacity and visual acquisition are also enhanced when the two aircraft are paired within close in-trail spacing. The draft RPAT Operations Plan states that ATC’s goal is to vector and make speed adjustments so the two aircraft are in-trail spaced 1 NM or less as the two aircraft cross their respective thresholds [4]. This also increases the capacity of multiple RPAT streams.

As a lead-in to future RPAT testing, this safety study examines pilot workload and crew coordination issues while both the ILS and RNAV aircraft are at 170 knots to the FAF and Precision Final Approach Fix (PFAF), respectively, and then slowing to final approach speed while the crew completes the required checklists. It should be noted that the start point for each run began with the RNAV aircraft in-trail spaced from the ILS aircraft at either 3,000 feet or 6,000 feet.

2.0 Description of the Evaluation

This section of the report describes the RPAT concept for closely spaced parallel runways, how the NSEs were simulated, and provides a synopsis of the thirty-four scenarios used in the B737-800 simulation. This section also includes details about the participants in the study and provides information about the human factors considerations.
2.1 General RPAT Concept of Operation

The RPAT concept for closely spaced parallel runways places two aircraft paired by ATC on the intermediate segments of the respective approaches with the RNAV aircraft abeam or behind the ILS aircraft. Prior to the PFAF, the RNAV flight crew must visually acquire the ILS aircraft and must report this fact to ATC. While the RNAV flight crew visually monitors the position of the ILS aircraft, the RNAV aircraft continues to fly the designated RNAV approach lateral and vertical paths. Between the PFAF, Final Roll-Out Point (FROP) and the runway threshold, the RNAV flight crew assumes responsibility for wake vortex avoidance and separation from the ILS aircraft. Figure 1 depicts the general RPAT concept.

![Figure 1: General RPAT Concept of Operations](image)

2.2 RPAT Airport and Approach

This simulator study was conducted using Memphis International Airport (MEM) as the model for the airport site. Memphis Runway 36R was the RNAV runway, separated by 927 feet from the ILS Runway 36C. Figure 2 shows the RNAV (RNP) Runway 36R approach chart\(^3\) (used for test purposes only) for this RPAT operation.

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\(^3\) This chart was used for the simulator testing environment only because RPAT charting specifications have not been formalized with the Aeronautical Charting Forum, under FAA Order 7910.5B.
The approach segment from CX36R to PFAFR was offset approximately 5,000 feet from the ILS 36C localizer course. The approach contained two RF legs: one from PFAFR to CTPTR and another from CTPTR to FROPR. These RF legs provided a smooth, repeatable transition from the intermediate segment to the course corresponding to the
extended Runway 36R centerline. The RF legs required approximately 10 degrees of bank. After FROPR, lateral guidance continued to the Runway 36R threshold (RWY36R). A vertical path of 3 degrees was provided between CX36R and RWY36R. An RNP level of 0.30 NM and GPS was specified to conduct the approach.

2.3 Navigation System Error Simulation

To simulate NSEs equal to 0.10 NM, three different versions of the RNAV 36R approach were programmed into the B737-800 simulator. These approach tracks were nominal, 0.10 NM left of course, and 0.10 NM right of course. The nominal programmed approach represented the RNAV (RNP) 36R approach with no attendant NSE. The 0.10 NM left and right approaches were programmed with all waypoints offset 0.10 NM to the left or right, respectively, to represent an approach in which the NSE resulted in a maximum 0.10 NM left or right error. The navigational databases for 0.10 NM left and right also shifted the MEM runway coordinates so that the cockpit navigational display showed the proper relationship of the runway to the final approach courses.

Although rare, pilots could encounter GPS-induced NSEs of 0.10 NM. The 0.10 NM left and right offset approaches are thought to represent the outer limit of an approximate 99% GPS accuracy expected during an RPAT scenario. As such, this study evaluates scenarios to assess pilot actions and flyability characteristics of the RPAT operation with potential NSEs of this magnitude.

2.4 B737-800 Flight Simulator Operational Scenarios

Thirty-four different scenarios were programmed in the B737-800 simulator. These scenarios are shown in Table 1.

<table>
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<tr>
<th>Run #</th>
<th>Approach</th>
<th>Spacing (feet)</th>
<th>Pilot Flying</th>
<th>Autopilot</th>
<th>Winds</th>
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Table 1: Operational Scenarios (continued)

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<td>ON</td>
<td>0/0</td>
<td>Auto-throttle and 145 knots</td>
</tr>
<tr>
<td>34</td>
<td>Nominal</td>
<td>3,000</td>
<td>First Officer</td>
<td>ON</td>
<td>0/0</td>
<td>Auto-throttle and 145 knots</td>
</tr>
</tbody>
</table>

All scenarios except Scenarios 33 and 34 were conducted with auto-throttles OFF to address standardization amongst flight crews and to account for variations in industry equipage and usage. Scenarios 33 and 34 were programmed to allow use of both the autopilot and auto-throttles to make workload comparisons using complete automation. Table 1 shows the following facts concerning the remaining flight simulator scenarios:

- Six scenarios used the NSE 0.10 NM left approach tracks and six scenarios used the NSE 0.10 NM right approach tracks. The remaining 22 scenarios used the nominal RNAV approach.

- Autopilot was used on all the NSE 0.10 NM approaches. Autopilot was not used for ten nominal approaches. Of these ten nominal approaches without autopilot, four were set-up for the 3,000 feet in-trail spacing.

- Twelve scenarios were in-trail spaced at 3,000 feet between the two aircraft. The remaining 22 scenarios were at 6,000 feet. Of the twelve 3,000 feet in-trail spacing scenarios, eight were nominal approaches (four without autopilot) and four were NSE 0.10 NM approaches.
The winds alternated between calm and a right to left crosswind of 10 knots. A total of 24 scenarios were designed with calm wind and the remaining ten scenarios were designed with a wind of 090/10⁴.

All scenarios were daytime scenarios.

Each captain and first officer had an equal number of nominal, NSE, autopilot, and in-trail spacing scenarios.

In addition to the winds shown in Table 1, other weather conditions included a 2,000-foot ceiling with a visibility of four statue miles. This ceiling and visibility combination allowed flight crews to visually acquire the ILS aircraft prior to the PFAF, but did not enable the flight crews to see the runway environment at the same time. The draft RPAT Operations Plan dictates that the runway environment must be visually acquired by the beginning of the second RF turn or four statue miles, whichever is greater.

The RNAV aircraft began each test run 3 NM (approximately 45 seconds) from the PFAF (PFAFR) in Instrument Meteorological Conditions at 2,500 feet Mean Sea Level (MSL) with an 800 feet per minute descent rate. The aircraft was stabilized on the lateral and vertical approach paths at 170 knots indicated airspeed. In addition, the RNAV aircraft was configured with gear down, flaps 5 degrees, flight director was ON with command steering bars from Lateral Navigation/Vertical Navigation (LNAV/VNAV) engaged.

Based on the scenario, the autopilot was either ON or OFF. Even though the B737-800 simulator is equipped with a Head-Up Display (HUD), it was not used due to variations in industry fleet equipment. The Traffic Collision Avoidance System (TCAS) was set to the Resolution Advisory (RA) mode. Depending on the spacing (3,000 feet in-trail or 6,000 feet in-trail) starting point, the TCAS indicated an adjacent aircraft on the cockpit navigation display at approximately the 9 to 11 o’clock position. The captain and first officer alternated approaches with the captain designated as the Pilot Flying (PF) for the odd numbered scenarios while the first officer flew the even numbered scenarios.

At 2,300 feet MSL, which was approximately 30 seconds from the PFAF, the RNAV aircraft exited the cloud base. During these 30 seconds, the parallel ILS aircraft (a Boeing 737 digitally produced on the simulator flight deck windows) also exited the cloud base. Both aircraft were maintaining a constant speed of 170 knots indicated airspeed.

A total of 170 RPAT runs were conducted. All resulted in landings except three in which aircrews executed the RPAT approach abandonment maneuver. These three abandonment’s were executed by the pilots in the RF turns and only during the 0.10 NM left NSE scenarios. Of the 170 RPAT runs, 50 nominal runs were without autopilot, 60 nominal runs were with autopilot, 30 runs were 0.10 NM left, and 30 runs were 0.10 NM right.

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4 The 10-knot crosswind restriction was adopted from Simultaneous Offset Instrument Approaches [SOIA] [2].
2.5 Simulator Data Collection

Forty-one different parameters were recorded at a 1-Hertz rate during each simulator session. These parameters are shown below:

- Crew number
- Pilot flying
- Aircraft latitude (degrees)
- Aircraft longitude (degrees)
- Aircraft radio altitude (feet)
- Aircraft rate of climb (feet per minute)
- Captain’s column position (inches)
- Captain’s wheel position (inches)
- Aircraft pedal position (inches)
- Aircraft flaps position (degrees)
- Aircraft horizontal stab position (degrees)
- Aircraft landing gear position (up or down)
- Aircraft indicated airspeed (knots)
- Aircraft roll angle (degrees)
- Aircraft pitch angle (degrees)
- Aircraft heading angle (degrees)
- Aircraft aileron position (degrees)
- Aircraft elevator position (degrees)
- Aircraft rudder position (degrees)
- Wind speed and direction at aircraft (knots, degrees)
- Left and right engine thrust (pounds)
- Left and right N1 (RPM)
- Left and right throttle lever angle (degrees)
- Main Landing Gear Weight on Wheels switch
- Autopilots A and B
- LNAV engage
- VNAV engage
- Take Off/Go-Around (TOGO) switch activation
- Left Flight Management Computer (FMC) cross track deviation (feet)
- Left FMC Vertical Deviation (feet)
- Left FMC RNP (nautical miles)
- Left FMC ANP (nautical miles)
- Aircraft distance to runway threshold (feet)
- Aircraft distance to runway centerline (feet)
- ILS aircraft latitude (degrees)
The collected data parameters supported analysis of the following Test Criteria Violation (TCV) metrics of interest regarding the RPAT scenarios:

1. Bank angles not greater than 25 degrees sustained for more than three seconds above 500 feet, or not greater than 5 degrees below 500 feet. Descent rate not greater than 1,000 feet per minute sustained for more than three seconds. This 3-second duration is for TCV benchmark only and not FAA Advisory Circular guidance.

2. Airspeed deviations from 500 feet Above Ground Level (AGL) to runway threshold not exceeding less than $V_{REF}$ or greater than $V_{REF} +10$ for more than three seconds. This 3-second duration is for TCV benchmark only.

3. Touchdown point of the RNAV aircraft not exceeding 3,000 feet (FAA Advisory Circular guidance)

4. In-trail spacing between the two aircraft at threshold crossing (baseline was 3,000 feet or 6,000 feet)

5. Autopilot disengaged point (altitude and location)

6. Flight Technical Error (cross track error) from programmed RNAV approach course not exceeding 200 feet (TCV benchmark only)

7. Vertical navigation deviation from programmed RNAV flight path profile not exceeding 75 feet (FAA Advisory Circular guidance)

Metrics 1 through 3 are considered general approach parameters and indicate how well the flight crews conducted a stabilized approach. Metrics 4 through 7 are RPAT-specific parameters and provide a quantitative measure of the effectiveness and viability of the RPAT operation and pilot workload issues.

2.6 Subject Pilots

A total of five flight crews (i.e., one captain and one first officer) participated in this study. The flight crews were qualified to perform the duties required of their respective
crew positions. Five major airline companies were represented and with the exception of two FAA pilots, pilots from different companies did not fly together (e.g., a Delta pilot did not fly with an American pilot). Table 2 contains the ratings, total flying hours and RNAV experience of the flight crews. As Table 2 shows, the crews were highly experienced, all had B737 type-rating or qualification and their RNAV exposure ranged from minimal to six years.

<table>
<thead>
<tr>
<th>Crew #</th>
<th>Crew Position</th>
<th>Ratings</th>
<th>Total Flight Hours</th>
<th>RNAV Experience</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Captain AA</td>
<td>ATP/FE, L-S80, 727, DC-10, 737</td>
<td>13,000</td>
<td>6 years</td>
</tr>
<tr>
<td></td>
<td>First Officer FAA</td>
<td>ATP, 737, HS-25, CL601, Beach 400/MU300</td>
<td>6,000</td>
<td>Minimal</td>
</tr>
<tr>
<td>2</td>
<td>Captain ATA</td>
<td>ATP/737, 757, 767, CE500, BE1900</td>
<td>9,000</td>
<td>Minimal</td>
</tr>
<tr>
<td></td>
<td>First Officer ATA</td>
<td>ATP, 737, 757, 767</td>
<td>6,000</td>
<td>Minimal</td>
</tr>
<tr>
<td>3</td>
<td>Captain DL</td>
<td>ATP, 737, 757, 767</td>
<td>9,300</td>
<td>Minimal</td>
</tr>
<tr>
<td></td>
<td>First Officer DL</td>
<td>ATP MD88, 737</td>
<td>7,500</td>
<td>2 years</td>
</tr>
<tr>
<td>4</td>
<td>Captain AWA</td>
<td>ATP, EMB-110, DHC08, A320, 737</td>
<td>14,000</td>
<td>2 year, trained for 0.3 RNP</td>
</tr>
<tr>
<td></td>
<td>First Officer AWA</td>
<td>ATP, A320, 737</td>
<td>3,500</td>
<td>2 year, sim/class RNAV instructor</td>
</tr>
<tr>
<td>5</td>
<td>Captain ASA</td>
<td>ATP, 707, 727, 737, DC-9, L-382</td>
<td>26,000</td>
<td>5+ years</td>
</tr>
<tr>
<td></td>
<td>First Officer FAA</td>
<td>ATP, 737</td>
<td>5,000</td>
<td>Sim only</td>
</tr>
</tbody>
</table>

A week before the test, each pilot received a brief description on the RPAT concept, a test copy of the MEM RNAV (RNP) 36R approach chart, and a test copy of the Aircrew All Users Page (Appendix A). Prior to each simulator session, the AFS-440 test director reviewed the RPAT concept and briefed each flight crew on the test procedures and conditions.

2.7 Human Factors Evaluation

The human factors data was collected using both subjective and objective methods. Subjective performance measures included post-run and post-simulation session questionnaires designed specifically to elicit comments from the subject pilots. A numerical weighting procedure was used to rate several human factors issues. The

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5 The briefing was in the form of a PowerPoint presentation and is available upon request from AFS-440.
questionnaires focused on any potential changes in either mental or physical workload encountered during the RPAT operation.

A test director and observer also evaluated the performance of the pilot and flight crew as they performed primary and secondary tasks. These tasks were observed during periods of high activity in the cockpit or during unusual situations, such as a NSE problem. For the purposes of this evaluation, primary task measurements included actions specific to performing this type of RNAV approach and RPAT operation (e.g., making RF turns, visually acquiring and maintaining contact with parallel traffic, responding to runway alignment [nominal and NSE], and avoiding weather conditions). Secondary task measurements included normal commercial aircraft operations (e.g., maintaining aircraft heading/airspeed/altitude, following communication procedures, and making aircraft configuration changes). The flight crews’ omission of any primary or secondary tasks may indicate the need to further investigate methods to change workloads during this operation.

The post-run questionnaire and post-simulation questionnaire are provided in Appendixes B and C, respectively. In addition to the questionnaires, a post-simulation debriefing was held with each flight crew using the format shown in Appendix D: Post-Simulation Debriefing. Post-simulation questionnaires were used with the post-simulation debriefing to elicit pilot responses. These results are contained in Appendix E: Post-Simulator Debriefing Synopsis.

3.0 Summary of Data Analysis

This section of the report examines the data collected during the simulation. The study collected data on (1) the actions the pilots took to recognize, resolve, and stabilize flight criteria during different types of NSEs; (2) TCV violations; and (3) the effects of autopilot and workload on the pilots’ ability to conduct an RPAT operation.

3.1 Navigation System Error Analysis

This analysis evaluated pilot actions in recognition, resolution, and stabilized flight criteria during a NSE of 0.10 NM.

There were 30 runs with a NSE of 0.10 NM left and 30 runs with an NSE of 0.10 NM right of the nominal track. In all cases, the pilots took no aircraft-related corrective actions caused by a NSE until the runway was visually acquired (i.e., the pilot did not recognize a NSE until the runway was visually acquired).

The pilots were asked if they were in an acceptable position to complete a landing with a NSE. (Refer to Appendix E, Question 2 for all crew comments regarding NSEs.) All
indicated they experienced no significant difficulty with the NSE and approach to landing. One pilot stated that he believed the effects of a NSE should be emphasized in training. In addition, a First Officer commented on the loss of visual contact with the ILS aircraft from the glare shield and canopy rail while in the turn away from the ILS aircraft.

3.1.1 Left Navigation System Error Conditions

Pilot corrective actions when presented with a left NSE primarily occurred near or just passing the CTPTR waypoint at approximately 3.0 NM from landing (during the second RF leg). This is supported by data that shows when the autopilot was disengaged. (All NSEs began with the autopilot engaged.)

Only one left NSE resulted in a descent rate TCV. This violation occurred at less than 1 NM from the runway at a descent rate of 1,185 feet per minute. It is assumed that this TCV was due to the pilot attempting to adjust his landing aim point and not due to the NSE. (There are simulator limitations from two-dimensional visual acuity systems.)

There was one bank angle violation during the very first left NSE run on the first day that occurred when the pilot abandoned the approach, disengaged the autopilot, and began a turn away from the ILS aircraft. The maximum bank angle achieved was 28 degrees for six seconds during this approach abandonment.

Of the 30 NSEs to the left, three resulted in an approach abandonment. One approach abandonment occurred during the 6,000 feet in-trail spacing scenario and the other two approach abandonments occurred during the 3,000 feet in-trail spacing scenario. Generally, all abandonments occurred at the pilot’s first exposure to an NSE in the simulator and pilot comments centered on uncertainty with the navigation system and sight picture of the ILS aircraft. However, no corrective actions were taken until the runway was visually acquired.

3.1.2 Right Navigation System Error Conditions

In the right NSE conditions, pilots continued with the autopilot ON even though the runway was in sight. Since the ILS aircraft was farther away on a right NSE and was not a perceived threat, the pilot did not disengage the autopilot until approximately 2.5 NM from the runway.

There were no bank angle TCVs for the right NSE. Had pilots waited longer to disengage the autopilot, it is surmised that the RNAV aircraft’s angle to the runway would be such that bank angle TCVs would have occurred as the pilots attempted to line up with the landing runway.
Only two descent rate TCVs occurred, both within 1 NM from the runway at approximately 1,200 feet per minute descent rate. Again, this is assumed to be at least partially attributable to typical simulator visual limitation with regard to runway aim point adjustments and not related to the NSE. Additionally, there were no approach abandonments during the right NSE.

3.1.3 Airspeed Test Criteria Violations

Approximately 20% of all NSE runs had airspeed TCVs where the $V_{REF}$ airspeed dropped below the 145-knot threshold for longer than three seconds. The average $V_{REF} +10$ TCV for airspeeds above 145 knots for longer than three seconds was approximately 30%. Note that there was an airspeed TCV spike for the left NSE at 3,000 feet in-trail spacing. With the captain as the Pilot Flying (PF), 50% of these runs exceeded $V_{REF} +10$. The slowest speed was 135 knots and highest speed 165 knots at 500 feet AGL.

There were no touchdown zone TCVs from the NSE runs.

3.2 Autopilot Use

This study also evaluated the use ofautopilot as a requirement to conduct an RPAT operation. As stated previously, there were 60 runs with the autopilot ON and 50 runs with the autopilot OFF.

There were no bank angle TCVs with the autopilot OFF or ON. There were no descent rate TCVs with the autopilot OFF. However, there were descent rate TCVs that did occur after the autopilot was disengaged during the autopilot ON runs. Just as in the NSE descent rate violations explained earlier, these violations occurred at less than 1 NM from the runway and were more likely due to adjustment to the landing aim point from the simulator visual acuity limitations.

A comparison of autopilot ON versus OFF cross track error (deviation from the programmed RNAV approach course) indicates that the overall average cross track error with autopilot OFF was approximately 100 feet right of the nominal track (wind and no wind). The maximum cross track error was 500 feet left of the nominal track and 1,000 feet right of the nominal track. For visual representations, see Figure 3 for the average cross track error, Figure 4 for the maximum left cross track error, and Figure 5 for the maximum right cross track error. The average cross track error with the autopilot ON was under ten feet left of the nominal track for all cases.

Figure 3: Average Cross Track Error
At time of maximum left cross track error, the ILS and RPAT aircraft were 7,200 feet apart.
At time of maximum right cross track error, the ILS and RPAT aircraft were 5,000 feet apart.

Over 90% of the autopilot OFF runs (wind and no wind) resulted in violation of the 200-foot overshoot TCV right of the nominal track. Almost 20% of the autopilot OFF runs resulted in the 200-foot TCV left of the nominal track. There were no 200-foot TCVs for the autopilot ON. It is clear that with the autopilot OFF, pilots elected to “err” on the conservative side and bias right of the nominal track and farther away from the ILS aircraft.

There were no vertical navigation deviation TCVs with the autopilot OFF or ON. The average vertical navigation deviation with autopilot OFF was 25 feet and 15 feet with the autopilot ON.

With the autopilot ON, the autopilot was disengaged on average 9,300 feet (1.5 NM) from the runway threshold, between the FOPR and Decision Altitude. However, observer notes and pilot comments indicate that at the first exposure to the RPAT scenarios, pilots felt more comfortable “hand flying” the final RF turn as the two aircraft

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6 This 200-foot TCV was incorporated from SOIA wake vortex studies for the San Francisco International Airport (SFO) closely spaced parallel operations. Although the runways at SFO are spaced 750 feet apart compared to the 927 feet at MEM which can impact wake vortex encounters, there currently are no studies on wake vortex based on varying runway spacing for closely spaced parallel operations[2].
merged for the closely spaced parallel operations. As exposure to the RPAT scenarios increased, pilots were more inclined to allow the autopilot to control the merge.

However, during the turn, pilots indicated that they were much more “heads down” when flying without the autopilot while attempting to maintain the flight director steering bars. As a result, pilots were distracted from monitoring the ILS traffic. Conversely, while attempting to take “quick peeks” at the ILS traffic, this affected the cross track, especially during the RF turns and the merge (note the 200-foot TCV). However, across all autopilot ON and OFF scenarios and within all crews, the pilots’ subjective responses indicated that their sense of mental workload remained relatively unchanged with a very slight decrease in perceived workload from the beginning of the evaluation to the end, regardless of whether the pilots were using autopilot.

Finally, there was a marginal difference in airspeed TCVs between the autopilot OFF versus ON. The worst case was airspeed below the 145 knot $V_{REF}$ airspeed TCV. However, regardless of whether pilots were using autopilot, aircraft averaged airspeeds below 145 knots approximately 25% of the time.

### 3.3 Percentage Test Criteria Violations

Table 3 shows overall percentages of TCVs for autopilot and NSEs as previously described in Section 3.1 and Section 3.2.

<table>
<thead>
<tr>
<th>Test Criteria Violation</th>
<th>Nominal</th>
<th>NSE 0.1L</th>
<th>NSE 0.1R</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A/P ON</td>
<td>A/P OFF</td>
<td>3,000</td>
</tr>
<tr>
<td>Bank Angle &gt; 500°</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Bank Angle &lt; 500°</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Descent Rate &gt; 1,000°/min</td>
<td>6.25%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Airspeed &lt; 145 knots</td>
<td>22.92%</td>
<td>27.08%</td>
<td>12.50%</td>
</tr>
<tr>
<td>Airspeed &gt; 155 knots</td>
<td>4.17%</td>
<td>2.08%</td>
<td>50.00%</td>
</tr>
<tr>
<td>Cross Track &gt; 200° right</td>
<td>0.00%</td>
<td>91.67%</td>
<td>N/A</td>
</tr>
<tr>
<td>Cross Track &gt; 200° left</td>
<td>0.00%</td>
<td>18.75%</td>
<td>N/A</td>
</tr>
<tr>
<td>Touchdown Point &gt; 3,000°</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Vertical Deviation &gt; 75°</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
</tbody>
</table>

*The 50% TCV under NSE 0.1L was at the 3,000 feet in-trail spacing with the captain as the PF.

### 3.4 Pilot Workload

The study evaluated pilots’ workload (e.g., maintaining in-trail spacing, completing the configuration checklist, and conducting autopilot OFF operations) while reducing airspeed. Workload is difficult to quantify without using equipment to measure physiological responses (e.g., eye movement and heart rate). However, this study recorded the pilots’ perception of both their physical and mental workloads. This report
primarily focuses on the results of the mental workload evaluation. Subjective observer and pilot comments from previous testing indicated that checklist management and crew coordination while simultaneously flying a challenging approach in close trail of parallel operations have been shown to increase pilot workload levels. As workload levels increase, the potential for mistakes increase such as $V_{\text{REF}}$ and cross track TCV explained earlier (an indicator of poor instrument crosscheck brought on by increased workload).

Observers universally noted an increase in pilot workload and, at times, a breakdown in crew coordination. Primarily, this occurred at or after the PFAF while reducing the airspeed, attempting to fully configure the aircraft, communicating to ATC, and completing the checklist items. Many times pilots completed the checklist below 1,000 feet, during the RF legs, and 2 to 3 NM from the runway (further discussed in Section 4.5). Although the pilots rated workload in the middle third of the scale, they did not perform all required secondary tasks.

Additionally, contrary to observer notes, pilots indicated that workload decreased very slightly from the beginning of the evaluation until the end. Unlike normal straight-in approaches, this procedure also required that pilots maintain visual contact and in-trail spacing with the ILS aircraft while simultaneously scanning to visually acquire the landing runway during reduced visibility operations. Not using autopilot also appeared to increase pilot workload. In addition, the closer the in-trail spacing and increased need for vigilance outside the cockpit, pilot scan patterns and visual acquisition strategies indicated an increase in the workload level.

However, the more the pilots were exposed to the runs and scenarios, the more comfortable they became with the RPAT operation. During the last few runs, little verbal communication occurred between the pilots. It should also be noted that no training program has been established as yet for an RPAT operation to address issues such as completing the checklist and improving coordination among crew members.

Table 4 shows the overall average ranking by scenario (from easiest to most difficult) of all mental workload questions completed by the pilot flying after each run. Please note that each pilot’s flying perception of scaling differs based on personal experiences and knowledge. That being said, the data consistently show that the pilot perception of mental workload increased when the autopilot was not used during the most difficult scenario (the 0.10 NM Left NSE). The three abandonments which occurred did so only during this workload-intensive scenario. The slight variances of the perceived difficulties of the scenarios are highlighted in yellow.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Crew 1</th>
<th>Crew 2</th>
<th>Crew 3</th>
<th>Crew 4</th>
<th>Crew 5</th>
</tr>
</thead>
<tbody>
<tr>
<td>A/P, A/T ON</td>
<td>1.0</td>
<td>2.0</td>
<td>2.5</td>
<td>2.5</td>
<td>4.0</td>
</tr>
<tr>
<td>Nom A/P ON</td>
<td>2.4</td>
<td>3.5</td>
<td>3.7</td>
<td>4.3</td>
<td>5.4</td>
</tr>
</tbody>
</table>
Table 5 shows the overall average ranking by scenario (easiest to most difficult) of all mental workload questions completed by the pilot monitoring after each run. Although the easiest (autopilot and auto-throttles ON) and hardest (0.10 NM Left NSE) were consistent with the pilot flying, the other scenarios varied and are highlighted in yellow. It is surmised that this variance may be due to no training program dictating cockpit duties for RPAT operations.

![Table 5](image)

Table 6 shows the overall average ranking by scenario (easiest to most difficult) of all crew coordination workload questions completed by the pilot flying after each run. The data again consistently show that the pilot perception of crew coordination workload increased when the autopilot was not used with the most difficult scenario (the 0.10 NM Left NSE). The order of scenario difficulty in Table 6 mirrors the mental workload for pilot flying as shown in Table 4. The slight variances of the scenario order are highlighted in yellow.

![Table 6](image)

Table 7 shows the overall average ranking by scenario (easiest to most difficult) of all crew coordination workload questions completed by the pilot monitoring after each run. For the most part, just as in Table 5, the easiest and hardest scenarios remained the same with a small variance in the other scenarios. The slight variances of the scenario order are highlighted in yellow.

![Table 7](image)
Table 8 shows the pilot responses to *post-simulation* autopilot ON and OFF workload question. The pilot responses indicate that 8 out of 10 pilots rated the overall workload lower with the autopilot ON versus OFF. The two responses that indicated otherwise are highlighted in yellow.

Table 8: Post-Simulation Autopilot ON versus OFF

<table>
<thead>
<tr>
<th>Crew #</th>
<th>Capt ON</th>
<th>F/O ON</th>
<th>Capt OFF</th>
<th>F/O OFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>3</td>
<td>9</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>3</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

4.0 Test Director/Observer/Subject Pilot Observations

Overall, all aircrews stated, as in the 2005 RPAT simulator test, that flying this RPAT operation was feasible, but they expressed concerns about training, crew coordination, and checklist performance. Again, there is no established training program for RPAT operations.

4.1 In-Trail Spacing

One observer and pilot-reported area of note was the in-trail spacing scenarios. Unlike the 6,000 feet scenario (8,500 feet laterally at start of run), all the aircrews reduced airspeed early before the PFAF during the 3,000 feet in-trail scenario (5,500 feet laterally at start of the run). The single reason given was that the pilots believed they might overtake the ILS aircraft, even though both aircraft were at co-airspeeds of 170 knots to the PFAF.

(Note that the ILS aircraft airspeed reduction began after the PFAF.) In addition, at the closer 3,000 feet in-trail spacing, first officers reported difficulty keeping the ILS traffic in sight while looking cross-cockpit due to obstructions from either the captain’s seat position or the glare shield while in a bank. None of these issues surfaced at the 6,000 feet in-trail spacing.

Additionally, one purpose of this test was to determine the pilot’s ability to visually assess the in-trail spacing geometry during airspeed reduction to final approach speed and/or to determine which in-trail spacing position made them more comfortable (or
induced more workload) from the in-trail spacing start point. For the 6,000 feet in-trail spacing scenarios, the average spacing crossing the threshold was 5,347 feet with a maximum of 7,820 feet and a minimum of 3,716 feet. Only 7% exceeded the 6,000 feet in-trail benchmark. For the 3,000 feet in-trail spacing scenarios, the average spacing crossing the threshold was 3,363 feet with a maximum of 4,474 feet and a minimum of 2,088 feet. Of these 3,000 feet in-trail spacing scenarios, 75% exceeded the 3,000 in-trail spacing benchmark. Considering that they were only 4.5 NM from the PFAF to the runway, it appears that pilots were relatively able to maintain the initial start in-trail spacing. However, based on the above numbers, the “comfortable” range was closer to the 4,000 to 5,000 feet in-trail spacing.

4.2 Progress Page 4

Pilots were allowed to use Progress Page 4 on the control display unit which shows the lateral and vertical cross track error. Actual navigation performance was also displayed. However, observers noted that the aircrews rarely cross-checked this progress page when it was displayed for every run and no pilot verbal comments were made in this area. This would be a training issue.

4.3 TCAS Resolution Advisories

The RPAT simulator test conducted in 2005 exposed some RPAT approach design flaws, most notably, TCAS Resolution Advisories (RAs) when the two aircraft merge. Subsequently, a RPAT/TCAS design tool was created to evaluate the approach design for TCAS RAs before final design approval. The finalized Memphis RPAT approach used for this test resulted in no TCAS RAs during the 170 runs. However, there were six Traffic Advisories (TAs). Table 9 shows the airspeed of the RNAV aircraft during the six TAs, which all occurred at the 3,000 feet in-trail spacing merge.

<table>
<thead>
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<th>Day</th>
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<th>Minimum</th>
<th>Maximum</th>
<th>Average</th>
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<tr>
<td>3</td>
<td>31</td>
<td>151</td>
<td>174</td>
<td>165</td>
</tr>
</tbody>
</table>

Note that the ILS aircraft was slowing from 170 knots to 145 knots and reached 145 knots while the RNAV aircraft was still in the second RF turn. It is surmised that the RNAV aircraft’s excessive speed differential with the ILS aircraft during the merge at the 3,000 feet in-trail spacing resulted in the TAs and could be linked to pilot workload.
4.4 Pilot Flying/Pilot Monitoring

All crews were asked who they thought should be the Pilot Flying (PF). (Refer to Question 7 in Appendix E: Post Simulator Debriefing Synopsis to read the responses of all crews to this issue.) Generally, aircrews thought that the PF should be opposite of the ILS traffic. With this delineation of cockpit duties, the PF could devote more attention to flying the approach while the PM (the captain) could devote more energy to monitoring the ILS traffic and visually acquiring the runway. Note the 50% airspeed TCV at the 3,000 feet in-trail spacing with the captain as the PF. Considerations such as the Head-Up Display (HUD) and in-trail spacing need to be factored into the training and crew coordination process.

4.5 Checklist

To enhance the pilot workload environment, the RNAV aircraft was not fully configured and the configuration checklist not completed at the start of the test run. Observers reported during every simulator session that both pilots were “heads down” for a significant time inside the cockpit, and completed the checklist while in the RF turns. Additionally, during a significant number of runs, aircrews completed the checklist below 1,000 feet AGL. After approximately one-third of the initial runs, aircrews discovered that if they completed the checklist before the PFAF, it reduced their workload and allowed them to properly monitor ILS aircraft. This would be a training issue.

4.6 Autopilot and Auto-Throttles

Run 33 and Run 34 were conducted with the autopilot ON and auto-throttles ON. It is noteworthy that during these runs, no bank angle, descent rate, airspeed, or cross track error TCVs occurred. In addition, observers noted that there was very little verbal interplay between the pilots during the approach. Pilots reported a significant reduction in workload and generally believed it was easier with the aircraft configured with both the autopilot ON and auto-throttle ON.

4.7 Flight Technical Error

Lastly, this study initially attempted to collect information on Flight Technical Errors (FTEs) from the cross track data during the RF turns. FTE is an error induced by the pilot or by the autopilot. The difficulty in validating the FTE data for this study was two-fold. First, the data collected would be RPAT-specific (potentially biased from simultaneous operations with the ILS aircraft) and unusable for general RF turn analysis. Second, as stated in Section 3.2, Autopilot Use, there was a clear bias towards a cross track error that
was right of the nominal course (and away from the ILS aircraft) when the autopilot was not used. There currently are no studies on FTEs during RF turns. However, a study is being developed to analyze FTEs during RF turns across all spectrums of Flight Management Systems. In addition, the next RPAT study will analyze the bias found in this study by placing the ILS aircraft on the first officer’s side of the aircraft.

5.0 Recommendations

The following recommendations are made as a result of this RPAT operation safety study:

1. Develop an RPAT training program to address crew coordination, aircrew workload, and checklist management. This is a repeat of the 2005 RPAT simulator test recommendation.

2. Mandate the use of autopilot for RPAT operations to mitigate pilot workload and ensure RNAV course guidance is maintained for closely spaced runway operations. This is a repeat of the 2005 RPAT simulator test recommendation.

3. Conduct a study to validate Pilot Flying versus Pilot Monitoring issues and cross track bias found in this test with the ILS aircraft on the right side of the RNAV aircraft. (All previous studies have been conducted with the ILS aircraft to the left side of the RNAV aircraft.)

4. Conduct a study to determine pilot’s ability to visually maintain proper in-trail spacing.

5. Conduct a study to evaluate night RPAT operations.

6. Conduct further studies to determine Flight Technical Errors in RNP approaches with RF legs.

Appendix A:

Aircrew All User Page (DRAFT-TEST PURPOSE ONLY)
MEM RNAV (RNP) RWY 36R

SPECIAL USE OF MEM RNAV (RNP) RWY 36R FOR RNP PARALLEL APPROACH TRANSITION (RPAT) OPERATIONS

Special pilot training required. This operation will be flown IAW FAA RPAT Concept Plan. Standard parallel monitoring services will be provided by ATC for the intermediate approach segment up to a point abeam the MEM RNAV (RNP) RWY 36R PFAF. Following the PFAF, the aircrew is responsible for safe separation.

Condensed Briefing Points:

- When instructed, **immediately** contact the Tower.
- **Report** the PFAF position and **ILS traffic in sight**.
- **DO NOT continue the approach beyond the PFAFR waypoint** without visually acquiring the ILS traffic. **Execute approach abandonment at the PFAF**.
- **DO NOT continue the approach beyond the CTPTR waypoint** without visually acquiring the runway. **Execute the approach abandonment procedure**
- **DO NOT PASS the ILS traffic**.
- **Remain on the RNAV approach path** to the DA.
- **Approach abandonment** by turning to 015 degrees and climbing immediately to 5000 ft MSL, expect radar vectors

1. **Dual VHF Communication Required.** Pilots will contact approach control for instructions to conduct the approach. Pilots will ONLY transmit on the primary approach control frequency, but will monitor the monitor controller’s frequency. It is important that pilots do not select the monitor frequency audio until instructed by approach to contact the tower. When instructed to do so, pilots will contact Tower and remain on that frequency until completion of the approach or as otherwise instructed by ATC. The Monitor controller’s transmissions, if needed, will override Tower control frequency. The volume levels should be set about the same on both radios so that the pilots will be able to hear transmissions on at least one frequency if the other is blocked.

2. **Breakouts.** All “Breakouts” are to be hand flown to assure that the maneuver is accomplished in the shortest amount of time. Pilots, when directed by ATC to break off an approach, must assume that an aircraft is blundering toward their course and a breakout must be initiated immediately.

   a) **ATC Directed “Breakouts”**: ATC directed breakouts will consist of a turn and a
climb or descent. Pilots must **always** initiate the breakout in response to an air traffic controller’s instruction. Controllers will give a descending breakout only when there are no other reasonable options available, but in no case will the descent be below minimum vectoring altitude (MVA) which provides at least 1000 feet required obstruction clearance. MVA for MEM airport is 2000 feet.

b) Phraseology – “TRAFFIC ALERT”: If an aircraft enters the No Transgression Zone (NTZ), the controller will breakout the threatened aircraft on the adjacent approach. The phraseology for the breakout will be:

“TRAFFIC ALERT, (aircraft call sign) TURN (left/right) IMMEDIATELY, HEADING (degrees), CLIMB/DESCEND AND MAINTAIN (altitude)”.

3. **Prior to PFAF:** If ATC advises that there is traffic on the ILS 36C, pilots are authorized to continue past the PFAFR waypoint to align with the 36R centerline when:

   a) The ILS traffic is in-sight and is expected to remain in sight, and

   b) Pilots have broadcasted that “traffic is in-sight.”

If ILS traffic is not in sight, execute approach abandonment at PFAFR by turning to 015 degrees and climbing immediately to 5000 ft MSL, contact Tower.

4. **PFAF to DA:** Pilots are responsible for separating themselves visually from traffic on the ILS approach. Remain on the RNAV approach path unless maneuvering the aircraft is necessary for safe separation until landing (DO NOT PASS), and providing wake turbulence avoidance, if applicable. **If visual contact with the ILS traffic is lost OR the runway is not visually acquired by CTPTR, advise ATC as soon as practical and execute the published abandonment procedure by turning to 015 degrees and climbing immediately to 5000 ft MSL.** Note runway centerline spacing between 36C and 36R is 927 feet.

NOTE: ATC may otherwise direct either aircraft to ensure aircraft separation.
Appendix B: Post-Run Questionnaire

1. In general, compare the VISUAL segment of this RPAT procedure, while maintaining the course guidance and visual separation, to other approaches that you perform (overall level of effort).

   
   Very Easy       Average       Very Hard
   1 2 3           4 5 6          7 8 9

2. Rate your comfort level with this RPAT approach procedure given the proximity of the parallel traffic.

   
   Very Comfortable   Moderately Comfortable   Uncomfortable
   1 2 3               4 5 6                        7 8 9

3. Rate your level of aircraft stabilization for the VISUAL segment portion of this approach based upon your organization’s guidance for a stabilized approach.

   
   High               Moderate               Low
   1 2 3               4 5 6                        7 8 9

4. Rate your perceived level of physical workload (e.g., head movement, switchology, controls) while flying this approach.

   
   Low               Moderate               High
   1 2 3               4 5 6                        7 8 9

5. Rate your perceived level of mental workload (e.g., searching, thinking, deciding, calculating) while flying this approach.

   
   Low               Moderate               High
   1 2 3               4 5 6                        7 8 9

6. Rate your perceived level of crew workload while flying this approach (e.g., thinking, coordinating, searching, communicating, etc.).

   
   Low               Moderate               High
   1 2 3               4 5 6                        7 8 9
Appendix C: Post-Simulation Questionnaire

1. How safe is this RPAT procedure, considering the proximity to parallel traffic, with respect to maneuvering speed, stabilized visual approach segment, transition to the runway, etc.?

   Very Safe  Average  Very Unsafe
   1 2 3 4 5 6 7 8 9

2. Compared to other approaches, rate the overall workload for this RPAT approach procedure, flown under nominal conditions.

   Very easy  Average  Very Hard
   1 2 3 4 5 6 7 8 9

3. Rate your overall comfort level with having to monitor the close proximity parallel traffic while maneuvering on the RNAV approach, flown under nominal conditions.

   Very Comfortable  Moderately Comfortable  Uncomfortable
   1 2 3 4 5 6 7 8 9

4. A. Rate the level of difficulty with the visual transition, from parallel traffic to the runway environment as the Pilot Flying.

   Very Easy  Average  Very Hard
   1 2 3 4 5 6 7 8 9

4. B. Rate the level of difficulty with the visual transition, from parallel traffic to the runway environment as the Pilot Monitoring.

   Very Easy  Average  Very Hard
   1 2 3 4 5 6 7 8 9

5. A. Rate the level of overall workload with autopilot.

   Very Easy  Average  Very Hard
   1 2 3 4 5 6 7 8 9

5. B. Rate the level of overall workload without autopilot.

   Very Easy  Moderately Easy  Very Hard
   1 2 3 4 5 6 7 8 9
Appendix D: Post-Simulation Debriefing

1. Overall, did you feel comfortable with this approach, based upon your experience with all other approaches that you perform? Why or why not?

2. Taking into consideration the Navigation System Error, at rollout for alignment with the runway centerline, were you in an acceptable position to complete a landing? Why or why not?

3. What additional mental or physical requirements, if any, were imposed on you during this approach?

4. Would you consider this approach to be stabilized based upon your company’s/organization’s guidelines for a “stabilized approach”? Why or why not?

5. Did you have any difficulty monitoring the parallel traffic while flying this RPAT approach? How about without the autopilot? Explain why or why not?

6. What impacted your performance most (i.e., monitoring the parallel traffic, flying the RNAV approach, transitioning to the runway environment/lining up with the runway centerline, descent rate to the TDZ)?

7. Based on this particular demonstration, who do you feel should be the PF? Why?
Appendix E: Post-Simulator Debriefing Synopsis

1. Overall, did you feel comfortable with this approach, based upon your experience with all other approaches that you perform? Why or why not?

   Crew #1: Comfortable. More so at the end, but never truly comfortable
   Crew #2: Only discomfort was when right behind traffic, on left NSE. Recognized this in later runs and kicked OFF autopilot.
   Crew #3: Capt: Uncomfortable initially due to no auto-throttle. Sum total: Easy after 34 runs.
   F/O: No better than moderated comfort level. Needs to be more discussion in briefing regarding division of responsibilities.
   Crew #4: More comfortable with more repetition.
   Crew #5: Very

2. Taking into consideration the Navigation System Error, at rollout for alignment with the runway centerline, were you in an acceptable position to complete a landing? Why or why not?

   Crew #1: Absolutely
   Crew #2: Yes, we could have made them all, no problem.
   Crew #3: Capt: Able to recognize error in timely manner and correct
   F/O: Yes
   Crew #4: Should be emphasized training issue. Should be automatic correction due to visual.
   Crew #5: Yes, especially with visual guidance on runway. Could always continue.

3. What additional mental or physical requirements, if any, were imposed on you during this approach?

   Crew #1: Flying without autopilot is higher workload (based on AA ops requirements)
   Crew #2: It was hard to find the runway lights. There was a lot going on right at that point. We decided to throw the company fuel savings policy out the window and said we need to do what needs to be done to safely fly this approach. Need to configure early and give us time. Each airline that flies these would need to train, policy and ops specs.
   Crew #3: Capt: Coordination of visual acquisition versus flying A/C introduced complexity
   F/O: “Formation flying” now part of crosscheck, new, different
Crew #4: Workload increased with A/P OFF. If checklist completed sooner, would be no problem
Crew #5: Shifted when PF had no A/P

4. Would you consider this approach to be stabilized based upon your company’s/organization’s guidelines for a “stabilized approach”? Why or why not?

Crew #1: Not always by the book definition. But not so much so that it was uncomfortable
Crew #2: Out company policy is that the PF flies the aircraft, and the PM is both outside and checking inside. We would consider this a stabilized approach.
Crew #3: Both yes and very stable
Crew #4: A few times, but corrected in a timely manner
Crew #5: RF turns very smooth. Never lost stabilization.

5. Did you have any difficulty monitoring the parallel traffic while flying this RNAV approach? How about without the autopilot? Explain why or why not?

Crew #1: Much more inside than outside. With A/P, we can be outside more
Crew #2: No, no problem in either case. Flying this is more taxing without the autopilot, but not hard to do
Crew #3: Almost impossible cross cockpit. In-trail spacing had a big impact on comfort level with approach
Crew #4: More difficult when aircraft was closer in trail
Crew #5: This is distance-dependent. More work, head movement. S-turn allowed spacing without having to speed adjust. Initially, perception was that we might pass the traffic. So we slowed down.

6. What impacted your performance most, i.e. monitoring the parallel traffic, flying the RNAV approach, transitioning to the runway environment /lining up with the runway centerline, descent rate to the TDZ?

Crew #1: With A/P on, spending more time inside versus outside (initially, quite a bit more until comfortable)
Crew #2: Capt: We had heading changes in such short distances, being lined up most difficult
F/O: Finding the runway environment was the most difficult
Crew #3: Capt: Runway acquisition…transitioning to pure visual for landing
F/O: Lack of autopilot
Crew #4: None
7. Based on this particular demonstration, who do you feel should be the PF? Why?

Crew #1: Capt: Capt should fly the more challenging approaches. Capt reaction time would be faster given the closer position (with A/P on)
F/O: Opposite pilot from the visual approach (A/P dependent)

Crew #2: PF should be on the side opposite to the parallel traffic. However, we should also consider the HUD if parallel traffic is on the left. In this case, because the HUD would block the right seater’s view of the traffic, the PF should be on the left

Crew #3: Capt: Need good brief to know who should be doing what
F/O: The guy opposite the traffic should be the PF…no easy answer though

Crew #4: Without the luxury of many repetitions and a more seasoned FO, might consider having FO fly on the right side to better maintain visual on traffic from left

Crew #5: Much more comfortable with cross cockpit due to relative movement of traffic to the crossbeams. May be company dependent, not much different
References


