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Simultaneous Independent and Dependent Parallel Instrument Approaches

Assumptions, Analysis, and Rationale

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Abstract

The Federal Aviation Administration has successfully conducted simultaneous independent approaches to parallel runways for over 40 years using Instrument Landing System (ILS) navigation and terminal radar monitoring. Parallel dependent approaches have also been conducted for many years. Recent advances in navigation and surveillance have sparked interest in reviewing the current standards for these approaches. This paper will attempt to describe the process that led to the current standards, including relevant assumptions, testing, and methodology. Future work will identify the most promising assumptions for further review.

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1 Introduction

The Federal Aviation Administration has successfully conducted simultaneous independent approaches to parallel runways for over 40 years using Instrument Landing System (ILS) navigation and terminal radar monitoring. Parallel dependent approaches have also been conducted for many years. Recent advances in navigation and surveillance have sparked interest in reviewing the current standards for these approaches. This paper will attempt to describe the process that led to the current standards, including relevant assumptions, testing, and methodology. For simplicity, the terms "simultaneous" and "dependent" approaches will be used throughout the paper. Note also that this paper refers to approaches conducted in Instrument Meteorological Conditions (IMC); instrument approaches in Visual Meteorological Conditions (VMC) are not discussed.

2 Current U.S. Standards for Simultaneous Approaches

Simultaneous approaches allow aircraft to approach runways independently of adjacent parallel runways. Aircraft may pass or be passed by aircraft on the adjacent approach path, but must maintain standard separation behind aircraft on the same approach path. The standards for simultaneous approaches are generally contained in FAA Order 7110.65R, paragraphs 5-9-7 and 5-9-8. Table 2-1 provides a summary.

Table 2-1. Simultaneous Instrument Approach Standards
(FAA Order 7110.65R)

# Runways	Radar/Update Rate (seconds)	Type Display	Min. Runway Separation (ft)	Remarks
2	Standard/4.8	Standard	4300	
2	PRM/2.4	PRM	3400	
2	PRM/1.0	PRM	3000	$\geq$2.5 deg Offset Localizer
3	Standard/4.8	Standard	5000	< 1000 ft Elevation
3	Standard/4.8	FMA	4300	< 1000 ft Elevation; Requires aeronautical study if $\geq$ 1000 ft elevation

Notes for Table 2-1:

- Standard radar generally consists of a Secondary Surveillance Radar (SSR) and a Primary Surveillance Radar (PSR). However, when used with an FMA display (see below), only the SSR returns are displayed.

- Precision Runway Monitor (PRM) is a monopulse SSR with a faster-than-standard update rate. Current PRMs use electronic scan (e-scan) technology.

- Standard displays are the standard analog and digital Automated Radar Terminal System (ARTS) green displays.

- The PRM display is a digital color display with alerting algorithms that is associated with a PRM radar. The Final Monitor Aid (FMA) is a similar display, but is used with standard radar. See the *PRM Demonstration Report* [PRM Program Office, 1991] for further description of the PRM display.

All standards require:

- A 1000-ft vertical separation until established on the appropriate approach path

- The use of normally-functioning straight-in ILS or Microwave Landing System (MLS) approaches

- A 2000-ft-wide No Transgression Zone (NTZ) placed equidistant between the centerlines of the approach paths on the controller radar display.

The NTZ begins at the highest glide-path intercept point and continues until one mile before the runway thresholds.[1] The remaining area between the NTZ and the course centerline is called the Normal Operating Zone (NOZ); see Figure 2-1. Note that the size of the NTZ remains constant regardless of the runway spacing. Therefore, the size of the NOZ is reduced at closer runway spacing. A radar controller with communications override and a discrete radio frequency is required to monitor each approach path. This controller is in addition to the normal radar and tower controller required for each runway.

NOZ

NTZ (2000 ft wide)

NOZ

Glide Path Intercept
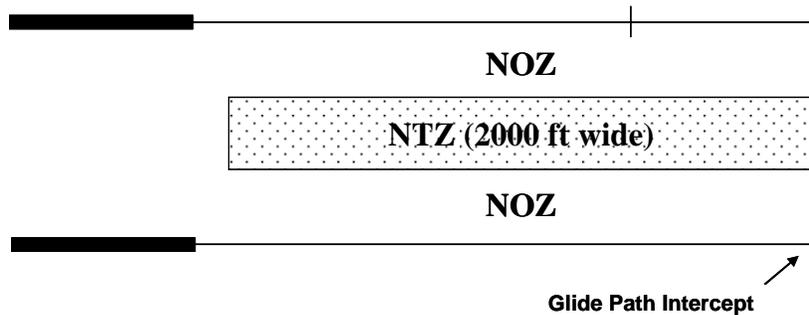
Figure 2-1. NTZ and NOZ

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[1] The NTZ continues to ½ NM beyond the departure end of the runway for closely spaced approaches using the PRM.

3 Current U.S. Standards for Dependent Approaches

Dependent approaches allow aircraft to approach parallel runways, but controllers must ensure a minimum separation from aircraft on the adjacent approach path (diagonal spacing) in addition to maintaining standard separation behind aircraft on the same approach path (in-trail spacing). Aircraft may not pass or be passed once they are established on their approaches. Table 3-1 provides a summary of the standards for dependent approaches, which are contained in FAA Order 7110.65R, paragraph 5-9-6. Note that there are no standards for mixed simultaneous and dependent approaches to three parallel runways, although research has been performed on this procedure [Lankford et al., 2003]. All standards require a 1000-ft vertical separation until established on the appropriate approach path, straight-in ILS or MLS, and a radar controller, but no NTZ or NOZ is required. Also, individual controllers are not required for each runway, nor are discrete communications frequencies required for each runway. See the Table 2-1 notes above for explanations of terms for Table 3-1.

Table 3-1. Dependent Approach Standards
(FAA Order 7110.65R)

# Runways	Radar/Update Rate (seconds)	Type Display	Min. Runway Separation (ft)	Remarks
2	Standard/4.8	Standard	2500–4300	1.5 mile diagonal
2	Standard/4.8	Standard	4301–9000	2.0 mile diagonal

4 Development of Simultaneous Approach Standards

The FAA began using simultaneous approaches to two parallel runways prior to 1962 at Chicago O'Hare International Airport (ORD), based on an analysis of the lateral deviation of aircraft on ILS approaches at ORD. The MITRE Corporation developed a computer simulation model in the early 1970s and investigated reduced runway spacing and improved equipment for simultaneous approaches [Haines, 1972; Haines and Swedish, 1981]. In 1974, the FAA reduced the spacing required for dual simultaneous approaches to 4300 ft, based on data [RESALAB, 1972] and experience at Atlanta airport, which at that time had runways spaced 4400 ft apart.[2]

As a result of modeling and analysis, the FAA decided to develop a high-update-rate radar that should allow closer spacing between runways. This decision led to the development of the PRM in the late 1980s. After analysis of test results, the FAA approved simultaneous approaches to two runways spaced 3400 ft apart [PRM Program Office, 1991].

In the late 1980s the FAA began a program, called the Multiple Parallel Approach Program (MPAP), to investigate conducting simultaneous approaches to three parallel runways. Over a period of several years, the MPAP performed analyses and testing of various simultaneous approach procedures for two and three runways, resulting in the publishing of the remaining standards in Table 2-1.

This paper will attempt to describe the process used to develop the current standards, including relevant assumptions, testing, and methodology. The discussion will focus on the analytical and testing methods used in the PRM Demonstration Program and the MPAP, because the majority of the current standards were developed in these programs, and the analytical and testing methods were similar.

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[2] The MITRE analysis at the time did not support 4300-ft spacing. When the FAA declared that 4300 ft was a safe separation, MITRE recalibrated its spacing model to fit the assumptions that would agree with the 4300 ft. See [Barrer, 1986].

5 Development of Dependent Approach Standards

The FAA has used dependent approaches to two parallel runways for many years. The original standards required 2 NM of diagonal spacing with runways separated by at least 3000 ft. The basis for this standard is not known. The runway spacing was reduced to 2500 ft in 1983. The diagonal separation was reduced to 1.5 NM for runways spaced 2500–4300 ft in 1992, based on analytical analysis, real-time simulation at the William J. Hughes FAA Technical Center (FAATC), and field testing [FAA Office of System Capacity and Requirements, 1992].

The FAA's rationale for the reduction in runway spacing and diagonal separation for dependent parallel approaches was partly influenced by MITRE analysis based on the technique in [Haines and Swedish, 1981]. This technique involved analyzing the miss distance that resulted from an aircraft deviating from one approach course towards another. Deviations of 3–30 degrees were analyzed and combined with speed overtakes of up to 30 knots. Analytical results showed that there was no danger of aircraft collision unless excessive overtake speeds were allowed. The results also indicated that closer runway spacing produced larger miss distances; the deviating aircraft would cross the other approach path and start to diverge sooner. After testing at the FAATC and field testing, criteria were approved that allow the current runway and diagonal separation standards shown in Table 3-1.

6 Criteria, Assumptions, Testing, and Methodology for Development of Simultaneous Approach Standards

6.1 Testing for Simultaneous Approach Standards

The testing accomplished for acceptance of simultaneous approach standards (with the exception of the original 4300 ft standard) consisted of real-time, human-in-the-loop simulation of simultaneous approaches combined with fast-time, Monte-Carlo simulation. MPAP simulations were guided and reviewed by an FAA Technical Working Group (TWG) that consisted of representatives from Flight Standards, Airport/System Capacity, Air Traffic, and the National Air Traffic Controllers Association (NATCA). PRM Demonstration simulations were viewed by a variety of observers, including the groups contained in the TWG. Both programs involved participation by airline industry, pilot, and controller groups in the planning, execution, and review of the simulations.

6.2 Considerations for Acceptance of a Procedure

The three considerations that were applied to determine if a procedure would be recommended for acceptance are described in the following subsections.[3]

6.2.1 Nuisance Breakout Rate

During normal operations, aircraft flying an ILS approach wander about the centerline. This is typical of the navigation and flight errors inherent in ILS approaches.[4] If an aircraft wanders near the NTZ, then the controller may vector or break the aircraft off from the approach to ensure separation and to re-sequence into the approach path at a later time. This is referred to as a *nuisance breakout*.[5] For closer runway spacings, the diminishing size of the NOZ may cause a higher rate of nuisance breakouts. Note that the nuisance breakout rate is not a safety issue, but rather a capacity issue, because aircraft must be re-sequenced into the landing flow. However, it could become a safety issue if the nuisance breakout rate was extremely high. There was not a

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[3] These criteria were used for the MPAP. The PRM Demonstration Program used a similar set of criteria [PRM Program Office, 1991].

[4] Flight and navigation errors observed during actual simultaneous approaches were used in the simulation. See later discussion and references.

[5] The testing discriminated between nuisance breakouts, where no blunder was programmed by the Test Director, and blunders, where a turn towards the other final was programmed by the Test Director. The controllers did not know if the closeness of the aircraft to the NTZ was caused by wandering or by a blunder. Also, the exact criterion for initiating a breakout to prevent loss of separation is at the discretion of the controller.

hard-and-fast upper limit for the nuisance breakout rate, but many TWG members considered 5 percent to be too high.

6.2.2 Target Level of Safety

The target level of safety (TLS) used for simultaneous approaches was no more than one fatal accident per 25 million approaches (i.e., 4×10^{-8} accidents per approach). This TLS was determined by apportioning the estimated accident rate of North American air carrier aircraft to account for a collision during the approach phase of flight. See [PRM Program Office, 1991].

6.2.3 Operational Assessment

An operational assessment from MPAP TWG members was conducted, based on their expertise and judgment, regarding the feasibility of implementing the procedure in the operational environment. Decisions were normally based on the observation and results of the real-time simulation and the results of the fast-time simulation.

6.3 Determination of the Standard To Be Tested

A goal for the testing was set by consensus. For example, a goal of 4300-ft triple simultaneous approaches was the original objective for the MPAP. Later goals included 5000-ft triple approaches with standard displays and surveillance, 4300-ft triple approaches with FMA displays and standard surveillance, etc. See [Morrow-Magyarits and Ozmore, 1999] for a summary of all scenarios tested during the MPAP.

6.4 Development of Scenarios

Specific scenarios were developed for each real-time simulation. The PRM demonstration program used scenarios specific to Memphis International Airport (MEM) and Raleigh-Durham International Airport (RDU). MPAP simulations generally consisted of a generic airport with parallel runways oriented north-south and spaced appropriately for the standard to be tested. There were no converging runways or separate departure runways.[6]

Traffic scenarios were created by using a sampling of traffic representative of busy simultaneous approach airports, including the types of aircraft, approach speeds, and traffic levels. Departures were simulated from each of the parallel runways.

Navigation errors during normal approaches were derived from ILS performance measured at ORD [Thomas and Timoteo, 1989], Los Angeles International Airport (LAX), [Thomas et al.,

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[6] The MPAP conducted airport-specific simulations for Dallas Fort Worth International Airport (DFW) and Denver International Airport (DEN). These simulations were similar to the MPAP simulations described above, but did not generally contribute to the development of national standards, so they are not included in this paper. See [Morrow-Magyarits and Ozmore, 1999].

1993], and MEM [PRM Program Office, 1991; Buckanin and Biedrzycki, 1987], and were modeled after the turn onto the localizer final by linearly decreasing the standard deviation of the lateral error as the aircraft approached the runway threshold. Because simultaneous approaches require a minimum of 1000 ft of altitude separation during the turn onto the localizer, no turn-on errors were contained in any of the scenarios.

6.5 Conduct of the Real-Time Simulation

Real-time simulations were conducted at the FAATC for the MPAP, and at MEM and RDU for the PRM Demonstration Program. Only the monitor controller positions were specifically simulated, although other positions were simulated in a limited manner to ensure the realism of the monitor-controller position.

Monitor controllers were seated at displays appropriate to the simulation (i.e., standard, FMA, or PRM displays) with a simulated sensor input appropriate to the simulation (e.g., 1-second update secondary targets for the PRM; 4.8-second primary and secondary targets for standard radars). Monitor controller displays were located at adjacent positions, allowing both intercom and direct voice communication between the controllers. Normally, several sets of controllers were selected from air-traffic facilities that conducted simultaneous approaches and were briefed to follow standard procedures and phraseology contained in the *Controllers Handbook* (FAA Order 7110.65), unless different phraseology was specifically being tested. Controllers received familiarization on the equipment, but were not briefed on the specific test criteria or specific goals of the simulation.

The majority of the aircraft in the simulation were computer-generated targets controlled by pseudo-pilots in communication with the test controllers. Blocked and clipped communications were incorporated into the MPAP simulations, and were incorporated in the post-simulation analysis for the PRM Demonstration Program. As noted above, no feeder, local, or other positions were established, although a supervisor position was established to facilitate answering controller questions. Computer-generated aircraft were generated on the final approach course at the appropriate speed and longitudinal spacing. Computer-generated aircraft slowed to final approach speed near the outer marker in accordance with a predetermined schedule, and reflected path-following errors appropriate to ILS. Pseudo-pilots could adjust the speed, heading, and altitude of the computer-generated aircraft if instructed by the monitor controller.

The MPAP simulations incorporated FAA-certified airline flight simulators flown by current airline pilots and a general-aviation simulator flown by current general aviation pilots. The airliner flight simulators were located at remote locations, and their position, altitude, and communications information were relayed to the FAATC via telephone link. The simulation test director inserted these simulators into the traffic flow, and the pilots "flew" the simulators on the approach, following instructions from the monitor controllers as appropriate, including speed-control and breakout instructions. In general, there was no overt way for the controllers to

differentiate between the flight-simulator and computer-generated aircraft, although controllers could sometimes differentiate between the phraseology of the airline pilots and the pseudo-pilots.

The PRM Demonstration Program real-time simulations did not explicitly include flight simulator traffic, but flight simulator data were incorporated in the analysis using the fast-time simulation.

Each simulation normally consisted of a series of "runs," usually lasting about one hour. During each run, traffic was started onto each final approach course, and controllers adjusted speed and conducted normal duties. If an aircraft strayed too near the NTZ, controllers would issue instructions to return to the centerline or break the aircraft off the final and return it to the feeder controller for re sequencing. Breakouts resulting from deviations near the NTZ were considered nuisance breakouts and were recorded.

At times determined by the Test Director, a computer-generated aircraft was instructed to execute a standard-rate turn off one of the approach courses towards another approach course. This was called a "blunder." The angle of the turn was predetermined by the test director, as was the rate of descent of the blundering aircraft (either level or continuing at a 3-degree rate of descent). The timing of the start of the blunder was computed to ensure that the blundering aircraft would pass close to a flight simulator aircraft if no corrective action were taken by the monitor controllers.

When the deviation was observed, the monitor controller for the approach course from which the aircraft deviated instructed the aircraft to return to course. The response of the pseudo-pilot was pre-specified by the Test Director. Some blundering aircraft returned to course after instructions by the monitor controller (a *responding* blunder), and some aircraft continued towards the other final approach path(s) on the course resulting from the blunder angle turn (a *non-responding* blunder).

The monitor controller(s) on the adjacent approach course(s) normally issued breakout instructions to aircraft threatened by the blundering aircraft. Typically, these instructions involved a turn away from the blundering aircraft and a climb, although other reactions were occasionally observed. Recall from above that the start of the blunder was timed to occur so that a flight-simulator aircraft was threatened by the blundering aircraft.

After the completion of a blunder event, blundering and threatened aircraft were removed from the displays and normal operations continued. Typically, 5–6 blunders were conducted per run, with some blunders on each final approach course involved.

There was an extensive data collection program for each blunder in the real-time simulations that included the following:

- Blunder start time

- Blunder angle and response mode (responding or non-responding)

- Blunder descent angle

- Time and type of PRM or FMA alerts

- Time of controller instructions to blundering and threatened aircraft

- Time of starting turn from the flight simulator aircraft

- Closest Point of Approach (CPA) between the blundering aircraft and threatened aircraft.

If the CPA in a particular blunder was less than the specified minimum of a 500-ft slant range, then a Test Criteria Violation (TCV) was recorded for that blunder. In addition, all voice communications and radar displays were recorded for later analysis. Debriefings of controllers after each run and after each simulation were conducted, and debriefing sheets were collected and analyzed. All runs were monitored by TWG and FAATC members and test personnel. Sufficient runs were scheduled so that approximately 200 blunders could be observed for each scenario.

6.6 Conduct of the Fast-Time Simulations

After gathering data from the real-time simulations, computer models were used to perform a Monte Carlo simulation analysis for the scenario tested. Monte Carle models developed by FAA (AFS-400), MIT Lincoln Labs, and The MITRE Corporation were used for fast-time simulations. (See [PRM Program Office, 1991; Gladstone, 1995; and Magyarits and Ozmore, 2002] for descriptions of the various models.)

In general, the fast-time models simulated a large number of blunder events using the same assumptions as the real-time simulations with respect to airport and final approach configuration, traffic levels, aircraft speeds and cross-track deviations, blunder angles, etc. Reaction times of pilots and monitor controllers were used to replicate the human responses.[7] Alerts generated by the PRM or FMA displays were replicated in the simulation software. The intent of the fast-time simulation was to use the human-response data collected to enhance the results of the real-time simulation, because blunders and pilot/controller reactions could be randomly combined tens of thousands of times—far beyond the possibilities of real-time simulation. The fast-time simulations reduced the statistical uncertainty of the real-time simulation results because more replications of blunders could be included in the fast-time simulations.

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[7] The MIT Lincoln Laboratory fast-time simulation did not include explicit pilot reaction times, but rather included entire flight simulator trajectories.

6.7 Post-Processing of Simulation Data and Risk Analysis

An extensive risk analysis was performed on each simulation to determine if the simulation met the TLS using the results of the real-time and fast-time simulations. In general, the analysis attempted to show that the accident rate for simultaneous approaches was less than the TLS, assuming that a collision resulted in two accidents.

$$P(\text{Accident}) * 2 \leq 4 \times 10^{-8}$$

Appendix A contains a detailed description of the risk analysis. It is recommended that the reader read the main report before reading Appendix A to be more familiar with assumptions and terminology in the risk analysis.

6.8 Review of Real-Time and Fast-Time Results/Recommendation for a Proposed Standard

After compilation of data and results from the real-time and fast time simulation, the TWG members met and decided by consensus whether a particular simulation was successful based on the following:

- The nuisance breakout rate observed in the simulation
- The results of the risk analysis showing if the TLS was met
- The operational evaluation by the TWG members

If the simulation was judged satisfactory under these criteria, then a recommendation was forwarded to publish the appropriate standard.

7 Significant Assumptions in the Development of Simultaneous Approach Standards

7.1 Blunder Angle

The MPAP tested aircraft deviations from centerline at angles of 10, 20, or 30 degrees, while the PRM Demonstration Program tested 15- and 30-degree angles. The FAA has used an assumption of 30-degree turns during parallel approaches since 1962 [Fain, 1994].

While research has shown that blunders do occur during simultaneous approaches [Higgins and Massimini, 1996], there has been little success at characterizing the severity or the frequency of the events. Statements of controllers indicate that blunders with 90-degree turns have occurred, but there are no data available that allow a characterization of blunders. The FAA published an order to collect blunder data [FAA, 1995], but no data were collected, and the order was subsequently cancelled.

During the initial development of the MPAP, the FAA met with airline industry, pilot and controller unions, and other interested groups concerning what blunder angles to test when developing standards. The consensus was that protecting against blunders as severe as 30 degrees was adequate.

In summary, there are data that show that blunders do occur during simultaneous approaches, but there are no documented data that support or refute the use of a specific blunder angle (whether 30 degrees or some other angle). The FAA has been analyzing simultaneous approaches using blunders with turns as large as 30 degrees for over 30 years.

7.2 Non-Responding Blunders/Worst Case Blunders

During the years of testing in the MPAP, all of the TCVs in the real-time simulations resulted from non-responding blunders with a 30-degree blunder angle. No TCVs resulted when the blundering aircraft responded to monitor controller instructions to return to course, or when the blunder angle was less than 30 degrees.

As with the blunder angle, there are indications that non-responding blunders occur, but there are no data that indicate the rate of occurrence. The PRM Demonstration Program and the MPAP recognized that non-responding blunders would be relatively rare, and assigned a probability of 1/100 that a blunder that deviated with a 30-degree angle would also be a non-responding blunder. These non-responding 30-degree blunders were denoted Worst-Case Blunders (WCBs).

For testing purposes in the real-time simulations, blundering aircraft were aligned by the computer to ensure that a TCV would occur if prompt action was not accomplished by the controller and pilot of the evading aircraft. This was accomplished by a computer program that

aimed the blundering aircraft directly at an aircraft on the adjacent course. Well-aimed blunders were called "at risk" blunders. A correction factor (see the Appendix) was used in the post-simulation analysis to incorporate the fact that most blunders in actual operations would not be sufficiently aligned to collide with another aircraft, because aircraft are spaced at least 2.5 miles on each final approach course.

7.3   500-ft Collision/Test Criteria Violation (TCV)

The PRM Demonstration Program and the MPAP adopted the assumption that if the center point of aircraft passed within a 500-ft slant range of the center point of another aircraft, a collision was deemed to have occurred. This is conservative, because there is a significant chance of two aircraft passing within 500 ft of each other and not colliding. In fact, standard vertical separation between VFR and IFR aircraft can be as little as 500 ft.

Similar to the blunder angle, the 500-ft TCV was determined by meetings with airline industry, pilot and controller unions, and other interested groups. The 500-ft TCV was considered an adequate compromise. Although the distance does not imply a collision with certainty, all concerned agreed that even a 500-ft miss would be an extremely serious event that should be prevented. Additionally, neither the PRM Demonstration Program nor the MPAP explicitly considered the effects of a wake vortex encounter, and the 500-ft TCV was considered to compensate somewhat for the lack of wake vortex consideration.

7.4   Target Level of Safety (TLS)

The TLS used in the MPAP and the PRM Demonstration Program was 4×10^{-8}, or 1 accident in 25 million simultaneous approaches. This TLS was derived by examining the accident rates of North American airlines and apportioning the rate among various phases of flight. See [PRM Program Office, 1991] for a description of the derivation of the TLS, and see Appendix A for a more detailed discussion of how the TLS was used to estimate the safety of a particular standard.

7.5   Blunder Rate

The TLS provided a safety-related goal for the conduct of simultaneous approaches, and the real-time and fast-time simulations provided an estimate of the collision rate given that a blunder occurred. As discussed earlier, the FAA has no data on the rate of blunders during simultaneous operations. If the blunder rate were near zero, then no consideration would be necessary for blunders when developing parallel approach standards. If the blunder rate were very high, then the TCV rate in the simulations would have to be very low to meet the TLS.

Discussions with controllers at various facilities that conducted parallel approaches gave only a vague estimate of the rate or severity of blunders. For example, controllers at ORD indicated

that "something" happened about once or twice a year during parallel approaches. At that time, ORD was conducting about 20,000 simultaneous approaches per year in instrument conditions. Although vague, these discussions indicated that blunders[8] may be happening at the rate of once or twice per 20,000 simultaneous approaches.

Using the TCV rates encountered during the PRM Demonstration Program and the assumption of the WCB rate, it can be shown that using a blunder rate of one blunder per 2000 simultaneous approaches in instrument conditions would meet the TLS. In other words, if a 1:2000 blunder rate was assumed, then the procedure would meet the TLS of 4×10^{-8}. This blunder rate is quite high, and all concerned believed that the true rate of blunders was certainly less than this rate. With a lower rate of blunders (such as the 1:20,000 discussed above for ORD), then the TLS would be met with extra margin.

Thus, the assumed blunder rate of 1:2000 was derived from the test data with the understanding that such a high rate did not exist, but rather provided an upper bound on the blunder rate.

7.6 ILS Navigation

As discussed earlier, current simultaneous approach standards require ILS or MLS navigation. The rate of nuisance breakouts was an important criterion for the simultaneous approach evaluation, although it was considered a capacity issue and not a safety issue.

The ILS path-following error was derived from several FAA data collections—at Chicago, Memphis, and Los Angeles airports. The path-following error generally consisted of a cross-track error that increased as a linear function of distance from the localizer antenna. Although this error was substantial, it was generally not a limiting factor in most simulations. However, the nuisance breakout rate was marginal in the PRM Demonstration Program (3400-ft parallel approach paths) and problematic for one simulation of 3000-ft parallel courses.

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[8] These blunders were not considered WCBs. The WCBs were assumed to occur only during one blunder in 100.

8 Observations and Next Steps

The intent of this report was to summarize the process that led to the current standards for simultaneous and dependent approaches that use conventional ground-based precision approach navigation solutions, including the relevant assumptions, testing, and methodology. Subsequent reports will review, re-examine, and evaluate the assumptions and methodology based on Performance-Based Navigation to determine if possible changes, specifically runway centerline spacing reductions and use of area navigation approaches, would be appropriate and beneficial.

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Appendix A   Calculations To Determine If the Target Level of Safety Had Been Met

The basic equation for determining the probability of an accident was Eq. (1) below. In this equation, an accident would occur if an at-risk WCB occurred and resulted in a TCV. Note that if a blunder was not a WCB, or if a blunder was not at risk, or if a blunder did not occur, then there was no accident. This is summarized by Eq. (1):

$$P(\text{Accident}) = P(\text{TCV and At-risk and WCB and Blunder}) \times 2 \tag{1}$$

Transformation of Eq. (1) using conditional probabilities results in Eq. (2):

$$P(\text{Accident}) = P(\text{TCV}|\text{At-risk and WCB and Blunder}) \times P(\text{At-risk}|\text{WCB and Blunder}) \times$$
$$P(\text{WCB}|\text{Blunder}) \times P(\text{Blunder}) \times 2 \tag{2}$$

These were the basic equations for evaluating the safety of simultaneous approaches.

If the simulation could show that $P(\text{Accident}) \leq 4 \times 10^{-8}$, then the procedure would have met the TLS. The following additional values were assigned:

$P(\text{WCB/Blunder}) = 1/100$.

$P(\text{At-risk}|\text{WCB and Blunder}) = 1/17^9$

$P(\text{Blunder}) = 1/2000$

Substituting in Eq. (2) and comparing with the TLS bound yields:

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[9] This value represents the chance of a blundering aircraft passing within 500 ft of an aircraft on an adjacent course if no action were taken. This value was calculated based on a 3-NM spacing between aircraft on final approach.

P(TCV|At-risk and WCB and Blunder) ≤ .068 (3)

Inequality (3) represents the main criterion for determining if simultaneous approaches to dual runways met the TLS criterion. The criterion for three runways was slightly different because of a factor that considered that a turn in either direction from the center runway would endanger aircraft on the outer courses. The calculations for three runways are not included in this document, but can be seen in [Morrow-Magyarits, S. and Ozmore, R., 2002].

Glossary

ARTS	Automated Radar Terminal System
CAASD	(MITRE's) Center for Advanced Aviation System Development
CPA	Closest Point of Approach
DEN	Denver International Airport
DFW	Dallas-Fort Worth International Airport
FAA	Federal Aviation Administration
FAATC	William J. Hughes FAA Technical Center
FMA	Final Monitor Aid
ft	foot(feet)
IFR	Instrument Flight Rules
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
LAX	Los Angeles International Airport
MEM	Memphis International Airport
MLS	Microwave Landing System
MIT	Massachusetts Institute of Technology, Cambridge, Massachusetts
MITRE	The MITRE Corporation
MPAP	Multiple Parallel Approach Program
NATCA	National Air Traffic Controllers Association
NM	nautical mile(s)
NOZ	Normal Operating Zone
NTZ	No Transgression Zone
ORD	Chicago O'Hare International Airport
PRM	Precision Runway Monitor
PSR	Primary Surveillance Radar
RDU	Raleigh Durham International Airport
SSR	Secondary Surveillance Radar
TCV	Test Criteria Violation
TLS	Target Level of Safety
TWG	Technical Working Group
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
WCB	Worst Case Blunder