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Safety Study Report on Simultaneous Parallel Instrument Landing System (ILS) and Area Navigation (RNAV) or Required Navigation Performance (RNP) Approaches - Phases 3 and 4

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Flight Systems Laboratory
6500 S. MacArthur Blvd.
Systems Training Building Annex, RM 217
Oklahoma City, Oklahoma 73169
Phone: (405) 954-8191

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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) or Required Navigation Performance (RNP) Approaches—Phases 3 and 4

Reviewed by:

7/28/2010

Stephen W. Barnes **Date**
Manager, Flight Systems Laboratory, AFS-450

Released by:

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Leslie H. Smith **Date**
Manager, Flight Technologies and Procedures Division, AFS-400

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12. Abstract

Federal Aviation Administration (FAA) Order 7110.65S *Air Traffic Control*, paragraph 5-9-8 contains the current provisions governing air traffic control separation for independent precision approach operations at airports with dual parallel runway configurations and high update radar systems. With the evolution toward performance-based navigation in the National Airspace System (NAS), Air Traffic Control (ATC) will increasingly be required to factor in Area Navigation (RNAV) and Required Navigation Performance (RNP) approaches to these operations. The Flight Systems Lab, AFS-450, was requested by the RNAV/RNP Group (AJR-37) to conduct a study to determine what combinations of RNAV or RNP simultaneous approach operations could be authorized by ATC. Earlier reports addressed dual and triple, independent and dependent approaches by Instrument Landing System (ILS), and RNP(GPS)/RNAV(GPS) aircraft flying with and without flight director guidance under conventional radar coverage. This report will consider operations to dual independent approaches at airports with high update surveillance systems such as the Precision Runway Monitor (PRM). The report will also address Simultaneous Offset Instrument Approach (SOIA) operations.

The Airspace Simulation and Analysis Tool (ASAT) has been used for a number of similar studies related to simultaneous approach operations. The tool models all components of the scenario (e.g., aircraft, avionics, pilot, controller, etc.) and performs a Monte Carlo simulation in which all significant parameters are varied according to appropriate probability distributions.

All of the scenarios tested with independent parallel approaches to dual runways separated by 3,400 feet with parallel approaches and by 3,000 feet with an offset localizer to one side met the established test criteria. Analysis of the results of the simulations indicated that, for the assumed performance levels and fleet mixes, GPS-equipped RNAV/RNP aircraft with flight director experienced no increase in Test Criteria Violation (TCV) rate over the same simulation with only ILS-directed aircraft. The TCV rate for all simulations met the defined acceptance criteria. SOIA operations are identical to the offset localizer case throughout the instrument flight rules phase of the approach and are, therefore, covered by the study. Additional SOIA issues are addressed in the body of the report.

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Addendum to Technical Report DOT-FAA-AFS-450-56

At the time this series of studies (DOT-FAA-AFS-440-16, -440-29, -450-41, and the current study -450-56) were initiated, several assumptions were made about simultaneous approach operations. The reports attempted to spell out the assumptions along with explanations for why they were made. With the evolution of Area Navigation (RNAV) and simultaneous operations over the last several years, some of the assumptions may no longer be as reasonable as they seemed at the time. A major assumption that has probably not been clearly explained is that simultaneous independent approach operations would only be used at major airports during high traffic periods where the vast majority of the arrivals were commercial aircraft that would be using at least flight director if not autopilot. General aviation traffic or manually flown aircraft without flight directors were considered low probability events and in the combinations of other low probability events that had to occur for an event of interest to happen, they were largely ignored. Lesser equipped Global Positioning System (GPS) or GPS with Wide Area Augmentation System (WAAS) traffic that could be considered RNAV were evaluated in the Phase 1B/2B report, DOT-FAA-AFS-450-41.

One assumption that may need to be re-examined was that RNAV or Required Navigation Performance (RNP) traffic would be using linear guidance on the approach. Currently certain systems that can do Localizer Performance with Vertical Guidance (LPV) approaches are either being approved or being considered for approval as RNAV systems. While WAAS guidance driving an LPV approach is generally equal to or better than ILS during the angular part of the approach, such systems may also allow manual flight with a course deviation indicator with ±1 NM sensitivity outside the final approach fix but inside the point where there might be parallel traffic on the adjacent glidepath. The problems with this potential situation were addressed in the 1B/2B report. Any angular system that was not at least as good as ILS would need further study prior to inclusion in independent simultaneous operations.

Studies are currently underway to reconsider the requirement for vertical guidance during dependent and, potentially, independent simultaneous operations. If the requirement were to be relaxed for independent operations, then there is the potential for inclusion of manually flown TSO-C129 equipped aircraft into the mix. This case has not been evaluated in the studies to date. There might also be other operational issues if such a relaxation were allowed.

One of the goals of the Closely Spaced Parallel Operations (CSPO) program is to reduce runway separation requirements for independent approaches for ILS operations. If such reductions are implemented, additional studies would be required for approval of RNAV or RNP operations to the closer runway separations. Depending on the rationale for the reductions, those studies may be very straightforward, but they would have to occur.

The documentation change package that addresses incorporation of RNAV and RNP aircraft into parallel runway operations for Order 7110.65T and associated orders has gone through several versions and is not finalized at this time. Some versions have not made it completely clear that

GPS availability and inclusion in the aircraft navigation solution is an absolute requirement for the RNAV or RNP aircraft involved in simultaneous independent operations. The studies only addressed GPS based navigation for the dependent cases but the requirement could be relaxed for those cases given other mitigations. But for the simultaneous independent approach case, the studies **do not** address RNAV(RNP) aircraft unless there are specific requirement for GPS equipage in either the aircraft certification process or the particular approach documentation.

An additional concern that is currently under study is the potential for multiple aircraft with GPS-based RNAV systems to experience simultaneous failures such as loss of the WAAS geostationary satellite, loss of a Local Area Augmentation System (LAAS) ground station, or a large area GPS signal outage (possibly due to jamming). If two aircraft on a simultaneous approach are both RNAV aircraft and both systems lose some or all of their guidance, what effect, if any, does that have on the probability of a blunder?

Executive Summary

Federal Aviation Administration (FAA) Order 7110.65S, *Air Traffic Control*, paragraphs 5-9-6 through 5-9-8 contain the current provisions governing air traffic control separation for dependent and independent precision approach operations at airports with dual or triple parallel runway configurations. These standards were developed in part from simulations performed by the FAA based on Instrument Landing System (ILS) precision approach operations to determine the parameters necessary to meet the Target Level of Safety (TLS) for the blunder scenario. This scenario involves two or more aircraft established on approach to parallel runways, where one of the aircraft deviates from the approach path towards the adjacent traffic. When such a scenario occurs, the system must permit Air Traffic Control to maintain safe separation between the blundering and evading aircraft

With the evolution toward performance-based navigation in the National Airspace System (NAS), Air Traffic Control (ATC) will increasingly be required to factor in Area Navigation (RNAV) and Required Navigation Performance (RNP) approaches to the operations referenced above. The Terminal Safety and Operations Support Director (ATO-T) has received waiver requests from three Operational Evolution Partnership (OEP) benchmark airports (Houston-KIAH, Atlanta-KATL, and Pittsburgh-KPIT) to authorize such operations.

The Flight Systems Laboratory (AFS-450) was requested by the RNAV/RNP Group (AJR-37) to conduct a study to determine what combinations of RNAV or RNP simultaneous approach operations could be authorized by ATC. The request resulted in a Memorandum of Agreement (MOA) among AFS-400, the Flight Technologies and Procedures Division (AJR-37), and the Avionics Certification System Branch (AIR-130) defining what cases were to be examined and their priorities. The results of the study will provide guidance for determining the allowable separation or operation of RNAV, RNP, and ILS approaches to parallel runways (dual and triple), without the necessity of waivers. The study would also address acceptable mitigations against which waiver requests would be considered. An important part of the MOA was an agreement that only Global Positioning System (GPS)-equipped RNAV aircraft would be considered. For convenience, the study was separated into several phases.

Previous reports [12, 13] addressed approaches to airports with conventional surveillance systems consisting of the Automated Radar Terminal System (ARTS), version IIIA, driven by an ASR-9 radar with the Data Entry Display Subsystem (DEDS) console or the Full Digital ARTS Display System (FDADS). Airports using these systems may have runways separated by as little as 4,300 feet for duals or 5,000 feet for triple approach operations. This report will consider operations to runways served by high update surveillance systems such as the Precision Runway Monitor (PRM). A PRM system consists of the following major components:

a. a high update rate radar capable of an update rate of 1.0 second or less. This requirement is typically met by an electronically scanned phased array (e-scan) radar.

b. a Final Monitor Aid (FMA). A FMA is a large (not less than 20" x 20"), high resolution, color monitor for use by dedicated final approach monitor controllers (one for

each runway in a multiple runway configuration). The FMA must be capable of displaying the 2,000 foot wide No Transgression Zone (NTZ) located equal distance between the runway final approach courses. In addition, the FMA is equipped with visual and/or audible alert algorithms which alert the monitor controller when an aircraft is projected to enter or has entered the NTZ.

Airports with a PRM system may conduct simultaneous approach operations to runways as close as 3,400 feet for parallel approaches or as close as 3,000 feet if one runway has an offset localizer that provides a slightly converging course (between 2.5° and 3.0°).

AFS-450's Airspace Simulation and Analysis Tool (ASAT) has been used for a number of similar studies related to simultaneous approach operations. The tool models all components of the scenario (e.g., aircraft, avionics, pilot, controller, etc.) and performs a Monte Carlo simulation in which all significant parameters are varied according to appropriate probability distributions. The ASAT allows examination of all combinations of ILS and RNAV/RNP aircraft performing simultaneous approach operations to parallel runways at user-defined separations and user-defined staggers along user-defined approach paths.

Analysis of the results of the simulations indicated that, for the assumed performance levels (defined in section 2.2.6), GPS-equipped RNAV/RNP aircraft with flight director experienced no significant increase in Test Criteria Violation (TCV) rate over the same simulation with only ILS-directed aircraft. RNAV aircraft without flight director (expected to be a very small fraction of the relevant fleet) are discussed in the body of the report. The TCV rate for all simulations met the historical acceptance criteria

Based on the simulation, GPS-equipped RNAV/RNP aircraft with flight director or autopilot could be mixed with ILS traffic in any configuration approved for ILS aircraft under high update radar (such as PRM) or equivalent surveillance systems, i.e., independent dual approaches to runways separated by as little as 3,400 feet with parallel approaches or as little as 3,000 feet where one runway has an offset localizer to provide a slightly converging course. All tested scenarios produced TCV rates that met the historical Target Level of Safety.

SOIA operations are identical to the offset localizer case prior to the Missed Approach Point and are, therefore, covered by the study. Before the aircraft on the offset approach of a SOIA begins to align with the extended centerline of the runway of intended landing, it must have visual contact with the adjacent aircraft, which should be ahead of it on the approach. From that point on, the pilot is assumed to be able to "see and avoid" the other aircraft and the blunder analysis is no longer applicable.

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1.0 Introduction

This report presents the results of Phases 3 and 4 of a safety study conducted on simultaneous parallel Instrument Landing System (ILS) and Area Navigation/Required Navigation Performance (RNAV/RNP) approaches. The safety evaluation was conducted by the Flight Systems Laboratory (AFS-450) of the Federal Aviation Administration (FAA) located at the Mike Monroney Aeronautical Center in Oklahoma City, Oklahoma. This section of the report describes the purpose and structure of this document, and provides a description of the problem.

1.1 Purpose and Structure of the Report

This study assessed the risk for simultaneous independent parallel approach operations involving mixed operations of ILS-equipped and Global Positioning System (GPS)-equipped RNAV or RNP aircraft under surveillance by high-update rate radar. The study used a Monte Carlo simulation of the operation to evaluate the risk associated with a blunder in which one aircraft deviates by approximately 30 degrees from the final approach course toward the other aircraft on the adjacent approach. The simulation examined a series of scenarios involving different combinations of ILS aircraft and RNAV or RNP aircraft conducting approaches to two runway configurations corresponding to the closest runway spacings allowed by FAA Order 7110.65S for airports using high update surveillance systems.

This report defines the problem (Section 1.2), explains the study methodology (Section 2.0), describes the structure of the Monte Carlo simulation involved (Section 2.1), details the inputs to the simulation (Section 2.2), and details the outputs used for validation of some of the new parts of the model (Section 2.3). The analysis of the results of the simulation (Section 3) is based on substantial work previously performed and summarized in a previous report, *Terminal Air Traffic Control Radar and Display System Recommendations for Monitoring Simultaneous Instrument Approaches* [6]. Conclusions and recommendations are given in Section 4.

Appendix A: Aircraft Mix and Performance Modeling details the fleet mix composition and representative performance models. Appendix B: Pilot Reaction Time Distribution Analysis details the data collected during the Multiple Parallel Approach Program (MPAP) testing and explains the Probability Distribution Functions (PDFs) developed from that data. Appendix C: Air Traffic Controller Reaction Time Distribution Analysis includes a list of runway and sensor configurations tested and discusses the PDFs developed. Appendix D: Risk Analysis contains relevant excerpts from a previous report [6] deriving the acceptable risk parameters used in the simulation. Appendix E: Johnson Distributions discusses the Johnson distributions used in the study. Input and output files are listed in Appendix F: ASAT Input Files and Appendix G: ASAT Output File. The Memorandum of Agreement among the Flight Technologies and Procedures Division, the RNAV/RNP Group, and

Avionics Certification Systems Branch is attached as Appendix H: Memorandum of Agreement.

1.2 Statement of the Problem

FAA Order 7110.65S, *Air Traffic Control* [4], paragraph 5-9-8 (Simultaneous Independent Dual ILS/MLS [Microwave Landing System] Approaches—High Update Radar) is the current Air Traffic Control (ATC) provision governing independent precision approach operations at airports with dual parallel runway configurations having runway centerline separation of at least 3,400 feet for straight-in approaches or at least 3,000 feet where one runway has a slightly converging approach path (normally accomplished by using an offset localizer to provide an approach course of between 2.5° and 3.0° off the extended runway centerline.) and monitored by a high update radar or equivalent surveillance system. The standards were developed in part from simulation exercises performed by the FAA based on ILS precision approach operations. The order requires a 2.4-second update rate for the 3,400 foot case and a 1-second update for the 3,000 foot case. The only system currently deployed as a high update radar is the Precision Runway Monitor (PRM) which has a 1-second update rate (see section 1.4). A high update surveillance system based on multilateration, PRM-A, is under development.

With the evolution toward performance-based navigation in the United States National Airspace System (NAS), ATC will increasingly be required to factor in RNAV and RNP approaches to the operations referenced above. The Flight Simulation Laboratory (AFS-450) was requested by the RNAV/RNP Group (AJR-37) to conduct a series of studies to determine what combinations of RNAV or RNP simultaneous approach operations could be authorized by ATC.

AFS-450's Airspace Simulation and Analysis Tool (ASAT) has been used for a number of similar studies related to simultaneous approach operations. The tool models all components of the scenario (e.g., aircraft, avionics, pilot, controller, etc.) and performs a Monte Carlo simulation in which all significant parameters are varied according to appropriate probability distributions. The tool is discussed in detail in section 2.1.

The results of this study should provide guidance for determining the acceptability of including RNAV/RNP equipped aircraft in the mix at airports running closely spaced parallel approach (CSPA) operations under high update surveillance.

Previous studies focused on operations under conventional radar surveillance. The first study (referred to as Phase 0) was specific to George Bush Intercontinental Airport (KIAH). For details of the study, refer to DOT-FAA-AFS-440-16 [11]. The results from that study, while largely favorable, led to additional discussions with the RNAV/RNP Group (AJR-37), the Avionics Certification System Branch (AIR-130), and the Flight Procedure Standards Branch (AFS-420) to define the required equipment for conducting RNAV/RNP simultaneous approach operations. It was apparent from the results of the KIAH study that "generic" RNP performance, with the track dispersion approaching the RNP containment limits, would not be sufficient to meet the current ILS simultaneous approach requirements in FAA Order 7110.65S [4]. The discussions led to the creation of a Memorandum of Agreement (MOA) that identified GPS guidance as a requirement for participation in RNAV/RNP approaches conducted simultaneously with ILS operations to parallel runways. The MOA is attached as Appendix H.

The study broke the work down into several phases. Phases 1 and 2 examined dual and triple independent and dual dependent operation to runways under conventional surveillance systems, such as the ASR-9 with a 4.8-second update. The Phase 1 and 2 reports also considered flight director/autopilot operations versus manually flown approaches using a relatively coarse CDI (Course Deviation Indicator). This report is to address Phases 3 and 4, both of which involve operations requiring high update radar.

- Phase 3 is to provide a study to show that inclusion of RNAV/RNP(GPS) aircraft complies with current standards for parallel independent approaches for duals with high update radar (as in FAA Order 7110.65S[4], paragraph 5-9-8a).

- Phase 4 is to provide a study to show that inclusion of RNAV/RNP(GPS) aircraft complies with current standards for Simultaneous Offset Instrument Approaches (SOIAs) as addressed in FAA Order 8260.49A[20]. Refer to section 1.5 for additional information and discussion.

The operation of interest is an independent simultaneous parallel approach procedure with an *at-risk* blunder. (See Figure 1 for an illustration). This blunder involves two aircraft established on approach (with vertical guidance from either an ILS or RNAV/RNP) to parallel runways, when one of the aircraft deviates from the approach path towards the adjacent traffic.

The term "at-risk" implies that if no corrective action is taken, the aircraft's centers of gravity come within 500 feet of each other and potentially collide as shown by the shadowed aircraft on the left runway in Figure 1 (which is actually the right runway of the approach). Violation of the 500-feet separation is referred to as a Test Criteria Violation (TCV). The TCV was defined by the PRM Program Office and later used by the MPAP for their test programs as a conservative parameter for evaluating risks associated with simultaneous approach operations.

ATC must be able to maintain at least a 500-foot slant range separation between the blundering and evading aircraft. For simultaneous independent approach operations, FAA Order 7210.3, *Facility Operation and Administration* [11], requires a "final monitor controller" position for each runway. The final monitor controllers maintain longitudinal spacing between landings to their assigned runway and are responsible for attempting to return a blundering aircraft to the correct course and, if that fails, direct threatened traffic to evade, usually by giving them an immediate turn command.

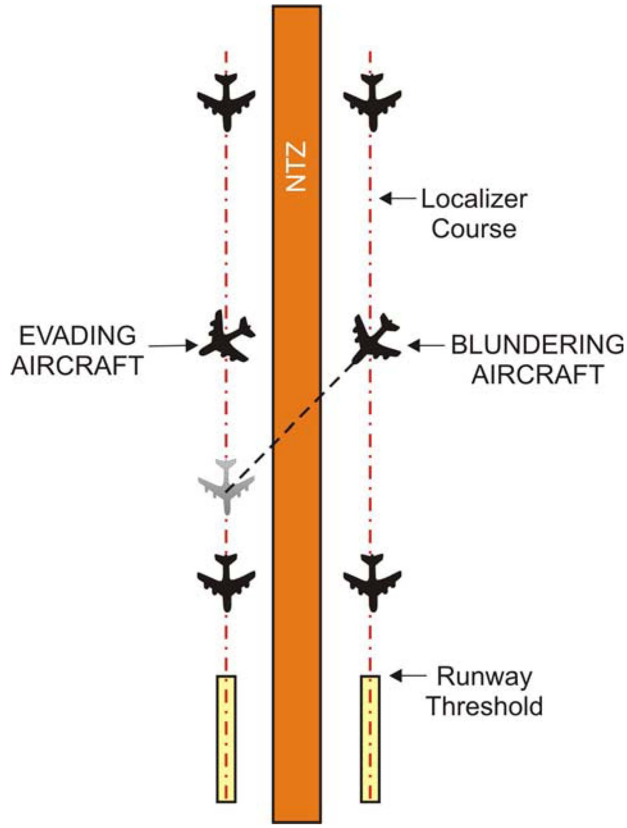

Figure 1: Dual Simultaneous Approach with Blunder

For independent operations, a 2,000-foot wide No Transgression Zone (NTZ) is depicted on the controller's monitor. The NTZ is located midway between adjacent pairs of approach paths to aid controllers in determining whether an aircraft is blundering. If an aircraft deviates from course far enough to penetrate the NTZ, the controller must assume that it is blundering and the adjacent aircraft must be directed to take evasive action. Controllers may determine that a blunder is occurring before the aircraft penetrates the NTZ and act accordingly. However, due to the time and fuel costs associated with a "nuisance" breakout, controllers should be reasonably certain that the blundering aircraft cannot be returned to its intended course before breaking the threatened aircraft out. A nuisance breakout occurs when an aircraft penetrates the NTZ, forcing the adjacent aircraft to be broken out of the approach pattern, and then returns to the approach course either on its own or with air traffic direction.

For the purposes of the MPAP, an acceptable Target Level of Safety (TLS) for approaches was determined to be 4×10^{-8} fatal accidents per approach (see Section 3.1 or Appendix C). This value was derived from historically safety data across multiple occupations and modes of transportation. From the TLS, a maximum acceptable TCV rate can be derived for simultaneous operations (also Appendix C). The TCV rate for at-risk blunders in a dual approach must be less than 6.8%. The TCV rate limit generates an unambiguous pass/fail criterion for each test scenario. It is a conservative criterion in that the applicable TCV does not guarantee a fatal accident.

1.3 RNAV/RNP Considerations

Advisory Circular (AC) 90-101, "Approval Guidance for RNP Procedures with SAAAR," defines RNAV as "a method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these."

RNAV procedures are developed in accordance with AC 90-100A, "U.S. Terminal and En Route Area Navigation (RNAV) Operations." In developing AC 90-100[1], industry partners and the FAA defined the minimum criteria for RNAV systems to operate on the RNAV routes and procedures.

For the purposes of this evaluation, an RNP aircraft is an aircraft with an approved RNP capability, as documented in the Aircraft Flight Manual (AFM) or AFM supplement. The demonstrated RNP capability must be equal to or less than the RNP value specified for the intended operation. An RNAV aircraft is one approved for instrument approach operations under FAA guidance such as AC 20-138, "Airworthiness Approval of Global Positioning System (GPS) Navigation Equipment for Use as a VFR or IFR Supplemental Navigation System;" AC 20-130, "Airworthiness Approval of Navigation or Flight Management Systems Integrating Multiple Navigation Sensors;" TSO-C129a, "Airborne Supplemental Navigation Equipment Using the Global Positioning System (GPS);" or TSO-C146b, "Stand-Alone Airborne Navigation Equipment Using the Global Positioning System (GPS) Augmented By the Wide Area Augmentation System (WAAS)." As mentioned previously, GPS must be an active component of the navigation position determination. In addition, RNAV and RNP aircraft approved for independent simultaneous approaches must have an Instrument Flight Rules (IFR) Vertical Navigation capability as required in the AFM or AFM supplement.

An RNP navigation system differs from an RNAV system primarily in that it has additional algorithms for detecting and alerting when the navigation system information might be providing incorrect information. This process is referred to as "integrity monitoring." There must also be processes in place for monitoring Flight Technical Error, either automatically or manually, and making the pilot aware of excessive values. Because the approach operations are under continuous radar surveillance (by multiple controllers in the independent case), integrity was not considered a significant element of concern for the simulation (if the navigation system is providing significantly misleading information, ATC will detect the course error and act accordingly.)

[1] The AC, along with additional RNAV supporting information, is available at the Web site of the FAA Flight Technologies and Procedures Division, Flight Operations Branch (AFS-410).

The principal issue with RNAV and RNP aircraft on simultaneous approaches with other aircraft using ILS is that RNAV and RNP aircraft will not be following the localizer/glide slope guidance that the current ATC approach monitoring system has been built around. The navigation systems on the RNAV and RNP aircraft generate their own three-dimensional flight paths based on their onboard position solutions and stored navigation database information. Because of position solution errors and possible database errors, as well as irregularities in the ILS signal, the course that the navigation system constructs may not completely correspond with the existing localizer/glide slope course and the aircraft may appear to be off the expected course on the ATC display. The extent to which ATC will tolerate significant cross-track deviations that are within the allowable range for the navigation system has yet to be determined. In a largely RNAV/RNP fleet, due to the linear nature of RNAV, cross-track deviations that previously would have generated immediate attention for an ILS track may become routine. Therefore, in an RNAV or RNP environment, controllers may delay their decision to command an evasion to avoid nuisance breakouts since they might become accustomed to that level of deviation.

Nuisance breakouts may also be caused by NTZ penetrations due to navigation errors. Purely as an example, at George Bush Intercontinental (KIAH), an aircraft that exactly meets the RNP 0.3 containment requirement, i.e., 0.3 NM Total System Error (TSE) 95% of the time, could be in the NTZ 5.1% of the time on Runway 26L/08R and Runway 26R/08L; that is, the aircraft could be more than 1,500 feet off course (the width of the Normal Operating Zone [NOZ]) and inside the NTZ while the aircraft's navigation system indicates that the aircraft is on the desired path. Given the MOA's requirement for GPS, with less than a 100-meter navigation system error 95% of the time, this is not expected to be an issue.

1.4 Precision Runway Monitor Considerations

Airports with parallel runways separated by less than 4,300 feet and conventional surveillance systems cannot conduct independent simultaneous operations during instrument meteorological conditions (IMC) because the surveillance equipment does not allow the controllers to maintain safe separation under some circumstances. This results in decreased capacity during inclement weather. To address this issue, the PRM program office developed a high-update-rate phased array electronically scanned, monopulse beacon radar, and computer predictive displays that enable controllers to monitor aircraft on independent instrument flight rule approaches to dual- and triple-parallel runways spaced less than 4,300 feet apart. The first system was deployed in the early 1990's at Minneapolis-St.Paul International Airport.

The electronically scanned antenna system (see Figure 2) provides a faster update rate than conventional radars because it uses a computer-controlled electronic scanning sensor beam. The update rate requirement for parallel runways, down to 3,400 feet spacing, is 2.4 seconds or less. For parallel runways separated by 3,000 feet, where one runway has an offset localizer, the requirement is 1.0 second updates. The fielded systems all have a 1.0 second update rate with a capacity of 35 aircraft tracks and a mean azimuth accuracy of 1.0

milliradian. The system includes high-resolution displays with specific blunder alarms to enable a monitor controller to precisely monitor landing aircraft.

The automation system that drives the PRM ATC display includes predictor and alerting logic. The predictor calculates the expected position of the target some number of seconds beyond the current target report based on the speed, heading, and rate of heading change associated with the particular target track file. While the predictor time is adjustable, the normal setting is 10 seconds. The alerts include a "yellow" alert that is triggered when the predicted aircraft position penetrates the NTZ and a "red" alert when the actual target report is inside the NTZ. The monitors also supported a scaling function that allowed the user to adjust the crosstrack:alongtrack aspect ratio. The MPAP tests used a 4:1 setting for all their monitors. This function magnified deviations from the approach course and was intended to allow ATC to more easily identify blunders.

Note that the displays that come with the Standard Terminal Automation Replacement System (STARS) have a built-in Final Monitor Aid (FMA) mode which includes an enhanced set of the PRM display capabilities, such as more alerting options, greater scaling capabilities, etc. STARS is currently installed at most major NAS airports.

Figure 2. PRM Electronically Scanned Antenna Array

The PRM program is currently conducting research and development for a multilateration, potentially lower-cost alternative to the electronically scanned system. The multilateration system will use small, strategically placed sensors, like ASDE-X, outside the airport and on the airport surface to triangulate an aircraft's position based on transponder beacon replies. The multilateration approach will capitalize on work being performed in the Airport Surface Target Identification System (ATIDS) program for future precision runway monitor requirements.

A key element of the ILS/PRM approach operation is the requirement for a short training session for all participating pilots. At the reduced separations allowed by ILS/PRM approach, an immediate pilot response to breakout instructions from ATC is essential to maintaining safe separation from blundering aircraft. The training material gives a brief explanation of how the PRM system works and why an immediate response to ATC commands is necessary. The training is currently available via Internet and other means. Additional briefing pages are also included with the approach plates for ILS/PRM approaches. Pilots are also required to review the “Attention All Users Page,” which covers the primary issues of conducting a closely spaced approach, prior to beginning the approach.

1.5 Simultaneous Offset Instrument Approach (SOIA) Operation Considerations

The SOIA concept was developed as a means to improve capacity at airports with parallel runways separated by less than 3,000 feet. These airports are not capable of supporting simultaneous, parallel instrument approaches under other criteria. From FAA Order 8260.49A, “SOIA consists of simultaneous approaches to parallel runways utilizing a straight-in ILS approach to one runway, and a localizer-type directional aid (LDA) with a glide slope instrument approach to the other runway. SOIA approach course separation provides the required close parallel instrument landing system/microwave landing system (ILS/MLS) approach criteria per 8260.3B Volume 3, appendix 3 to the LDA precision runway monitor (PRM) decision altitude (DA). A visual segment for the LDA approach is established between the LDA PRM DA and the runway threshold, permitting aircraft to transition in visual conditions from the LDA course, align with the runway, and be in a stabilized approach configuration by 500 ft above the touchdown zone elevation. Between the LDA PRM DA and the runway threshold, pilots of the LDA aircraft are responsible for visually separating themselves from traffic on the ILS approach. This requires maneuvering the aircraft as necessary to avoid the ILS traffic until landing and applying wake turbulence avoidance procedures and techniques as necessary.” An example of a SOIA operation is depicted in Figure 3. (Note that the figure does not depict the actual SOIA into SFO).

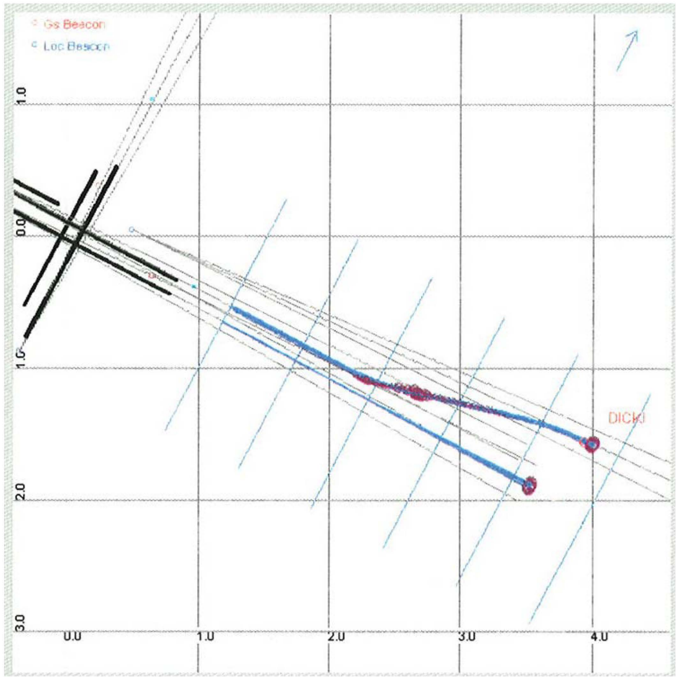

Figure 3. Example SOIA Approach into San Francisco Int'l Airport

After passing the LDA MAP the LDA aircraft maneuvers to align with the runway. Prior to the LDA MAP, the track separation for the two aircraft is the same as for the offset localizer case to runways separated by 3,000 feet. So the study results for the offset localizer scenarios should apply. During the visual (maneuvering) segment, the LDA aircraft must have the other aircraft in sight and the pilot accepts separation responsibility. Presumably the response time to initiate an evasion maneuver based on visual reference would be better, but certainly no worse, than if ATC intervention was required during the IFR phase. In short, if the offset localizer scenarios are acceptably safe, the SOIA operation should meet the expected safety standards.

1.6 Other Considerations

Considerations relevant to WAAS aircraft equipped with TSO-C145b/C146b receivers have been covered in DOT-FAA-AFS-450-41 [15]. Procedures should be in place to insure that all WAAS equipped aircraft participating in PRM or SOIA operations should be operating in Vector-to-Final mode.

2.0 Study Methodology

This study used a Monte Carlo simulation of the operation to evaluate the risk of collision. The simulation examined a series of scenarios involving different combinations of ILS, RNAV or RNP aircraft with flight director. This report considered only RNAV or RNP aircraft that were GPS-equipped. It is fundamentally a comparative analysis between ILS approaches and RNAV or RNP approaches as the ILS case is regarded as acceptable and the RNAV/RNP case compared to it. The primary output of the simulation was the percentage of TCVs (center of gravity to center of gravity separation less than 500 feet) occurring during each scenario (combination of aircraft types, runway configuration, and fleet mix). Those percentages were compared to the pass/fail requirements stated in Section 1.2 and the scenarios were identified as acceptable or not acceptable.

2.1 Description of the Model

The ASAT consists of software components running on a collection of high-speed computers. The system performs Monte Carlo studies involving 10^4 to 10^6 runs to represent the full ranges of parameter values. The ASAT uses high-fidelity models of all components of an aviation scenario to achieve the most realistic simulation possible with the information provided. Wherever available, data provided by the manufacturer were used as a basis for the components of the simulation. When empirical data were available from relevant tests, they were used to the extent possible as a basis for some of the components of the simulation. The various data components are discussed in detail in the next section.

The particular ASAT component used for this task was called ASAT4ILSRNPAsrMlat. Figure 4 shows the ASAT screen for a typical run. The aircraft approaching Runway 36C (the center runway on the screen), a generic Large aircraft, has blundered and the Runway 36L traffic, another generic Large, has successfully evaded. A generic Small was selected for the Runway 36R traffic but since that runway was not involved in the scenario, no simulated track data was generated. ("Heavy", "Large", and "Small" will be defined in the next section.) The Closest Point of Approach (CPA) between the blundering and evading aircraft was 989 feet slant range or 985 feet, ignoring vertical separation. As shown on the "36C" tab of the ASAT screenshot (in the lower left quadrant), the generic Large on Runway 36C was an RNP aircraft with an effective RNP level of 0.07. The derivation of this value is discussed in Section 2.2.6. The other Large was using ILS for navigation. This would be seen on the tab for "36L".

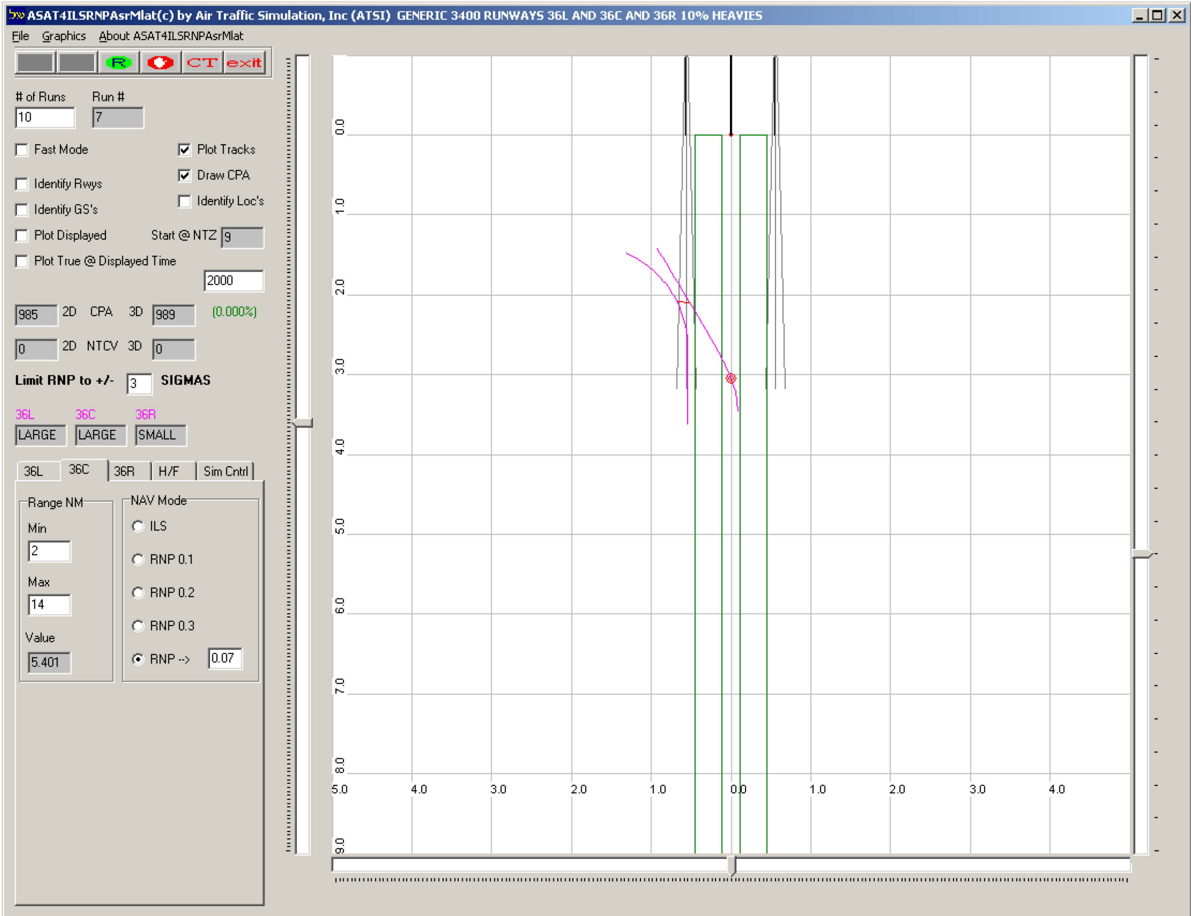

Figure 4: Typical ASAT Run

The simulation was set to initiate blunders between 2 and 14 NM from threshold. Outside 14 NM, there was at least 1,000-feet vertical separation per requirements for simultaneous operations. Inside 2 NM, the evader has landed before the blunderer could cross its approach path. The blunder here was initiated at about 3.5 NM from threshold (the 5.401 shown in the value field is the starting position of the next blunder). If an outer runway was selected, the lower box would contain fields that allow for shifting the localizer by a specified angle around a pivot point specified as a distance from threshold. This functionality supports the offset localizer scenarios. The display can show both the actual and reported position of the blundering aircraft. When running in high-speed mode, all display features are not updated to minimize run times.

An ASAT run consists of the three following phases (not to be confused with the study phases):

- Phase 1: Initialization. The aircraft types were selected randomly according to the fleet mix. Their performance data were loaded and appropriate airspeeds were determined. They were assigned to a runway and the blunderer was selected. The blundering aircraft was positioned at a random distance from the airport (uniformly distributed within the selected range limits) with appropriate lateral and vertical errors. The adjacent evader aircraft was positioned laterally and vertically and then placed longitudinally to maximize the chance of a collision if corrective action was not taken in a timely manner. The time to the next surveillance system update was selected from a uniform distribution ranging from 0 to 1 second for the PRM. All parameters that were based on Probability Distribution Functions (PDFs), such as evader rate of climb, roll rate, pilot and ATC response times, etc., were selected.

- Phase 2: Performance. The aircraft were "released" and the simulation advanced in simulated 50-millisecond steps with continuous updates of the aircraft state vectors based on their flight dynamics and performance data. Course deviations and corrections were based on the FTE filter and the navigation system models. Immediately after release, the blunderer started a 30-degree heading change and began converging on the evader aircraft. Surveillance system reports were generated at appropriate times with appropriate errors in range and azimuth. These errors affected where the targets were depicted on the controller's screen and, hence, when it was perceived by the controller as being in or headed toward the NTZ. A certain percentage of target reports were randomly dropped per the surveillance system specifications. When the surveillance system generated a "yellow" alert (the 10 second prediction of the aircraft position placed it inside the NTZ), an ATC response time was generated and when that time was reached, the evader was ordered to perform a 90-degree course change. Note that the simulation did not allow an evasion command to be issued before the yellow alert, although controllers in the real time MPAP testing did occasionally order evasion maneuvers prior to any alerts being issued. After another delay for the pilot response time, the evader began to climb and roll into the course change (per the selected performance parameters). Slant range and system plane separation were continuously monitored and the simulation continued for approximately 20 seconds (simulation time) past the point where the slant range stopped decreasing and started increasing, i.e., the CPA.

- Phase 3: Reporting the run. For each run, critical parameters were recorded and saved to output files. These included the aircraft types and runways involved, the pilot and ATC response times, the range of the blunderer from the threshold when the blunder began, the minimum two-dimensional and three-dimensional separation, and a flag indicating that a TCV had occurred. For runs that included RNP aircraft, additional data were collected to verify that the track distributions matched the expected navigation performance for the RNP level involved. A sample output file is included as Appendix G.

The study examined three different arrangements of ILS and RNAV or RNP aircraft on approach to dual parallel runways for each of the runway separations (3,400 feet straight-ins and 3,000 feet with offset localizer). Runway stagger was not addressed in this report since it had been dealt with in the three previous studies [11, 12, 15]. Runway stagger creates an initial altitude separation between the two glideslopes so that two aircraft that are "wingtip to wingtip" have about 100 feet vertical separation for each 2,000 feet of stagger. The previous studies have all shown that, as expected, as stagger increases, the TCV rate decreases. The different runway configurations are shown in Table 1. For each dual configuration, there were three fleet mixes: 10% Heavies, 20% Heavies and 30% Heavies. The percentages of Small and Large types and the airframe equivalences are explained in Appendix A. Each scenario was performed 100,000 times so that all reasonable combinations of aircraft types, performance parameters, radar update times, and pilot and controller response times were considered.

Table 1: Navigation System/Runway Configurations*

TEST SCENARIO RUNWAY CONFIGURATIONS					
Phase	Rwy Sep	Comments	Rwy 36L	Rwy 36C	Rwy 36R
			DUALS		
3	3,400	Baseline	ILS	ILS	N/A
3	3,400		ILS	RNP	N/A
3	3,400		RNP	RNP	N/A
4	3,000	Baseline	ILS	ILS	N/A
4	3,000		ILS	RNP	N/A
4	3,000		RNP	RNP	N/A

*ILS=ILS/MLS; RNP=RNAV(GPS) or RNP(GPS) with vertical guidance

2.2 Summary of Data Used

The primary data components of the ASAT system are listed below. The data components allow accurate representations of particular scenarios at particular airports but for the purposes of developing national standards, the system also supports a variety of generic elements.

2.2.1 Geography

Where an actual airport is being studied, ASAT uses the latest FAA databases to establish runway coordinates (including elevation), localizer and glide slope antenna positions, and relevant obstacle and terrain feature locations. For this study, generic airports were constructed with the desired runway separations and localizer headings.

2.2.2 Aircraft

Where a specific airport is being studied, aircraft fleet mix information is requested and incorporated into the simulation. For this study, generic aircraft models with typical performance values for commuter aircraft (referred to in the program as Small), Large turbojet, and Heavy turbojet aircraft types were used in various percentages to achieve the desired scenario.

This report uses class definitions partly based on weight classes established for wake turbulence purposes in [4] but separates the Large turbojet aircraft from the regional and business jet and commuter turboprops. This grouping effectively produces a new class that includes the heavier parts of the Small and the lighter parts of the Large classes that is intended to be more representative of commuter aircraft (particularly regional jets) performance. For the ASAT routine, the three classes used are labeled as Heavy, Large, and Small based on the following criteria (similar but not identical to what is defined in FAA Order 7110.65 [4]):

- Heavy - Large turbojet aircraft capable of takeoff weights of more than 255,000 pounds whether or not they are operating at this weight during a particular phase of flight. It consists of Boeing 747, 767, and 777 models, Airbus A310, A330, A340, and some A300 models, and a handful of older types.

- Large - Turbojet aircraft of more than ~90,000 (the limit in 7110.65 is 41,000) pounds, maximum certified takeoff weight, up to 255,000 pounds. This class includes all Boeing 737, 727, and 707 models, Airbus A319, A320, and A321 models, and the DC-9/MD80/B717 family.

- Small - Primarily commuter aircraft with weights ranging from 10,000 to ~90,000 pounds, intended to capture the regional jet and business jet categories as well as the commuter turboprops.

Details of fleet mix composition and representative performance models are discussed in Appendix A.

2.2.3 Environmental Conditions

The ASAT aerodynamics models automatically compensated for altitude effects based on the airport elevation and for any wind or turbulence conditions included in the model. Because the approach paths are relatively close and parallel, wind effects were considered to be negligible since all aircraft were similarly affected. Earlier MPAP studies supported this assumption.

2.2.4 Pilot Response Times

The pilot response time was defined as the period from the start of the ATC evasion command until the aircraft achieves 3 degrees of bank. These distributions are based on data collected during the MPAP testing and are discussed in more detail in Appendix B.

2.2.5 Air Traffic Controller Response Times

For tests which included alerts, the air traffic controller response time was defined as the delay from yellow alert to the activation of the microphone by the evading aircraft's monitor controller to begin the evasion command. The MPAP testing encompassed a range of surveillance systems, displays, and runway spacings and collected response times for each. Appendix C lists the configurations tested. The test configurations that the MPAP examined included 3,400-foot straight-in duals and 3,000 foot duals with an offset localizer with a PRM e-scan radar and high resolution monitors with functionalities described previously. The controller response times in the simulation were further restricted to occur no earlier than when the yellow alert was issued. (In the MPAP tests, the controllers frequently responded even earlier.) This was a conservative assumption to address the requirement in FAA Order 7110.65S, paragraph 5-9-7.c.2 that the evasion command should only be given "when an aircraft is observed penetrating or in the controller's judgment will penetrate the NTZ." Note that it is assumed there is nothing in the RNAV of RNP operational scenarios that would affect these times (such as delayed responses to excessive deviations).

2.2.6 Navigation

Previous testing for evaluating ILS operations used the International Civil Aviation Organization (ICAO) Collision Risk Model to determine initial positions (lateral and vertical). The simulation proceeded along the localizer and glide slope using control filters to simulate FTE. Because the blunder is initiated immediately after the simulation begins, this phase of flight is very short, even for the evading aircraft.

For the RNAV/RNP aircraft with flight director considered for this study, the initial lateral position was selected based on a Gaussian distribution derived from the combination of the GPS Navigation System Error (NSE) (specified as 100 meters, 95%) and conservative FTE values. Actual GPS NSEs are typically around 15 to 20 meters 99% of the time, so this represents a very conservative estimate for the NSE component.

Historical flight test data were consulted to determine representative FTE values for flight director-guided precision approaches. These data were collected during the FAA Microwave Landing System testing of the mid-1980's [22], the Air Force GPS testing of the early 1990's [16], and a variety of other flight test programs [22] conducted by Flight Standards and the FAA Technical Center. The standard deviations reported from these tests were up to 8 meters at Decision Height (DH) and no larger than 40 meters at 7 miles out from the threshold. Data collected on RNAV approaches flown with GPS and flight director produced standard deviations of less than 20 meters. Using a standard deviation (σ) of 40 meters should represent a very conservative estimate. This gave a 2σ, approximately 95%, value of 80 meters. Root-sum-squaring the NSE and FTE values translated to a lateral TSE 2σ value of 0.07 NM (i.e. 95% of the tracks would be within 0.07 NM of the desired track) for flight director-guided RNAV or RNP approaches using GPS. Vertical navigation was based on typical glide path deviations around a glide slope whose ground point of intercept

(GPI) was shifted due to the same Gaussian distribution. The aircraft then navigated along the adjusted path to the runway.

The difference between an RNP navigation system and an RNAV system has been discussed previously (Section 1.3).

RNAV aircraft that rely on DME/DME/IRU (Inertial Reference Units) are extremely dependent on DME coverage and availability for their navigation solutions and, for an approach operation such as this, are flying into poorer coverage and decreasing signal quality as they descend. The expected performance of an RNAV/DME/DME/IRU aircraft would be marginally RNP 0.3 to 0.5 NM where good coverage is available. These types of aircraft were not considered for this study.

2.2.7 Surveillance System

A PRM surveillance system, with appropriate errors and latencies was part of the simulation. The model was based on data provided by the William J. Hughes Technical Center and the manufacturer.

2.3 Simulation Performance

The runway configuration test scenarios are depicted in Table 2. As mentioned earlier, the variations between the scenarios are the arrangement of ILS and RNAV/RNP aircraft across the runways, the runway separation, and the fleet mix. One hundred thousand runs were performed for each scenario.

For each scenario, the blunders were evenly distributed across the runways and only blunders toward other aircraft were considered, i.e., there were no runs where the aircraft on the left runway blundered left (away from the other traffic). For the dual runway case, approximately 50,000 runs had the left aircraft blundering right and 50,000 runs had the right aircraft blundering left.

Table 2: Test Scenarios*

Scenario #	% Heavies	Display	36L Nav	36C Nav	36R Nav
Independent 3,400-Foot Duals					
1	10	FMA	ILS	ILS	N/A
2	10	FMA	ILS	RNP	N/A
3	10	FMA	RNP	RNP	N/A
4	20	FMA	ILS	ILS	N/A
5	20	FMA	ILS	RNP	N/A
6	20	FMA	RNP	RNP	N/A
7	30	FMA	ILS	ILS	N/A
8	30	FMA	ILS	RNP	N/A
9	30	FMA	RNP	RNP	N/A
Independent 3,000-Foot Duals with 2.5° Offset Localizer					
10	10	FMA	ILS	ILS	N/A
11	10	FMA	ILS	RNP	N/A
12	10	FMA	RNP	RNP	N/A
13	20	FMA	ILS	ILS	N/A
14	20	FMA	ILS	RNP	N/A
15	20	FMA	RNP	RNP	N/A
16	30	FMA	ILS	ILS	N/A
17	30	FMA	ILS	RNP	N/A
18	30	FMA	RNP	RNP	N/A

*ILS indicates a conventional precision approach; RNP, a GPS RNAV or RNP approach with vertical guidance

3.0 Summary of Data Analysis and Risk Evaluation

This section defines the acceptability of the results for operational implementation and examines the results of the simulation.

3.1 Summary of Acceptable Level of Risk

In 1988, the MPAP was initiated to investigate capacity-enhancing procedures for simultaneous ILS approaches to parallel runways. The program established the MPAP Technical Work Group (TWG) to unite various areas of expertise to evaluate multiple parallel approaches in an effort to increase airport capacity in a safe and acceptable manner. FAA representatives from the Secondary Surveillance Product Team, Office of System Capacity, Flight Standards Service, Air Traffic Operations, Air Traffic Plans and Requirements, and various regional offices comprised the MPAP TWG.

MPAP researchers extracted the total number of air carrier accidents as well as the number of fatal accidents on final approach from National Transportation Safety Board (NTSB) data from 1983 to 1989. This number, together with the total number of ILS approaches flown during this time period, lead to an estimated fatal accident rate during ILS operations performed during Instrument Meteorological Conditions (IMC) of 4×10^{-7} fatal accidents per approach. There are a number of causes of accidents during final approach, such as structural failure, engine failure, or midair collision. An initial estimate was that there are nine possible causes of accidents on final approach. Implementing simultaneous parallel approaches created a tenth possible accident cause, a collision with an aircraft on an adjacent approach. The researchers assumed that the risks of the ten potential accident causes are equal. Thus, the contribution of any one of the accident causes would be one-tenth of the total accident rate. Based on this rate, the TLS for midair collisions on simultaneous parallel approaches is 4×10^{-8}, or:

1 accident per 25 million approaches

The MPAP test team adopted a method for determining a simulation's maximum acceptable Test Criteria Violation (TCV – Center of Gravity separation less than 500 feet) rate from the Precision Runway Monitor (PRM) Demonstration Program. In the PRM Demonstration Report [1], researchers computed a TCV rate from the population of all Worst-Case Blunders (WCBs). They found that a TCV rate not greater than 0.004 TCV per WCB would meet the TLS, provided that the overall 30-degree blunder rate did not exceed one 30-degree blunder per 2,000 approaches.

The Monte Carlo simulation, however, measured a TCV rate based on at-risk WCBs, not the population of all WCBs. Therefore, for comparison purposes, the population TCV rate was converted to an at-risk TCV rate. Based on a simulation of aircraft speeds and types, a conservative ratio of 1/17 at-risk WCB per WCB was applied, resulting in an at-risk TCV rate criterion of 6.8% for dual approaches.

To achieve a fatal accident rate that meets the TLS, a Monte Carlo simulation with the evader at-risk must result in a TCV rate (plus twice the standard error) that does not exceed 6.8% for each proximate pair of dual approaches. A Monte Carlo confidence interval that extends above 6.8% indicates that the operation might not meet the TLS. For these simulations, the confidence intervals on the results are quite small (standard errors<0.1%) due to the large number of runs.

The risk analysis is explained in more detail in Appendix D, which is excerpted from Appendix C of [3].

3.2 Summary of the TCV Probability Analysis

Table 3 and Table 4 list the resultant TCV counts, number of runs for each scenario, and the associated TCV rate for each scenario. The dual straight-in and dual with offset results are discussed in separate sections.

The simulation included algorithms to longitudinally place evader aircraft relative to the blundering aircraft so that they were at-risk.

3.2.1 Independent 3,400-Foot Dual Parallel Approach Scenarios

Table 3 shows the resultant TCV rates for the simulations of the independent simultaneous dual approaches to runways separated by 3,400 feet. The table shows that all scenarios were well within the TCV (CG separation less than 500 feet) rate criteria (<6.8%). Under high update surveillance, it appears that there may actually be a small decrease in the TCV rate for the dual RNAV case, perhaps due to the linearity of the RNAV approach guidance versus the angular ILS. Comparing this to the results of the conventional surveillance system study [12], where the RNAV participants seem to cause an increase in the TCV rate, indicates that the target update rate and alerting algorithms are very significant parts of the blunder resolution scenario.

As had been shown in previous studies, adding proportionally more Heavy aircraft generally caused the TCV rate to rise. More massive aircraft, such as Boeing 747s, bank more slowly and, because of their higher approach speed, tend to achieve a lesser rate-of-turn for the same bank angle than do smaller aircraft and thus take longer to achieve a heading change.

Table 3: Test Scenarios*
Independent 3,400-Foot Duals

Scenario #	% Heavies	36L Nav	36C Nav	TCV %
1	10	ILS	ILS	4.7
2	10	ILS	RNP	4.8
3	10	RNP	RNP	4.8
4	20	ILS	ILS	5.1
5	20	ILS	RNP	5.1
6	20	RNP	RNP	5.0
7	30	ILS	ILS	5.1
8	30	ILS	RNP	5.2
9	30	RNP	RNP	5.0

*ILS indicates a conventional precision approach; RNP, a GPS RNAV or RNP approach with vertical guidance

3.2.2 Independent 3,000-Foot Dual with Offset Localizer Scenarios

None of the scenarios for the 3,000 foot scenarios produced TCV rates above 1%. Most were substantially less. While these values initially seemed too small to be realistic, re-examination of the historical data placed them in a more reasonable light. Similar studies performed in the mid-90's produced similar values for dual ILS approaches. The effect of the offset localizer is extremely significant. At the expected 2.5º offset, the separation between the closer approach paths is less than 3,400 feet for only the last 1.5 out of the 14 miles of the scenario considered and less than 4,300 feet for nominally the last 5 miles, i.e. the separation between flight tracks is greater than the allowed value for conventional radar for more than half of the approach. A sensitivity analysis run on the localizer offset angle [3] showed that the angle would be less than 1º before the TCV rate became unacceptable. During the MPAP studies, the separations that were considered unacceptable were driven by the number of nuisance breakouts as much as by the difficulty in resolving a blunder.

4.0 Results and Conclusions

In this study, a risk analysis methodology was employed that was developed by the MPAP for simultaneous independent ILS approaches to parallel runways. This methodology was utilized to determine the acceptability of including RNAV and RNP aircraft in simultaneous independent dual approach operations with high update radar surveillance as specified in FAA Order 7110.65S, *Air Traffic Control* [4], paragraph 5-9-8.

The study used a high-fidelity simulation of the operation to perform a Monte Carlo analysis. The study examined 18 test scenarios that mixed ILS and GPS-equipped RNAV or RNP with flight director traffic. The simulation modeled RNAV/RNP performance as a Gaussian distribution with the RNP level equivalent to 1.96 standard deviations. The standard deviation was determined by root-sum-squaring approved GPS navigation error values with FTEs determined from consideration of flight test data. Note that this produces a smaller RNP value than any of the current certification standards allow. It was assumed that the integrity, availability, and continuity functions inherent in RNP were covered for RNAV aircraft by the required ATC surveillance and by the other conservative assumptions.

4.1 Independent 3,400-Foot Dual Parallel Runways

For all the scenarios examined, all combinations of GPS-equipped RNAV or RNP aircraft and ILS aircraft considered in the simulation achieved an acceptable TCV rate and passed the test criteria.

4.2 Independent 3,000-Foot Dual Parallel Runways with One Localizer Offset by 2.5°

For all the scenarios examined, all combinations of GPS-equipped RNAV or RNP aircraft and ILS aircraft considered in the simulation achieved an acceptable TCV rate and passed the test criteria.

4.4 Conclusions

The study results support the approval of incorporating RNAV or RNP aircraft approaches with simultaneous independent operations to runways separated by as little as 3,400 feet with straight-in approaches or 3,000 feet with an offset approach course to one runway (course equivalent to one produced by a localizer offset by 2.5). The study only considered flight director equipped RNAV or RNP aircraft. A previous study [15] was performed for WAAS equipped aircraft without flight director that might be participating in these operations. That study indicated that WAAS aircraft could safely participate in independent simultaneous approach operations to runways separated by 4,300 feet with conventional surveillance as long as they were operating in "vector to final" mode which emulates ILS operations. Hand-flown WAAS operations could not be supported by aircraft not in that mode. That restriction would be even more applicable at the reduced separations considered in this study. In "vector to final" mode, a WAAS receiver generates lateral guidance that is as good as or better than an ILS, and can be considered equivalent to an ILS operation.

Appendix A: Aircraft Mix and Performance Modeling

One of the ASAT initiation files contains a section where the number of each type of aircraft is given. It automatically sets the frequency of occurrence for each aircraft type during the simulation. For this generic study, three fleet mixes were considered containing different percentages of Heavy aircraft: 10, 20, and 30%. The percentages are shown in the table below.

Table A-1 Fleet Mix Percentages Used in Simulations

ASAT Class	% in 10% mix	% in 20% mix	% in 30% mix
Small	50	45	40
Large	40	35	30
Heavy	10	20	30

The Small aircraft class used in the simulation, intended to represent commuters, regional jets, and business jets, has performance parameters similar to a Embraer Regional Jet 145 (ERJ). Based on comparisons between various performance parameters such as rate of climb and vertical acceleration, the ERJ-145 should be a conservative representative of the class. Note that the Small class used in the simulation incorporates many aircraft types defined as Large in FAA Order 7110.65S [4].

The Large aircraft class, intended to represent large turbojets, such as Boeing 737s, MD-88s, and Airbus A320s was represented by the A320, which seemed to be at about the mid-point of the performance range.

The Heavy class, covering Boeing 747, 757, 767, and 777 models and Airbus A300, A310, A330, and A340 models, was represented by performance parameters similar to the Boeing 777. The 777 seemed to be about the middle of the performance range for the class. The 747 would have been a conservative representative but, in terms of percentage of operations, is only a significant player at one or two airports in the NAS.

Based on the type, several aircraft performance distributions are loaded: approach speed, go around speed, deceleration, acceleration, rate-of-climb, and rate-of-change of rate-of-climb, roll rate, and achieved bank angle. Certain limits were applied to many of these parameters to eliminate extreme maneuvers from consideration during the simulation. For instance, banks of 40 degrees or more were seen during the MPAP tests, but the simulation limited the bank to 30 degrees. Approach speed was adjusted by an amount based on distance from threshold. The appropriate increase was determined from a study of radar data collected during IFR simultaneous approaches at most of the airports performing those operations.

Appendix B: Pilot Reaction Time Distribution Analysis

The MPAP testing included line pilots operating high-fidelity full motion simulators. The simulators were connected to the test facility at the William J. Hughes Technical Center by phone (so that the pilots were in direct contact with the controllers) and high-speed data lines. One of the parameters that was recorded during the testing was the time from the controller's initial evasion command until the aircraft achieved a 3-degree angle of bank in a roll that was determined to be part of the evasion maneuver. Every attempt was made to eliminate normal control motions from being considered as the start of the maneuver.

Test results that involved the use of the Precision Runway Monitor system to monitor closely spaced parallel runways led to the development of a training requirement to ensure that the pilots did not delay their response to a traffic alert message. Though not required, a significant part of the present pilot population has completed the training, which consists of a short video presentation. This training was not considered necessary for operations using conventional radar systems with runways separated by 4,300 feet or more.

A problem identified by the pilots during the testing in the late 1980s was controllers' use of the word "immediate." The pilots, at that time, claimed that controllers frequently used the term when there was no need for an immediate response and this tended to lower pilot sensitivity to phrases that included the word. As a result, Air Traffic directives were modified to limit the use of the term except for real emergencies that did require "immediate" action. The current directive, FAA Order 7110.65S, provides only three phraseologies that include immediate: two of those are associated with simultaneous approaches; the third is when collision with terrain appears imminent. Contemporary pilots are aware of the urgency of action required when the word "immediate" is used.

The pilot response time distribution selected for this test was based on data collected during two test programs performed in 1995 and 1996. It was averaged across the fleet so there was no attempt to correlate response time with aircraft type. A Johnson S_L distribution was fitted to the data resulting in the following parameters shown in Table B-1. (Johnson distributions are discussed in Appendix E.)

Table B-1: Johnson S_L Distribution Parameters

Parameter	Value
Type	S_L
Delta	3.5
Gamma	0.0
Lambda	7.4
Epsilon	0.83
Truncation-Low	1.0
Truncation-High	17.0

The truncation points were chosen to reflect the results of the pilot training requirement. Subsequent testing of trained pilots indicated that there was little change in the bulk of the distribution but that the slower response times were eliminated. No data points were collected from trained pilots greater than 15.5 seconds so the maximum value considered was set to 17.0.

Figure B-1 shows the resultant distribution overlaying the histogram of the pilot response times. The dashed blue lines represent the approximate quartile (25%, 50%, and 75%) points of the histogram data and the 97.5% point (cumulative to +2 standard deviations). The solid red lines are the equivalent points for the Johnson S_L function fitted to the data. Note that the S_L distribution values for the quartiles and 2 σ points are all to the right of the data values, indicating the function is a conservative representation of the data.

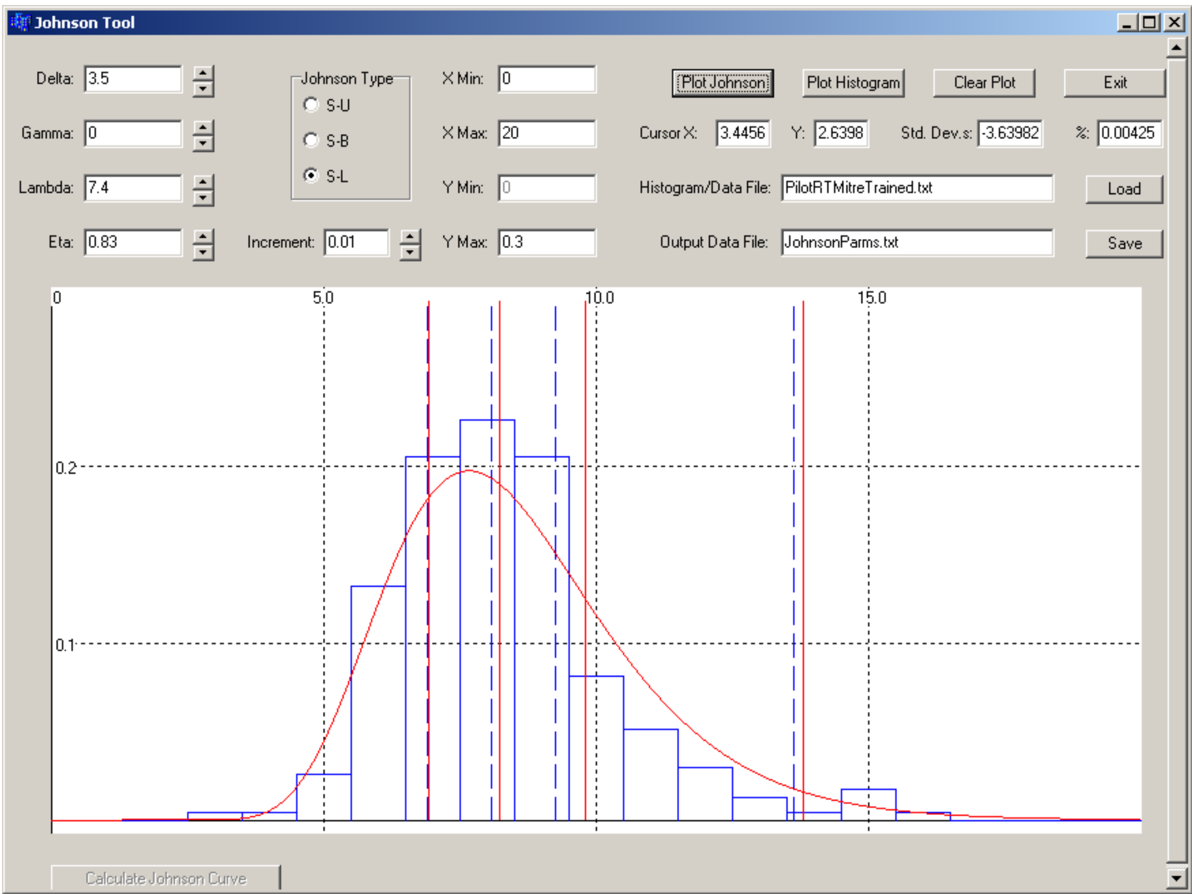

Figure B-1: Pilot Response Times Distribution

Also note that the parameter referred to as epsilon elsewhere in the document is labeled eta on the Johnson Tool.

Appendix C: Air Traffic Controller Reaction Time Distribution Analysis

The controller response time represents the time from alert onset, i.e. the change in color of the FMA predictor line and aircraft data block from green to yellow, to the time the controller keyed the microphone to communicate with the pilot of the evading aircraft. The yellow alert is based on a 10 second software algorithm predictor of NTZ penetration. If actual NTZ penetration occurs, a red alert is issued (the predictor line and aircraft data block change to red.) The monitor controller response times to the yellow FMA alert were modeled in this study as normal distribution with a mean (μ) of 2.2 second and a standard deviation (σ) of 1.4 seconds for the 3400 feet straight-in case and a mean of 1.0 seconds and a standard deviation of 1.5 seconds for the 3000 feet offset case. In neither scenario is the response time generated by the simulation allowed to be earlier than the yellow alert (although this "anticipation" was seen in the real time studies).

In 1993, Lincoln Labs published a study [2] of controller performance using the PRM system at Memphis International Airport. Simulated track data to parallel runways was presented to controllers while a number of parameters, such as runway spacing, blunder angle, and update rate, were varied. One hundred ninety-eight events were included in the set of data for 30 degree blunders on runways separated by 3,400 feet with a one-second update radar. Unfortunately, the original response time data from the test has been lost and only descriptive statistics remain, including the means, standard deviations, minima, and maxima. Based on the available values, we assumed a normal distribution for the simulation.

For the offset localizer case, reference [3] reports the statistical results of controller responses to 299 blunders using an offset ILS to one runway with runways separated by 3,000 feet. Response times ranged from -3 seconds to +3 seconds. (The negative response times were the result of controllers closely monitoring aircraft tracks and taking action prior to the actual yellow alert.) The mean response time of the 299 blunders was 0.5 seconds and the standard deviation was 1.1 seconds. As Figure 6 of Reference [3] (reprinted below as Figure C-1) shows, the data corresponds closely to a normal distribution. Because the values were significantly smaller than those produced in other similar tests, a small upward "correction" was made to the data, producing a mean of 1.0 second and a standard deviation of 1.5.

Note that in both cases, the distribution were truncated on the low side at 0.0 so that the there were no responses that "anticipated" the yellow alert. Both distribution were also truncated at 7.0 seconds on the upper end since no controller responses were recorded greater than that.

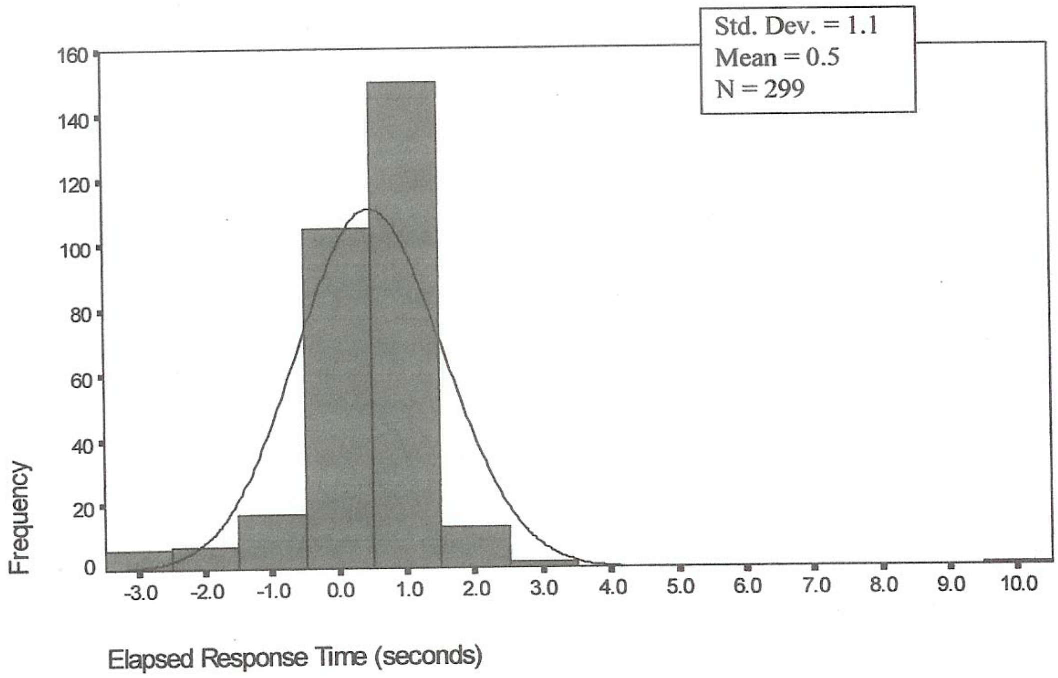

Figure C1: Controller Response Times
(Offset ILS Approach, 3,000 Feet Runway Separation)

Appendix D: Risk Analysis

Several events must occur simultaneously for a collision to occur during simultaneous instrument approaches. Clearly, a blunder must occur, or there would be no significant deviation from course. Previous testing has shown that blunders other than Worst-Case Blunders (WCBs: 30 degree blunder with lost communication) are of negligible risk, so the blunder must be a WCB. Also, the blundering aircraft must have a critical alignment with an aircraft on an adjacent course (i.e., the aircraft must be at risk). If all of the above events develop, a TCV occurs if the controller and pilots cannot react in sufficient time to separate the blundering and the evading aircraft. In addition, one collision will involve two aircraft and will probably produce two accidents, as defined by the National Transportation Safety Board (NTSB).

Assuming that a TCV will result in a collision, the probability of a collision accident can be expressed in mathematical terms by:

$$P(\text{Accident}) = P(\text{TCV and At-risk and WCB and Blunder}) \times 2 \qquad \text{(D1)}$$

or

$$\begin{aligned} P(\text{Accident}) = {} & P(\text{TCV}|\text{At-risk and WCB and Blunder}) \times \\ & P(\text{At-risk}|\text{WCB and Blunder}) \times \\ & P(\text{WCB}|\text{Blunder}) \times \\ & P(\text{Blunder}) \times 2 \end{aligned} \qquad \text{(D2)}$$

Where:

- P(TCV and At-risk and WCB and Blunder) is the probability of all relevant events occurring simultaneously (i.e., an at-risk WCB that results in a TCV).

- P(TCV|At-risk and WCB and Blunder) is the probability that a TCV occurs given that an at-risk WCB has occurred. This quantity is estimated by the simulation of at-risk WCBs in the real-time and Monte Carlo simulations (i.e., the TCV rate in the simulation).

- P(At-risk|WCB and Blunder) is the probability that a WCB has critical alignment with an aircraft on an adjacent approach. Analysis conducted in preparation for this simulation indicates that a value of 1/17 is a good approximation of this quantity, given 3 NM in-trail spacing.

- P(WCB|Blunder) is the probability that a blunder is a WCB. This probability is unknown, but is estimated to be approximately 1/100 [1].

- P(Blunder) is the probability that a blunder occurs during a simultaneous instrument approach. This rate is also unknown, but is estimated to be no more than 1 30-degree blunder per 1,000 dual approach pairs or 1 30-degree blunder per 2,000 approaches. This is a conservative value that the MPAP researchers derived from the risk analysis conducted during the PRM demonstration program. Until a blunder rate estimate can be derived from field data of actual blunder occurrences or other evidence suggests using a different value, the TWG has agreed to use 1/1,000 30-degree blunders per dual approach pair.

- The factor of 2 represents two accidents per collision.

Target Level Of Safety

The total number of air carrier accidents, as well as the number of fatal accidents on final approach, has been extracted from NTSB data for the time period, 1983-1989. This number, together with the total number of ILS approaches flown during this time period, leads to an estimated fatal accident rate during ILS operations performed during IMC of 4×10^{-7} fatal accidents per approach. There are a number of causes of accidents during final approach, such as structural failure, engine failure, or midair collision. An initial estimate is that there are nine possible causes of accidents on final approach. A tenth possible accident cause, a collision with an aircraft on an adjacent approach, is created with the implementation of simultaneous parallel approaches.

For simplicity of model development, it is assumed that the risks of the ten potential accident causes are equal. Thus, the contribution of any one of the accident causes would be one-tenth of the total accident rate. Based on this, the Target Level of Safety for midair collisions on simultaneous parallel approaches is 4×10^{-8}, or:

1 accident per25 million approaches

Maximum Allowable Test Criterion Violation Rate

Because the only undefined variable in Equation (D2) used to compute the maximum acceptable accident rate is the TCV rate, it is possible to determine the maximum allowable TCV rate which would meet the Target Level of Safety. Knowledge of this number would allow the TWG to quickly decide if the simulated operation would meet the Target Level of Safety. The maximum allowable TCV rate may be found from following analysis.

Given the Target Level of Safety, P(Accident) = 4×10^{-8}, then the Equation (D2) becomes:

$$P(TCV|\text{At-risk and WCB and Blunder}) \times P(\text{At-risk}|\text{WCB and Blunder}) \times P(WCB|\text{Blunder}) \times P(\text{Blunder}) \times 2 = 4 \times 10^{-8}$$

or,

$$P(\text{TCV}|\text{At-risk and WCB and Blunder}) = \frac{4 \times 10^{-8}}{1} \times \frac{1}{P(\text{At-risk}|\text{WCB and Blunder})} \times \frac{1}{P(\text{WCB}|\text{Blunder})} \times \frac{1}{P(\text{Blunder})} \times \frac{1}{2} \quad \text{(D3)}$$

Substituting values from (D2) into (D3):

$$P(\text{TCV}|\text{At-risk and WCB and Blunder}) = \frac{4 \times 10^{-8}}{1} \times \frac{17}{1} \times \frac{100}{1} \times \frac{2{,}000}{1} \times \frac{1}{2} = 6.8\% \quad \text{(D4)}$$

Thus, if the simulation results support the assertion that the probability of a TCV, given that an at-risk WCB occurs (P(TCV|At-risk and WCB and Blunder)), is less than 6.8%, then the simultaneous approach procedure simulated should have an acceptable accident rate

Appendix E: Johnson Distributions

The Johnson family of empirical distributions is based on transformations of a standard normal variate. An advantage of such a transformation is that estimates of the percentiles of the fitted distribution can be obtained either from a table of areas under a standard normal distribution or from a computer program which computes areas under a standard normal distribution. Another advantage is that during a Monte Carlo simulation, variates from the distribution are readily computed from the standard normal distribution. The Johnson distributions also can be fitted to the data with relative ease compared to the Pearson distributions. The Johnson distributions are divided into three families as follows:

1. The S_L family is characterized by the transformation:

$$z = \gamma + \delta \ln\left(\frac{x-\varepsilon}{\lambda}\right), \; x > \varepsilon, \lambda > 0 \qquad \text{(E1)}$$

where *x* is the variable to be fitted by the Johnson distribution and *z* is a standard normal variate. Each curve in this family is bounded on the left by ε and is unbounded on the right. By performing a certain transformation of the parameters δ and γ the curves can be converted to the log-normal distribution.

2. The S_B family is characterized by the transformation:

$$z = \gamma + \delta \ln\left(\frac{x-\varepsilon}{\lambda+\varepsilon-x}\right), \; \varepsilon < x < \varepsilon + \lambda. \qquad \text{(E2)}$$

where *x* is the variable to be fitted by the Johnson distribution and *z* is a standard normal variate. Each curve in this family is bounded on the left by ε and on the right by ε + λ. These curves resemble the Weibul or extreme-value families. The parameters γ and δ are shape parameters, ε is a location parameter, and λ is a scale parameter.

3. The S_U family is characterized by the transformation:

$$z = \gamma + \delta \sinh^{-1}\left(\frac{x-\varepsilon}{\lambda}\right), \; -\infty < x < \infty, \lambda > 0. \qquad \text{(E3)}$$

where *x* is the variable to be fitted by the Johnson distribution and *z* is a standard normal variate. Each curve in this family is unbounded and unimodal. The parameters γ and δ are shape parameters, ε is a location parameter, and λ is a scale parameter.

To use the Johnson family of curves it is necessary to invert Equations (E1), (E2), and (E3); that is, each of the equations must be solved for *x*.

1. The S_L transformation after inversion is:

$$x = \varepsilon + \lambda \exp\left(\frac{z-\gamma}{\delta}\right), \ -\infty < z < \infty. \qquad \text{(E4)}$$

2. The S_B transformation after inversion is:

$$x = \varepsilon + \frac{\lambda}{1+\exp\left(\frac{\gamma - z}{\delta}\right)}, \ -\infty < z < \infty. \qquad \text{(E5)}$$

3. The S_U transformation after inversion is:

$$x = \varepsilon + \lambda \sinh\left(\frac{z-\gamma}{\delta}\right), \ -\infty < z < \infty. \qquad \text{(E6)}$$

Because the variable *z* in each transformation is a standard normal variate, the probability distribution of each Johnson family of curves may be determined from a normal table.

1. The Probability Density Function of a member of the Johnson S_L family has the following form:

$$f_1(x) = \frac{\delta}{(x-\varepsilon)\sqrt{2\pi}} \exp\left\{-\frac{1}{2}\left[\gamma + \delta \ln\left(\frac{x-\varepsilon}{\lambda}\right)\right]^2\right\}, \ x \geq \varepsilon, \qquad \text{(E7)}$$

$$\delta > 0, -\infty < \gamma < \infty, \lambda > 0, -\infty < \varepsilon < \infty.$$

2. The Probability Density Function of a member of the Johnson S_B family has the following form:

$$f_2(x) = \frac{\delta\lambda}{(x-\varepsilon)(\lambda - x + \varepsilon)\sqrt{2\pi}} \exp\left\{-\frac{1}{2}\left[\gamma + \delta \ln\left(\frac{x-\varepsilon}{\lambda - x + \varepsilon}\right)\right]^2\right\}, \qquad \text{(E8)}$$

$$\varepsilon < x < \varepsilon + \lambda, \delta > 0, -\infty < \gamma < \infty, \lambda > 0, -\infty < \varepsilon < \infty.$$

3. The Probability Density Function of a member of the Johnson S_U family has the following form:

$$f_3(x) = \frac{\delta}{\sqrt{2\pi\left[(x-\varepsilon)^2+\lambda^2\right]}} \exp\left[-\frac{1}{2}\left(\gamma + \delta \ln\left\{\left(\frac{x-\varepsilon}{\lambda}\right) + \left[\left(\frac{x-\varepsilon}{\lambda}\right)^2 + 1\right]^{1/2}\right\}\right)^2\right], \quad \text{(E9)}$$

$$-\infty < x < \infty, \delta > 0, -\infty < \gamma < \infty, \lambda > 0, -\infty < \varepsilon < \infty.$$

Sampling From a Johnson Curve

After the appropriate Johnson curve has been selected and the parameters γ, δ, ε, and λ have been determined, then it is a simple matter to select random variates from the Johnson distribution. The method involves the following steps:

1. Select two random numbers r_1 and r_2 from the uniform interval (0, 1).

2. Use one of the Box-Muller equations to compute a random variate z from the standard normal distribution, N(0, 1).

3. Substitute z into the appropriate Johnson transformation. If the Johnson curve is of type S_L then substitute z into Equation (E4) to obtain the random variate x. If the Johnson curve is of type S_B then substitute z into Equation (E5) to obtain the random variate x. If the Johnson curve is of type S_U then substitute z into Equation (E6) to obtain the random variate x.

Appendix F: ASAT Input Files

1. APF file: Fleet mix, Aircraft actions, Links to airport and CRM data, and Air Traffic and Pilot response time parameters

```
Description: K002 Runways 36L and 36R with 10% heavies and no stagger
;
;      Aircraft types and % of overall traffic
;      - - - - - - - - - - - - - - - - - - - - -
Aircraft:     DATA\\SMALLRJ.TXT
PercentageMix:      500                 ;      [-] out of TOTAL mix
Aircraft:     DATA\\LARGE.TXT
PercentageMix:      400                 ;      [-] out of TOTAL Mix
Aircraft:     DATA\\HEAVY.TXT
PercentageMix:      100                 ;      [-] out of TOTAL Mix
;
AirportFile: Airports & ASAT Projects\\GEN_DUAL_3400.out
;
Radar_Update_Every_Sec:                 1.0
Radar_Processing_Delay_Sec:             0.5
Radar_Display_Delay_Sec:                0.0
Radar_Sigma_Circular_Error_Ft:         50.0
Radar_Max_Circular_Error_Sigmas:        2.0
;
;      Active runways (from LEFT to RIGHT)
;      - - - - - - - - - - - - - - - - - - -
Runway:             36L
FlightMode:     REJECT
Runway:             36R
FlightMode:      REJECT
Runway:             36Z
FlightMode:      REJECT

;      Air Traffic Control Response Time Definition
;      - - - - - - - - - - - - - - - - - - - - - - - - -
AtcJohnsonType:     3       ;1:SB   2:SL    3:SU
AtcEpsilon:          2.2
AtcLambda:          14000.0
AtcDelta:           10000.0
AtcGamma:           0.0
AtcMin:             0.0
AtcMax:             7.0
AtcDeltaTime:       0.0


;      Pilot response type
;      - - - - - - - - - -
; GRM18
PilotJohnsonType:     2            ;1:SB   2:SL    3:SU  pdf by grm 01/02/07
PilotEpsilon:         0.83
PilotLambda:          7.4
PilotDelta:           3.5
PilotGamma:           0.0
PilotMin:             1.0
PilotMax:            17.0
;
CrmData:      DATA\\CAT1030.TXT                ;      CRM distributions
;
```

2. Airport Description: Airport and runway coordinates. A third runway is included to meet requirements of the simulation tool.

```
AirportName        : GENERIC DUAL
AirportIdentifier  : K002
AirportLocation    : HOUSTON
AirportState       : TX
AirportLatLon      :  30 00 00.00,      100 00 00.00
AirportElevation   : 1000
AirportMagVarYr    : 1985
;- - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - - -
;
RunwayName         : 36L
RunwayTrueBearing  : 0
RunwayLength       : 10000
RunwayThLatLon     :  29 59 33.34, 100 00 24.49
RunwayThElevation  : 1000

RunwayName         : 36C
RunwayTrueBearing  : 0
RunwayLength       : 10000
RunwayThLatLon     :  29 59 33.34, 099 59 45.87
RunwayThElevation  : 1000

RunwayName         : 36R
RunwayTrueBearing  : 0
RunwayLength       : 3000
RunwayThLatLon     :  29 59 33.34, 099 57 0.00
RunwayThElevation  : 1000
```

Appendix G: ASAT Output File

ASAT Output file for C:\ASAT4ILSRNP\Airports & ASAT Projects\Generic Dual

RunNumber	AcType2	AcType1	CPA2D	CPA3D	BATCRT	BPRT	EATCRT
1	ERJ	B732	4607.3	4614.6	15.4	3.2	13.6
2	B732	F100	2926.1	2932.8	27.8	3.1	17.4
3	B732	ERJ	1666.6	1666.7	18.7	3.1	25.2
4	F100	F100	3042.4	3042.6	15.1	2.4	9.7
5	B738	ERJ	2399.8	2431.7	10.7	5.0	19.1

```
Total Number of Runs     : 5

TCV Range: 500[Ft]
NTCV2D(LCR): 0 / 5
NTCV3D(LCR): 0 / 5

NTCV2D(LC) : 0 / 3
NTCV3D(LC) : 0 / 3

NTCV2D(CR) : 0 / 2
NTCV3D(CR) : 0 / 2
```

Right half of output -----→
on next page -----→

Notes:
RunNumber: Run Number
AcType2: Aircraft Type of Evader aircraft
AcType1: Aircraft Type of Blundering aircraft
CPA2d: Closest Point of Approach in system plane (2-dimensional)
CPA3d: Closest Point of Approach – slant range (3-dimensional)
BATCRT: Blunderer ATC Response Time
BPRT: Blunderer Pilot Response Time
EATCRT: Evader ATC Response Time
EPRT: Evader Pilot Response Time
TCV2D: Flag
TCV3D: Flag
BlunderStatus: Which aircraft blunders which way
TCV: Same as TCV3D
Rwy: Evader Runway
NAV: Evader Nav Mode (1=RNP 0.1, 2=RNP 0.2, 3=RNP 0.3)
Blunder Range: Range from thld when blunder initiated
Edev: Evader crosstrack deviation at ATC response to blunder

27 26L 26R.apf ASAT project input file

```
EPRT     TCV2D       TCV3D              BlunderStatus        TCV
Rwy NAV        Blunder Rge    Edev
3.1          0           0        C_Blunders_to_Left            0
0  3       73016.4      -401.3
6.9          0           0        L_Blunders_to_Center          0
1  3       26372.5       789.4
2.5          0           0        C_Blunders_to_Right           0
2.9          0           0        C_Blunders_to_Right           0
3.6          0           0        L_Blunders_to_Center          0
1  3       89558.6      -335.8
```

Appendix H: Memorandum of Agreement

Federal Aviation Administration

MEMORANDUM OF AGREEMENT

between the

Flight Standards Service, Flight Technologies and Procedures Division, AFS-400

and

Area Navigation (RNAV)/Required Navigation Performance (RNP) Group, AJR-37

and

Avionics Certification System Branch, AIR-130

Article I. Purpose: The purpose of this agreement is to document the requirements for the analysis and subsequent criteria development for instrument landing system (ILS)/Microwave Landing System (MLS)/and RNAV(GPS) and RNAV (RNP) Dual Simultaneous dependent and independent approaches and ILS/MLS/and RNAV (GPS) and RNAV (RNP) Triple independent approaches to dual and triple parallel runways. The agreement is between the offices of AFS-400, AIR-130, and AJR-37.

Article II. Roles and Responsibilities: The Flight Operations Simulation and Analysis Branch, AFS-440, will conduct an analysis including the agreed to items listed in the Background paragraph, develop standards and write a technical report documenting analysis findings. Based upon the analysis findings, the Flight Procedure Standards Branch, AFS-420, will then develop instrument approach criteria for ILS/MLS/and RNAV Dual, Triple Simultaneous dependent and independent approaches to dual and triple parallel runways, as appropriate.

Background: The following is a summary of agreements with regard to the subject analysis issues and parameters discussed during our meeting on April 13, 2006.

We agree to the following:

- All RNAV operations considered must be based on Global Positioning System (GPS).
- The performance level studied will be RNAV/GPS where the navigation system error (NSE) will be 100 meters, based on a Gaussian distribution at the 95 percent probability level.

- The primary analysis first order of priority will be to consider Flight Management System (FMS), flight director and/or autopilot equipped aircraft where the greatest capacity and efficiency benefit to the National Airspace System (NAS) may first be realized. However, the need to consider incorporation of panel mounted GPS equipment into the model at some point in the future is acknowledged and will be coordinated at a later date. This panel mounted GPS equipment analysis would account for use of full scale deflection (FSD) in initial and intermediate segments where the FSD is equal to 1 nautical mile (NM) until 2 NM prior to Final Approach Fix (FAF). The FSD is greater in the initial and intermediate segments than in the final approach segment (FAS).
- Performance of barometric vertical navigation (Baro VNAV) may not be as accurate as ILS glide slope, but does not matter as separation is achieved based on lateral performance.
- There should be no need to model implementation of VNAV for the intermediate segment; however, AFS-410/420/430 and AIR-130 need to consider procedure coding, approach selection, and crew procedures for use of these procedures.
- This analysis may require amending United States Standard for Terminal Instrument Procedures (TERPS) as necessary to support inclusion of RNAV/VNAV approaches.

Order of Priority for Flight Standards analysis:

- ➢ First priority of analysis is to provide a policy to comply with current standards regarding the addition of RNAV(GPS) approaches to Parallel Dependent and Simultaneous Independent ILS/MLS Approaches - with runway spacing of 4,300 feet or greater for dual parallel approaches and 5,000 feet or greater for triple parallel approaches, as discussed in Federal Aviation Administration (FAA) Order 7110.65, Air Traffic Control, paragraphs 5-9-6 and 5-9-7.
- ➢ Second priority of analysis is to provide analysis to support development of a policy to comply with current standards regarding the addition of RNAV/GPS approaches to Parallel Dependent ILS/MLS Approaches with runway spacing greater than 2,500 feet and less than 4,300 feet, as discussed in FAA Order 7110.65, paragraph 5-9-6.
- ➢ Third priority of analysis is to provide analysis to support policy to comply with current standards regarding the addition of panel mounted GPS equipment as previously discussed.
- ➢ Fourth priority of analysis is to provide analysis to support development of a policy to comply with current standards regarding the addition of RNAV/GPS approaches to Simultaneous Independent Dual ILS/MLS Approaches - High Update Radars (i.e., PRM) at the runway spacing discussed in FAA Order 7110.65, paragraph 5-9-8a.
- ➢ Fifth priority of analysis is to provide analysis to support development of a policy to comply with current standards regarding the use of RNAV/GPS approaches during Simultaneous Offset Instrument Approach (SOIA) operations addressed in FAA Order 8260.49A, Simultaneous Offset Instrument Approach (SOIA).
- ➢ Sixth priority of analysis will be to provide analysis to support development of acceptable mitigations to support waiver requests to the FAA Order 7110.65 standards.

- Flight Standards analysis used to establish standards and policy may serve as input to future requirements under the FAA Safety Management System Manual.

- Any Air Traffic Organization (ATO) Document Change Proposal (DCP) with regard to this subject will be held in abeyance pending the outcome of these associated analyses.
- All issues and/or requests from the PARC, agency or any other industry group with regard to this subject or RNP/RNAV shall be vetted thru AJR-37.
- In the event of implementation of the requested policy resulting from this analysis, data will be collected for a period of one year to determine the actual tracking performance on the RNAV (GPS) equipped aircraft. This data will be used to validate any operational impacts.

Article III. Amendment: Any change in the provisions of this agreement must be formalized by an appropriate written amendment. This amendment must outline in detail the exact nature of the change.

Article IV. Effective Date: This agreement is effective upon signature of all parties.

Article V. Revocation: Any party may revoke this agreement in writing at any time.

APPROVED:

Bruce DeCleene
Navigation Lead, Avionics Certification System Branch, AIR-130

7/12/06
Date

Jeffrey T. Williams
Manager, RNAV/RNP Group, AJR-37

7/12/06
Date

John W. McGraw
Manager, Flight Technologies and Procedures Division, AFS-400

7/12/06
Date

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