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Separation Requirements for Simultaneous Offset Independent Dual Instrument Approaches - High Update Rate Surveillance Not Required

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12. Abstract

The Federal Aviation Administration (FAA) Flight Standards closely spaced parallel operations team evaluated the risk of collision during simultaneous offset independent dual instrument approach operations using an approach with an offset of 2.5° to 3.0° to one runway without high update rate surveillance. The FAA Safety Management System acceptable level of risk of 1×10^{-9} per operation was used as the success criterion. The results indicate that the risk of a collision is below 1×10^{-9} per operation for operations to parallel runways separated by 3,000 feet or greater.

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Blunder Data Collection Effort (DCE) Deviation GBAS Landing System (GLS) Ground-Based Augmentation System (GBAS) High Update Rate (HUR) Human Factors (HF) Human in the Loop (HITL) Instrument Landing System (ILS) Localizer No Transgression Zone (NTZ) Normal Operating Zone (NOZ) Precision Runway Monitor (PRM) Probability Density Function (pdf) Simultaneous Independent Parallel Instrument Approach (SIPIA) Simultaneous Offset Instrument Approach (SOIA) Satellite-Based Augmentation System (SBAS) Test Criterion Violation (TCV) Traffic Alert and Collision Avoidance System (TCAS)	Uncontrolled
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EXECUTIVE SUMMARY

This report addresses the collision risk for simultaneous offset independent dual instrument approach operations using an Airport Surveillance Radar-9 (ASR-9) in lieu of the Precision Runway Monitor (PRM) system high update rate (HUR) surveillance required by the Federal Aviation Administration (FAA) JO 7110.65V.

The runway configuration studied included a runway centerline spacing of 3,000 feet with no stagger between thresholds, a Standard Terminal Automation Replacement System (STARS) Final Monitor Aid (FMA) and a 2,000 feet wide no-transgression zone (NTZ). The FMA presents the predicted position of each aircraft target with a 10 second predictor target line. A yellow caution alert is triggered both visually and aurally if an aircraft is predicted to be within 10 seconds of entering the NTZ. If the aircraft enters the NTZ, a red warning alert is triggered visually and aurally. An aircraft fleet mix representative of the traffic at major airports such as Dallas Fort Worth International, San Francisco International, John F. Kennedy International (JFK), etc., was used with a 20% heavy mix (i.e. 300,000 pounds or more).

Instrument Landing System (ILS), Satellite-Based Augmentation System, Ground-Based Augmentation System Landing System, Area Navigation (RNAV) Global Positioning System [RNAV(GPS)] and RNAV Required Navigation Performance [RNAV(RNP)] approach types were applicable for use in this operation. The offset approach path must be offset 2.5° to 3.0° away from the straight-in approach path. Any combination of the approach types may be used on either approach. The offset provides an increase in separation as the distance from the runway threshold increases.

The analysis indicated that the risk of collision during simultaneous offset independent dual instrument approach operations using an approach with an offset of 2.5° to 3.0° to runways separated by 3,000 feet or greater meet the FAA Safety Management System (SMS) acceptable level of risk of 1×10^{-9} per operation without HUR surveillance.

A unique offset approach called a Simultaneous Offset Instrument Approach (SOIA), being conducted at San Francisco International Airport runways 28L and 28R which are spaced 750 feet apart, requires HUR surveillance. The 3° offset course to 28R is displaced to the right of the runway centerline by 1,130 feet at the landing threshold. The SOIA transitions to visual separation prior to the point on the offset approach course where the lateral separation from the straight-in course to runway 28L is 3,000 feet. Inside this point, pilots navigate under visual conditions to maintain separation from the straight-in traffic and align with runway 28R to land.

Therefore, the results of this study may be used to alleviate the HUR surveillance requirement for SOIA operations. This study focused on the risk of collision only. No other safety risks were evaluated.

1.0 INTRODUCTION

The FAA is evaluating standards and methods for conducting Closely Spaced Parallel Operations, with the goals of increasing capacity during instrument meteorological condition operations, reducing delays and maintaining safety. The risk of collision due to a blunder, where one aircraft unexpectedly turns toward the other aircraft on the final approach course to a parallel runway is the prime concern.

The FAA Air Traffic Organization requested a collision risk evaluation for eliminating the 1.0 second surveillance update rate requirement for the offset operation.

1.1 Purpose

The purpose of this study was to determine if simultaneous offset independent dual instrument approach operations using a 2.5° to 3.0° offset to runways separated by 3,000 feet or greater without HUR surveillance meet the FAA SMS acceptable level of risk requirements.

1.2 Background

This report builds upon the results and recommendations contained in two reports. The first report, DOT-FAA-AFS-450-69 *Simultaneous Independent Close Parallel Approaches - High Update Radar Not Required*, proposed a reduction in the runway centerline spacing from 4,300 feet to 3,600 feet for simultaneous independent parallel instrument approach (SIPIA) operations to dual parallel runways without HUR surveillance. [1]

The second report, DOT-FAA-AFS-400-80, *Dual Simultaneous Independent Parallel Instrument Approach (SIPIA) Closely Spaced Parallel Operations (CSPO) Site Specific Evaluation for Chicago O'Hare*, evaluated the future runway 28C and 28L configuration at Chicago O'Hare International Airport (ORD). [2] These runways have a centerline spacing of 3,100 feet and a 2,306 feet stagger between thresholds. That evaluation was conducted in two phases. Phase one utilized a surveillance update rate of 1.0 second, an NTZ width of 1,600 feet between the runway pair, and straight-in ILS approaches to both runways. Phase two utilized a surveillance update rate of 4.8 seconds, an NTZ width of 2,000 feet spaced equidistant between the runway approach courses, a straight-in ILS approach to runway 28C, and a 2.5° offset ILS approach to runway 28L.

FAA Order JO 7110.65V, *Air Traffic Control*, paragraph 5-9-8, *Simultaneous Independent Close Parallel Approaches – High Update Radar*, states that controllers may authorize simultaneous independent close parallel approaches to dual runways when centerlines are separated by 3,400 to 4,300 feet. [3] This operation requires a PRM system and HUR surveillance with an update rate of 2.4 seconds or less. Dual runways may be utilized when centerlines are separated by at least 3,000 feet with one final approach course offset by 2.5° using a PRM system with a 1.0 second radar update rate.

The order also requires instrument approach procedures which authorize the simultaneous independent operation. The controllers must provide a minimum separation of 1,000 feet

vertical or a minimum separation of 3 nautical miles (NM) between aircraft during turn-on to parallel final approach paths. They must also provide the minimum applicable radar separation between aircraft on the same final approach course. An NTZ at least 2,000 feet wide is required to be established at an equal distance between extended runway final approach courses and depicted on the monitor display. Separate monitor controllers, each with transmit, receive, and override capability on the local control frequency, are required and must issue breakout instructions if an aircraft penetrates the depicted NTZ.

FAA Order 8260.49A, *Simultaneous Offset Instrument Approach (SOIA)*, provides criteria and guidance for constructing and operating simultaneous offset instrument approaches to parallel runways spaced at least 750 feet apart, and less than 3,000 feet apart. [4] A SOIA operation is a dependent, non-precision approach to dual, parallel runways with one final approach course offset by 2.5° to 3° from the runway centerline, and away from the other course. It is dependent because the aircraft on the offset approach must be the trail aircraft. Prior to this point, the aircraft may operate independently, and it is the air traffic controller's responsibility to sequence the offset aircraft in the trail position prior to transitioning to visual separation.

An analysis was previously completed on the use of RNAV(GPS) and RNAV(RNP) approaches during simultaneous offset independent dual instrument approach operations. [5] That report concludes "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 Test Criterion Violation (TCV) rate and passed the test criteria."

1.3 Runway Configuration and System Description

The use of an offset approach to one of the runways in dual simultaneous independent instrument approach operations provides for greater aircraft lateral separation at increasing distance from the threshold, see Figure 1-1. As required by FAA Order 8260.3b, United States Standard for Terminal Instrument Procedures (TERPS), for a precision approach, the final approach segment course is normally aligned with the runway centerline extended (±0.03°) through the runway threshold (± 5 feet). [6] Where a unique operational requirement indicates a need to offset the course from runway centerline, the offset must not exceed 3°. The offset course must intersect the runway centerline at a point 1,100 to 1,200 feet inside the DA point. For offset courses, the minimum height above the threshold at the DA is 250 feet. For a representation of the offset geometry for a precision approach, see Figure 1-1.

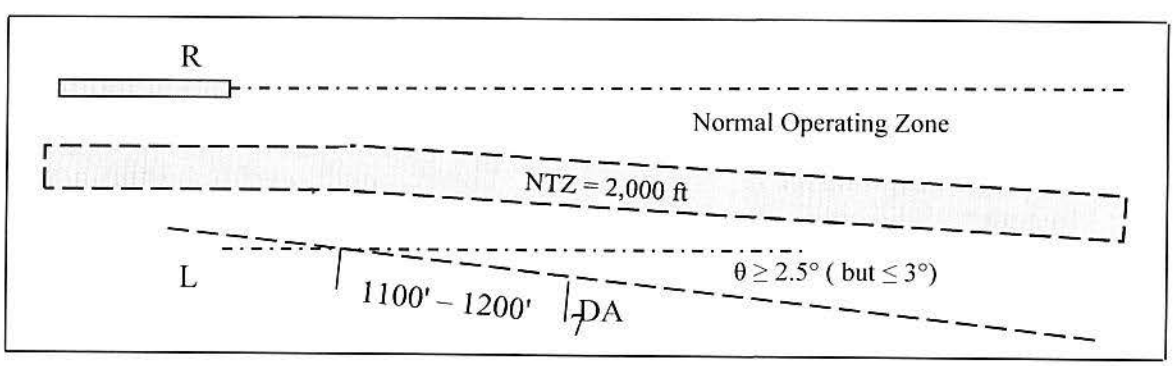

Figure 1-1. Offset Approach Path Separation Diagram

The dual parallel runways evaluated in this simultaneous offset independent dual instrument approach evaluation had a centerline spacing of 3,000 feet and no stagger between runway thresholds. The NTZ was 2,000 feet wide, resulting in a normal operating zone (NOZ) of 500 feet at the runway thresholds. The NOZ allows for the normal deviations of the aircraft about the final approach course as well as for anomalies of the navigation signal in space. With an offset approach, the width of the NOZ increases with distance from the threshold.

During a SOIA operation, the offset course is not required to intersect the runway centerline prior to the threshold. Additionally, the SOIA operation requires an "S-turn" to align with the runway for landing. For example, the localizer for the LDA PRM RWY 28R approach course at San Francisco International Airport is located 3,892 feet inside the threshold and 975 feet perpendicular to the right of the runway centerline. The course splays at an angle of 3° to the 28R and 28L runway centerlines. Every SOIA has a visual point, and the aircraft on the offset approach must report the leading aircraft in sight to continue to maneuver for a landing. If the traffic is not in sight the pilot must execute a missed approach. This visual point is located before the point where the final approach courses are separated by a minimum of 3,000 feet. At San Francisco International Airport, 3,000 feet separation occurs at 3.4 NM prior to the 28R threshold. Since SOIA operations are identical to simultaneous offset independent dual instrument approach operations throughout the non-visual phase of the approach, i.e., prior to the visual point, the findings of this study regarding HUR surveillance may be applied to SOIA operations (see also paragraph 5-9-10 of Reference 3). Additional SOIA issues are addressed in Section 3.0 of this report.

1.4 Scope

This study addresses the collision risk associated with removing the requirement for the use of HUR surveillance systems for simultaneous offset independent dual instrument approach operations using a 2.5° to 3.0° offset. Since the operation studied in this report utilized runways separated by 3,000 feet or greater, wake vortex encounters and their associated risks were not evaluated. No other safety risks were evaluated. However, operational considerations due to Traffic Alert and Collision Avoidance System (TCAS), nuisance breakouts (NBO), and controller workload were considered.

2.0 STUDY METHODOLOGY

This study utilized the runway geometry described in Section 1.3, an ASR-9 with a 4.8 second update rate, a STARS automation system FMA with color digital display, visual and aural alerts, and a 4-to-1 (4:1) aspect ratio (AR). This AR is specified by FAA Order JO 6191.3a. [7] The FMA displays each runway, the approach course to each runway, and an outline of the NTZ between them. It also displays each aircraft target, the aircraft type and call sign, and a 10 second predictor target line which depicts the target position 10 seconds into the future. When the predictor target line indicates an aircraft is within 10 seconds of entering the NTZ, the outline of the NTZ turns yellow, a yellow "NTZ" flashes directly above the aircraft call sign, the call sign of the aircraft and "caution" is announced. If the aircraft enters the NTZ, the outline of the NTZ turns red, the flashing "NTZ" turns red, the call sign of the aircraft and "warning" is announced. With the exception of HUR surveillance, the requirements for simultaneous offset independent dual instrument approach procedures meet those of FAA Order JO 7110.65V, *Air Traffic Control*, paragraph 5-9-8; Simultaneous Independent Close Parallel Approaches – High Update Radar. [3]

2.1 Fast Time Simulation

The primary analysis tool for this study was the Flight Systems Laboratory Branch Airspace Simulation and Analysis Tool – New Generation ($ASAT^{ng}$). $ASAT^{ng}$ is a multifaceted fast-time simulation tool for aviation related safety assessments which uses high fidelity models of all components of an aviation scenario to evaluate the overall risk of an operation. A wide range of parameters were used to realistically model these complex operational scenarios. These parameters include:

- Aircraft fleet mix;
- Pilot response times;
- Controller response times;
- Aircraft performance;
- Atmospheric conditions;
- Navigation system performance; and
- Air Traffic Control (ATC) monitoring and surveillance equipment.

2.1.1 Assumptions

Assumptions used in this study included the following:

- Aircraft were established on the final approach course pursuant to all other criteria contained in FAA Order JO 7110.65V; [3]
- Aircraft followed approach control directed speeds up to the point of configuring for the final approach;
- Aircraft did not slow until within 2 NM prior to the Final Approach Fix;
- The surveillance source provided adequate coverage and was independent from the navigation system;
- Vertical guidance was utilized;
- The aircraft was flown using a flight director or autopilot;
- Breakout obstacle assessments were completed in the design of the instrument approach procedure;
- Controllers were qualified and certified for final monitor duties;
- Pilots were qualified to fly simultaneous close parallel approaches;
- Pilots reviewed and complied the requirements contained within the Attention All Users Page published with the approach procedure;
- Blunders were initiated uniformly along the final approach course; and
- Aircraft fleet mix included a 20% heavy aircraft which is representative of the traffic at major airports such as Dallas Fort Worth International, San Francisco International, JFK International, etc.

The fleet mix used in this study and the study in Reference 1 was developed to be a representation of the traffic observed in the National Airspace System (NAS). It was developed using data obtained from the Extended Traffic Management System count of aircraft at all major airports in the NAS that operate simultaneous instrument approaches. The Extended Traffic Management System count data suggests that on average, the percentage of heavy aircraft in the NAS is approximately 5%. During peak intervals, this percentage can increase to a higher level, but it has never been greater than 20%. Not all aircraft types are used in this study. This particular fleet mix reflects a conservative representation of NAS traffic as it includes a higher percentage of heavy aircraft. The mix was comprised of 20% heavy aircraft (10% Boeing 747-400 and 10% Airbus A330-200), 40% Boeing B737-800 and 40% Embraer Regional Jet ERJ-145, where the Boeing 747-400 and Airbus A330-200 have the slowest dynamic response to a breakout command.

3.0 COLLISION RISK EVALUATION

A collision between aircraft is the catastrophic event used to determine the acceptable level of risk specified in the FAA SMS. The TCV shape used in this study was a cylinder, with a radius of 265 feet and a height of 160 feet (±80) centered on the endangered aircraft's center of gravity. [9] If the blundering aircraft center of gravity penetrated this TCV cylinder, a TCV, i.e., a collision, was assumed to have occurred. Several human in the loop (HITL) data collection effort (DCE)s conducted since July, 2009, have been used to refine the controller response time, pilot response time, and aircraft dynamics used in the ASAT^{ng} fast-time simulations to study various runway spacings and proposed operations within the NAS. [1]

A test environment can sometimes lead to erroneous sample results. For example, in the HITL simulations used to collect pilot and controller response times, blunders are simulated at an unrealistic rate. Since each pilot or controller participates in numerous blunder scenarios, there is the possibility that response times are shortened due to the learning effect. The investigator can gain insight into the significance of the learning effect by a process called sensitivity analysis. In this case, the mean of the controller or the pilot response time can be shifted or increased by known increments to determine the effect of longer response times than those observed during the HITL simulation.

The mean of a distribution used in a fast time simulation can be easily increased during a simulation by adding the desired amount of the shift to each random value generated by the probability density function (pdf). In study DOT-FAA-AFS-450-69, *Simultaneous Independent Close Parallel Approaches – High Update Radar Not Required*, a sensitivity analysis was performed on the total collision risk to determine compensation requirements resulting from the learning effect. The sensitivity analysis recommended a two second shift in the mean of the controller response time (CRT) pdf to compensate for the learning effect. [1] Therefore, the mean of the CRT pdf was shifted to the right by two seconds in this study.

An initial collision risk assessment of simultaneous offset independent dual instrument approach without HUR surveillance was completed using the CRT pdf obtained from a data set collected in November 2011 at ORD Terminal Radar Approach Control. This data set was collected using parallel approaches to runways separated by 3,100 feet and an NTZ that was 2,000 feet wide. Using ASAT^{ng} and an offset approach course of 2.5°, NTZ widths of 1,600 feet and 2,000 feet and runway separations of 3,100 feet and 3,000 feet were simulated. For tabulated results, see Table 3-1.

Table 3-1. Initial Collision Risk Assessment Results

2.5° Offset	Lateral Runway Separation (feet)	
NTZ Width (feet)	3,000	3,100
1,600	5.92E-10	5.58E-10
2,000	5.06E-10	4.57E-10

Additional CRT and human performance data were collected during a May 2012 DCE to analyze potential simultaneous offset independent dual instrument approach operations at ORD and a SIPIA operation at JFK. At ORD, a straight-in ILS approach to runway 28C and a 2.5° offset ILS approach to 28L was simulated. The runway spacing was 3,100 feet and runway 28L threshold was 2,306 feet beyond (West) of 28C. An NTZ width of 2,000 feet was spaced equidistant between the runway pair and their approach courses and a surveillance update rate of 4.8 seconds was used. At JFK, straight-in ILS approaches to Runways 22L and 22R were simulated. The airport layout was modified for this DCE such that the runway spacing was 3,000 feet, the thresholds had no stagger, the NTZ was 1,600 feet wide, and a surveillance update rate of 1.0 second was used.

Utilizing the CRT data from these two DCEs, a refined CRT pdf was developed and used in additional fast-time simulations to evaluate the collision risk at 3,000 feet runway separation and an NTZ width of 2,000 feet. For results, see Table 3-2. The fast-time simulation scenarios included both 2.5° and 3.0° offset. The increased spacing provided by the 3.0° offset reduces the risk of collision over the 2.5° offset.

No offset analysis was specifically performed in this evaluation for the actual runway 22L and 22R configuration at JFK. These runways are separated by approximately 3,000 feet. For results of the 3,000 feet runway separation with no threshold stagger, see Table 3-2. For offset approaches to the actual runways at JFK, there is additional altitude separation between glideslopes, due to a displaced threshold of 2,696 feet on 22R. Thus, a simultaneous offset independent dual instrument approach operation using the current 3.0° offset approach to 22R and the straight-in approach to 22L at JFK will have a collision risk less than shown in Table 3-2 without HUR surveillance.

Table 3-2. Final Collision Risk Evaluations

Lateral Runway Separation (feet)	NTZ Width (feet)	Offset Angle (degree)	
		2.5	3.0
3,000	2,000	4.05E-10	3.17E-10

Given the analysis in this report and in References 1 and 5, RNAV(GPS) and RNAV(RNP) equipped aircraft, using the flight director or autopilot can be mixed with ILS traffic in any configuration approved for ILS equipped aircraft. Ground-Based Augmentation System Landing System and Satellite Based Augmentation System approaches with vertical guidance, have been deemed equivalent to or better than ILS for lateral conformance.

As explained in Section 1.2, SOIA dependent approach operations are identical to simultaneous offset independent dual instrument approach operations prior to the SOIA DA and are, therefore, covered by the study. Before the aircrew on the offset approach of a SOIA begins to align with the extended centerline of the runway of intended landing, they must have visual contact with the adjacent aircraft, which should be ahead of them

on the approach. The final approach course of the SOIA operation at the DA is separated laterally from the straight-in approach course by 3,000 feet or greater. 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. [4, 5]

4.0 OPERATIONAL IMPACTS DUE TO NUISANCE BREAKOUTS

Any reduction in NAS capacity reduces the benefit and viability of the new operation. Controller directed breakouts due to NTZ incursions and pilot initiated vertical maneuvers in response to TCAS resolution advisories are examples of situations that can reduce capacity.

4.1 NTZ Incursions

An NBO is defined as a controller-anticipated aircraft incursion into the NTZ that was not caused by a blunder. Calculations using the ASAT^{ng} NTZ Incursion Analysis Tool show the NTZ incursions for dual approach operations. For the results from the tool for a Category I ILS with a 2.5° or 3.0° offset, using the *hand flown* International Civil Aviation Organization collision risk model, see Table 4-1. A similar study was performed for the implementation of PRM approaches with an offset. [10] That report demonstrated an NTZ incursion rate of 1.3% of approaches flown was acceptable. The offset approach operation analyzed in this study will have a comparable-to-lower rate of NTZ incursions than was seen during the evaluation of PRM proposed at Raleigh-Durham International Airport, see Table 4-1. NBOs should not increase for RNAV(GPS) and RNAV(RNP) approaches when flown using the autopilot or flight director. [5]

Table 4-1. Estimated NTZ Incursion Rates

Lateral Runway Separation (feet)	NTZ Width (feet)	Offset Angle (degree)	
		2.5	3.0
3,000	2,000	1.5%	0.7%

4.2 TCAS

Previously, a PRM system was installed and used at JFK for runways 22L and 22R with a 3.0° offset approach to runway 22R. Analysis of TCAS behavior in the closely spaced approach environment concluded that the rate of approaches terminated due to TCAS resolution advisories was not excessive for offset approaches at 3,000 feet runway spacing. [8]

5.0 DATA ANALYSIS

CRT was measured from the FMA display caution alert to the time the controller pressed the push-to-talk switch. It is unlikely that controllers will press the push-to-talk switch prior to a caution alert during actual operations. Therefore, negative values of CRT were deleted.

The offset of the ILS localizer increases the approach path separation with increasing distance from the runway threshold. Regression analysis was used to test whether there was any linear correlation between distance from threshold and the CRT data. The regression indicated that there was no correlation.

For the data analysis used for this report, see Appendix A. The analysis used in the ORD site-specific evaluation includes additional details and findings. [2]

6.0 HUMAN FACTORS ANALYSIS

In May, 2012, a HITL DCE was conducted with the primary purpose of measuring CRT during a blunder scenario when parallel runways are closely spaced, in this case, 3,100 feet. During this DCE, several scenarios, including an offset scenario, were evaluated. [2] Human factors analysis was conducted on each scenario. This report addresses the offset scenario analysis.

Objective controller performance measures were collected by using subject matter expert observers during each scenario. Objective performance measures were recorded using an empirical method of observing controller activities as they managed traffic and reacted to course deviations during their session. The objective performance measures included data obtained through direct observation of controller(s) performance. Observers were unobtrusively located behind the subject controllers in order to observe and record behaviors and anomalies that were specific to this operation.

Subjective performance measures were recorded through the use of questionnaires that asked subjects to individually rate their perceived level of workload, timeliness, comfort, and difficulty experienced during their session. A thorough examination of the observer notes, surveys, questionnaires, and de-brief notes from the offset scenario indicate that the controllers felt more comfortable with an offset approach as compared to parallel approaches at the same runway separation. In addition, the controllers indicated that their workload was reduced, see Figure 6-1.

For comparison, Figure 6-1 includes responses for the dual SIPIA operation at 3,600 feet taken from DOT-FAA-AFS-450-69 *Simultaneous Independent Close Parallel Approaches - High Update Radar Not Required.* [1] This operation was recently approved via FAA Notice N JO 7110.625, *Simultaneous Independent Close Parallel Approaches – High Update Radar Not Required*, June 2013. [11] The questionnaires used for all the referenced DCEs have remained the same and were collected in the same manner. The subject controllers were drawn from facilities throughout the NAS. While they did not all participate in every DCE some of them did attend both DCEs. From Figure 2, the offset scenario responses indicate less workload. The figure indicates more comfort with blunders in the offset scenario, but less comfort issuing a breakout instruction.

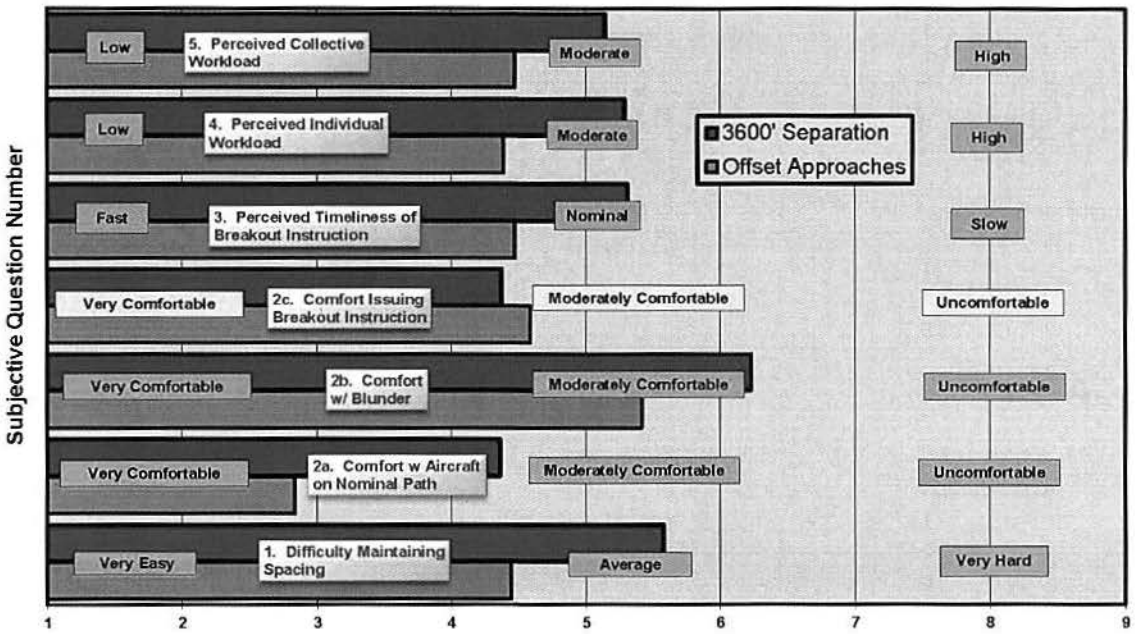

Figure 6-1. Mean Subjective Controller Responses

Several relevant issues surfaced during the course of this DCE. Among those were controller experience and exposure to blunders, controller phraseology in the breakout instruction, familiarity with the STARS FMA, and the 4:1 AR used on the STARS FMA display for this DCE.

Controller training, experience, and daily operations in their current positions do not provide a high level of exposure to blunders and the required corrective action. Controllers are highly trained, but they function optimally in those conditions for which they are habitually exposed. Those habit patterns may have influenced the use of phraseology and instruction sequences during this DCE. This may be the reason for the decrease in comfort with issuing a breakout instruction.

The controllers were briefed on the phraseology that is directed in FAA Order JO 7110.65V. [3] However, this phraseology was not used during the breakout instructions observed in the DCE. Several controllers used the proper sequence of phraseology, but omitted the required initial phrase, "traffic alert". This issue was also found in previous DCEs. [1] Controllers conveyed that the required phraseology contains extraneous information that detracted from the primary task of getting a pilot to modify the path of his aircraft quickly in order to avoid a collision. During post-simulation de-briefs, controllers stated that breakout phraseology must be effective enough to minimize total response time and should include the minimal basic information that is required, i.e., aircraft call-sign, heading, and altitude instructions. These elements comprise the FAA

Order JO 7110.65V phraseology, but are preceded by "traffic alert". [3] The sequence of those words may not be as critical as the essential elements of information to prevent a collision.

Only 7 of 36 subject controllers had experience using the FMA display. Of those seven, six were familiar with the 4:1 AR or at least had experience using it. The 4:1 AR expands the display four times perpendicular to the final course. This exaggerates any deviation of the aircraft from the final approach course. The lack of experience for the other 30 controllers may have impacted workload and comfort levels during this DCE.

Other observed factors that affected controller performance included:

- Visual and aural alerts;
- Controller teaming (familiarity and interaction);
- Learned behavior and strategy modification;
- Aircraft data block displayed information;
- Controller display tools;
- Assumptions about TCAS intervention; and
- Vigilance vs. fatigue.

For a complete discussion of these factors along with the human factors analysis, see Appendix B.

7.0 CONCLUSIONS

The FAA Air Traffic Organization requested a collision risk evaluation for eliminating the 1.0 second surveillance update rate requirement for the offset operation described in FAA Order JO 7110.65V, *Air Traffic Control*, paragraph 5-9-8, Simultaneous Independent Close Parallel Approaches – High Update Radar. [3] The purpose of this study was to determine if simultaneous offset independent dual instrument approach operations using a 2.5° to 3.0° offset to runways separated by 3,000 feet or greater without HUR surveillance meets the FAA SMS acceptable level of risk requirements. For operations conducted with the assumptions listed in Section 2.1.1, the analysis indicates that the risk of a collision is below 1×10^{-9} per operation for dual simultaneous independent instrument approaches without HUR surveillance using:

- Parallel runways separated by 3,000 feet or greater;
- An offset of 2.5° to 3.0°;
- An NTZ width of 2,000 feet;
- A surveillance update rate of 4.8 seconds or less;
- An FMA with a color digital display, 4:1 AR with visual and aural alerts;
- Any combination of RNAV(GPS), RNAV(RNP), ILS, Ground-Based Augmentation System Landing System or Satellite Based Augmentation System Approaches with vertical guidance; and
- Flight director or autopilot;

All other requirements of FAA Order JO 7110.65V continue to apply. [3] TCAS RAs were not excessive, and NTZ incursion rates were acceptable.

SOIA lateral separation is identical to simultaneous offset independent dual instrument approach lateral separation analyzed in this study prior to the transition to visual separation. Therefore, a surveillance update rate of 4.8 seconds or less (such as an ASR-9) can be substituted for the current requirement to use HUR surveillance with a 1.0 second update rate.

During breakout events, none of the subject final monitor controllers used the required FAA Order JO 7110.65V phraseology. [3] Several controllers used the proper sequence of phraseology, but omitted the phrase, "traffic alert". During the post-simulation de-briefing, the subject controllers stated that the essential breakout phraseology should include the aircraft call-sign followed by the breakout maneuver instruction.

This study focused on the risk of collision. No other safety risks were evaluated.

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APPENDIX A. RISK ANALYSIS

A.1 Probability of a Collision

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 as shown in Figure A-1. The blundering aircraft must be aligned so that a TCV will occur without timely action from both the ATC and the pilot of the evading aircraft. An aligned blunder is called an at-risk blunder (ARB) and is denoted in the equation. If all of the above events develop in a manner supporting a collision, a TCV occurs if the controllers and pilots fail to react in sufficient time to separate the blundering and the evading aircraft.

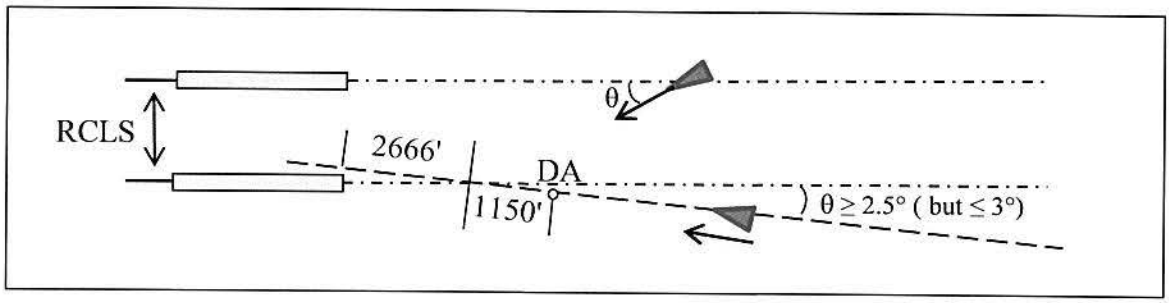

Figure A-1. Blunder Depiction

In addition, the blundering aircraft does not respond to ATC directions to return to the localizer azimuth course. This is called a non-responding blunder (NRB). The value used for NRB (1/100) has been used in numerous prior studies. [12, 13] This number is further validated by the results of an extensive blunder data collection effort performed by MITRE. [14] MITRE investigated over 1.8 million simultaneous approaches at 12 United States airports and observed 82 deviations of aircraft from their final approach courses that entered the NTZ, whether or not there was an aircraft on the parallel approach. These were determined to be blunders. Of these 82 blunders, all deviating aircraft corrected back to course. The majority of these corrections are assumed to have been initiated by air traffic controllers, highlighting the importance of air traffic controllers monitoring the approach. This data is consistent with an NRB rate of 1/100 NRB as follows.

If the random variable X represents the number of successes in n trials of a binomial experiment in which the probability of a single independent success is p, the probability that $X = x$ is given by the binomial distribution equation:

$$P(X = x) = \binom{n}{x} p^x (1-p)^{n-x} \qquad \text{(A-1)}$$

If there are 82 trials (i.e., $n = 82$) and no successes (i.e., $x = 0$) then:

$$P(X = 0) = \binom{82}{0} p^0 (1-p)^{82} = (1-p)^{82} \qquad \text{(A-2)}$$

Therefore, a distribution for the unknown parameter, p, the probability of a success given the empirical result of no successes in 82 trials can be based on Equation A-2.

Since p represents a probability, its values must range between 0 and 1 and a pdf for the distribution derived from Equation A-2 must integrate to the value 1 between those bounds. This is enough information to derive a unique pdf for p, given the empirical result. Equation A-3 is that pdf and Figure A-2 is its graph.

$$f(p) = 83(1-p)^{82} \qquad \text{(A-3)}$$

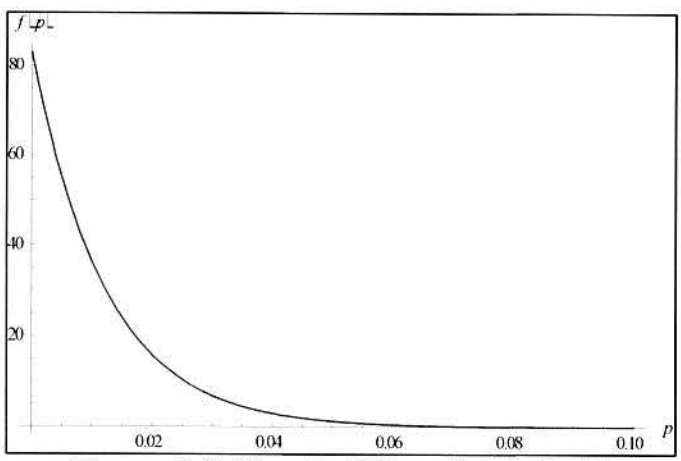

Figure A-2. Graph of Equation A-3 pdf

The pdf can be used to calculate likely values for p, see Equation A-3. For example, the median value for p, is the value p_m for which the integral from 0 to p_m is 0.5. This calculation shows that $p_m = 0.00832$. This value would then be the most realistic estimate, statistically, for p, given the empirical result. Thus, the value of 1/100 is a conservative estimate for the NRB factor in calculations below.

A collision involves two aircraft and results in two accidents, as defined by the National Transportation Safety Board. Assuming that a TCV will result in a collision, the probability of a collision can be expressed in mathematical terms by:

$$P(\text{Collision}) = P(\text{TCV}|\text{NRB} \cap \text{ARB} \cap \text{BL}) \times P(\text{NRB}|\text{ARB} \cap \text{BL}) \times P(\text{ARB}|\text{BL}) \times P(\text{BL}) \quad \text{(A-4)}$$

The symbol "∩" stands for "and". The symbol " | " stands for "given".

Factor 1 in the equation is expressed as:

$$P(\text{TCV}|\text{NRB} \cap \text{ARB} \cap \text{BL}) \quad \text{(A-5)}$$

Factor 1 determines the probability that a TCV occurs given that a non-responding, at-risk blunder has occurred. This is the TCV rate that is determined from the simulation.

Factor 2 in the equation is expressed as:

$$P(\text{NRB}|\text{ARB} \cap \text{BL}) \quad \text{(A-6)}$$

Factor 2 determines the probability that the blundering aircraft does not respond to air traffic controllers' instruction to return to course given that an at-risk blunder has occurred. The value of this factor is 1/100.

Factor 3 in the equation is expressed as:

$$P(\text{ARB}|\text{BL}) \quad \text{(A-7)}$$

Factor 3 is the probability that the blunder is an at-risk blunder given that a blunder has occurred. The value of this factor was estimated from simulation data using the TCV shape described in Section 3.0 of this report and was found to be 3.17×10^{-2}.

Factor 4 in the equation is expressed as:

$$P(\text{BL}) \quad \text{(A-8)}$$

Factor 4 is the probability of a blunder of a specified angle such as 20°. The probability and frequency of the occurrence of various blunder angles up to 35° has been determined from blunder data captured from actual simultaneous approaches conducted in less than visual conditions. [13]

APPENDIX B. HUMAN FACTORS ANALYSIS

B.1 Test Methodology

In May 2012, a HITL DCE was conducted with the primary purpose of measuring CRT during a blunder scenario when parallel runways are closely spaced, in this case, 3,100 feet. Subject controllers who were required to be full-performance-level controllers and qualified to control dual simultaneous independent ILS approaches, were used as final monitor controllers. They were required to monitor, correct minor course deviations, and breakout the aircraft for major course deviations. They had the capability to override the tower and local controller and had an additional frequency that pilots were required to monitor to ensure those commands were received.

B.2 General

Several relevant issues surfaced during the course of this DCE. Among those were controller phraseology in the breakout instruction, familiarity with the STARS with FMA, and the 4:1 AR used on the STARS FMA display for this DCE. Each will be discussed further.

Controllers were instructed to, "control as you do every day at your facility," i.e., perform as they would in normal operations. After lengthy discussions during the post-simulation de-briefing, it seems the concept of blunders and directing an evasive maneuver is not consistent with day-to-day controller experience with planning and positioning aircraft. This appeared to influence the use of phraseology during breakout events. Most of the phraseology used was consistent with typical day-to-day traffic management rather than the specific breakout phraseology required by Air Traffic Orders for closely spaced operations.

Controller training, experience, and daily operations in their current positions do not provide a high level of exposure to blunders and the required corrective action. Controllers are highly trained, but they function optimally in those conditions for which they are habitually exposed. Those habit patterns may have influenced the use of phraseology and instruction sequences during this DCE. This may be the reason for the decrease in comfort with issuing a breakout instruction.

Controllers received a short 5 - 10 minute presentation on the visual aspects of the STARS FMA display, what they could expect, and the functions of the system that were available for them to modify in accordance with their own desires. Vigilance requirements were appropriately higher as controllers had to modify their own culturally established levels of automaticity in detecting, strategizing, and reacting to a blunder.

B.3 CONTROLLER RESPONSE ANALYSIS

B.3.1 Subjective Controller Response Data

Subjective response data from each controller was elicited immediately following each final monitor session. Controller feedback was given for each of the seven questions, designed to get controller response in the areas of perceived workload, comfort, and difficulty, all as they compare to their controller duties during normal operations which is shown in Figure 6-1, in the main body of this report. As the graph indicates, with the exception of comfort with aircraft on the nominal path and comfort with a blunder, controller subjective feedback hovered close to the median value of five. Note that both of these indices represent testing conditions on both ends of the induced difficulty spectrum. Inherent with the closer proximities of aircraft is a decrease in comfort levels. In a later discussion, controllers pointed out that this is a result of having less time to react to abnormal situations (e.g. blunder). Additionally, this data was compared to the response data from a previously completed report that studied dual SIPIA at 3,600 feet runway separation. [1]

B.3.2 Phraseology

Throughout the evaluation, during breakout events, none of the final monitor controllers used the required FAA Order JO 7110.65V phraseology. [3] Several controllers used the proper sequence of phraseology, but omitted the phrase, "traffic alert". There is a common perspective among controllers concerning what information is essential to having an aircraft break off an approach. Despite the feedback from all subject controllers that the essential information should be the call-sign followed by a directive, actual transmissions do not validate this. For instance, several controllers used: "cancel approach clearance" before issuing control instructions. Others simply directed the aircraft on a heading correction. Also, despite having been briefed on the proper phraseology prior to the test, very few controllers actually used the phrase, "traffic alert". Those that did use the phrase used it in an improper sequence. While they were briefed of its inclusion in the FAA Order, in all de-briefings, controllers conveyed that it was superfluous information that detracted from the absolute primary task of getting a pilot to modify the path of their aircraft quickly in order to avoid a collision. Usually, the aircraft call sign was stated first in the sequence, but this is counter to the requirement(s) outlined in FAA Order JO 7110.65V. [3]

B.3.3 ASR-9 (4.8 second update rate), STARS FMA, 4:1 AR

With an ASR-9 update rate of 4.8 seconds, some of the surveyed-controllers felt they could recognize a blunder, but a timely and effective response might be problematic. Others were somewhat more optimistic, indicating that they were confident in keeping aircraft from colliding, but most probably could not maintain required separation, at least not with any degree of comfort.

Of the seven controllers with FMA display experience, six were familiar with the 4:1 AR. The 4:1 AR expands the display four times, perpendicular to the final course. The 4:1 AR provides a more definitive indication of any deviation from the final approach course. Controllers often issued traffic headings as if the 4:1 presentation was a ratio of 1:1. This exaggerated presentation in addition to the repeated blunder scenarios that were presented, may have primed the controllers to breakout parallel traffic at an earlier indication of a course deviation than what they normally would have. Regardless, most controllers felt that the 4:1 AR would be much better than the 1:1 for this operation. Consistent comments were that a 1:1 ratio would place the controllers in an untenable position with very little time to react to fix a problem.

The FMA yellow caution alert was set to 10 seconds prior to an NTZ penetration. The red warning alert occurred at the time of an NTZ penetration. Some of the controllers stated that they waited for the red warning alert indication before directing a breakout. There seemed to be a heavy reliance on the yellow and red alerts as critical cues for making breakout or course deviation decisions. Controllers that pointed this out stated, that since they could not clearly discern trends, they could not anticipate course deviation. Therefore, when using a 4.8 second update rate and a 4:1 AR, the degree and speed of blunder deviation provides little or no time to react. This caused the subject controllers to rely heavily on the yellow and red alerts (both visual and auditory).

Note: Some facilities do not broadcast alerts or warnings over an intercom to the entire facility; only to each individual screen. In this particular simulation, alerts and warnings were broadcast to the entire room. One controller did not attend to the speakers as he was accustomed to having alarms on his individual monitor.

B.3.4 CONTROLLER STRATEGY ELEMENTS

- Most controllers relied on the yellow and red alerts to react to blunders;
- Preference for and a heavy reliance on a consistent and accurate altitude readout in the data-block (versus the alternating altitude and heading information used in this DCE as this directly impacts controller strategy and reaction to blunders;
- An even mix of altitude changes and direction changes to separate aircraft, this is very controller-specific. However, when direct coordination is effected between controllers, it is almost exclusively done in the altitude dimension; and
- Few controllers were very situationally aware of the altitude differences between paired aircraft and made conscious decisions to separate blundering aircraft by altitude versus heading differential. The required phraseology is to deliver a heading change followed by an altitude assignment.

B.4 POST-SIMULATION DEBRIEFING DISCUSSION

- Most subject controllers were confident that they could detect a blunder, but were not comfortable in their ability to react in a timely manner. This was based upon either the update rate of the radar, the aspect ratio or a combination of both. Those same controllers felt they could keep the situation safe, but they would lose aircraft separation;
- All crews voiced that the current breakout phraseology requirement in Order JO 7110.65V is unrealistic. The essential elements of "call-sign", followed by a "direction and altitude change" are most important;
- There are definitely increased training implications should this system be implemented at this facility. Evaluators did not specifically query controllers concerning the type and amount of training that should be mandated;
- All controllers felt that the depiction of both speed and degree of blunder is unrealistic, i.e. 4:1 AR relative to what they're most accustomed to or expect with a 1:1 AR. When asked, controllers felt that their vigilance levels were higher, resulting in a higher level of workload, both individually and collectively. This is not consistent with the subjective scores in Figure 6-1; and
- Most controllers perceived that they did not have enough time to process the trend of an aircraft deviation from the centerline and intervene in time to prevent an NTZ incursion. More than half of the controllers stated that they relied heavily on the alerts (red or yellow visual and auditory) as prompts to issue breakout instructions.

B.5 HUMAN PERFORMANCE OBSERVATIONS AND POTENTIAL IMPLICATIONS

- Visual and auditory alerts: Redundant alert coding (i.e. more than one modality) may be a factor in controller reaction time, strategy and compliance. Some controllers felt that they paid more attention to and reacted better to visual representations of blunders; others felt that they reacted better to auditory stimuli; still others preferred both;
- Direct interaction between paired controllers is not necessarily a given. Some of the pairs relied heavily upon interaction, while others did not. It appeared that those controllers that engaged in frequent and effective interaction were very familiar with each other's techniques and procedures;
- As the simulation progressed, controllers' strategies became more efficient through learned behavior (i.e. controllers were more reluctant to let traffic deviate drastically from the required path and were more likely to intervene earlier). It is noted that this may have artificially affected the consistency of reaction times between the early versus later scenarios;
- Performance could be affected when mixing controller pairs from different facilities (i.e. different habit patterns, local requirements and cultural expectations). Anecdotally, controller pairs from the same facility tended to have greater interaction between each other;
- The use of controller display tools and alerts vary between facilities, and not all facilities have STARS with FMA displays. These differences between the controllers' "home" facility and the Flight Operations Simulation Branch ATC Lab could have affected performance during the DCE;
- Observers recorded, both during the simulation and during the de-briefing, controllers verbalizing that TCAS would always intervene and keep aircraft from colliding, most often well before controllers would have to take action. This might be a dangerous assumption;
- Aural and visual NTZ alerts provide a redundancy that enhances vigilance and reduces controller perceptual and cognitive requirements; and
- The situations presented in this DCE required that controller vigilance be at heightened levels to ensure rapid identification and processing of a blunder.