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Analysis of Missed Approach Radar Coverage at the Minneapolis-St. Paul International Airport

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12. Abstract

The parallel runways, 12L/30R and 12R/30L at Minneapolis-St. Paul International Airport (MSP) are separated by 3380 feet. In order to conduct simultaneous independent parallel approaches, FAA Order 8260.39A requires that a Precision Runway Monitor (PRM) radar system must be used for traffic monitoring and a No Transgression Zone (NTZ) must be established for the approach and missed approach. From the definition of the NTZ, PRM coverage is required throughout the extent of the NTZ. However, because of siting considerations at MSP, a wedge beginning at the radar site, extending toward runway 12L/30R, and subtending an angle of approximately 15 degrees is without radar coverage. The FAA/AFS-420 Airspace Simulation and Analysis for TERPS (ASAT) computer system was modified to conform to the MSP conditions and simulated simultaneous missed approaches were conducted the equivalent of 3,600,000 times. The results of the simulation were used to compute the risk of collision. The risk was found to be comparable to the risk of collision during the final approach and is considered to be acceptably low. Therefore, the radar blockage, as simulated, does not adversely affect the safety of dual parallel operations at MSP and Category I operations, with a 200 foot decision height, are acceptable at MSP.

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EXECUTIVE SUMMARY

The parallel runways, 12L/30R and 12R/30L at Minneapolis-St. Paul International Airport (MSP) are separated by 3,380 feet. According to FAA Order 8260.39A, Close Parallel ILS/MLS Approaches, simultaneous instrument approaches may be conducted at MSP if, among other requirements, a Precision Runway Monitor (PRM) radar system is used for traffic monitoring and a No Transgression Zone (NTZ) is established for the approach and missed approach. The NTZ is a 2,000-foot wide zone, located equidistant between parallel runway final approach courses in which flight is not allowed. The NTZ begins at the point where adjacent inbound aircraft first lose 1,000 feet of vertical separation, and extends to 0.5 NM beyond the farthest departure end of runway (DER), or the point where a combined 45 degree divergence of the missed approach courses occurs, whichever is farthest.

From the definition of the NTZ, it is clear that PRM coverage is required throughout the extent of the NTZ. However, a special flight inspection conducted by Flight Inspection Policy and Standards Branch revealed that because of certain siting considerations at MSP, a wedge beginning at the radar site and extending toward runway 12L/30R is without radar coverage. When flown at an altitude of 50 feet, the wedge subtended an angle of approximately 15 degrees. This resulted in a loss of coverage of approximately 600 feet along the runway centerline of runway 12L/30R. When flown at 100 feet, the wedge subtended an angle of approximately 3 degrees resulting in a loss of coverage of approximately 120 feet. It is the purpose of this paper to determine whether the loss of coverage during the missed approach will result in an increase of collision risk during simultaneous missed approaches from both runways and whether the risk of collision is acceptably low.

The Flight Procedure Standards Branch Airspace Simulation and Analysis for TERPS (ASAT) computer system was modified to conform to the MSP conditions, including runway spacing, localizer alignment and siting, decision height, and radar blockage wedge. The scenario that was simulated involved simultaneous dual missed approaches from the runway pair 12L and 12R, and the runway pair 30L and 30R. The simulation was performed the equivalent of 3,600,000 times and the number of times the minimum distance between the aircraft was less than 500 feet, called a Test Criterion Violation (TCV), was recorded. The probability of a TCV was found to be between 1.75×10^{-9} and 1.75×10^{-8} for the 600 foot radar blockage. Other radar blockages, ranging from 0 feet to 2,400 feet were also simulated and comparable TCV probabilities were found for each radar blockage. The range of the possible values of the probability of a TCV encompasses the final approach Target Level of Safety and is considered to be acceptably low. Therefore, the radar blockage, as simulated, does not adversely affect the safety of dual parallel operations at MSP and Category I operations, with a 200-foot decision height, are acceptable at MSP. However, radar blockage with different runway spacing and/or different siting or angular wedge would require additional simulation.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

TABLES

FIGURES

ANALYSIS OF MISSED APPROACH RADAR COVERAGE AT THE MINNEAPOLIS-ST. PAUL INTERNATIONAL AIRPORT

1.0 INTRODUCTION

The parallel runways, 12L/30R and 12R/30L at Minneapolis-St. Paul International Airport (MSP) are separated by 3,380 feet. According to FAA Order 8260.39A, Close Parallel ILS/MLS Approaches, simultaneous instrument approaches may be conducted to runways spaced 3,400 feet apart if the following conditions, among others, are satisfied:

a. A Precision Runway Monitor (PRM) radar system must be used for traffic monitoring.

b. A No Transgression Zone (NTZ) must be established for the approach and missed approach.

The NTZ is a 2,000-foot wide zone, located equidistant between parallel runway final approach courses in which flight is not allowed. The NTZ begins at the point where adjacent inbound aircraft first lose 1,000 feet of vertical separation, and extends to 0.5 NM beyond the farthest departure end of runway (DER), or the point where a combined 45 degree divergence of the missed approach courses occurs, whichever is farthest. The PRM must be used to monitor traffic whenever aircraft are adjacent to the NTZ, from a height of 50 feet above ground level to a minimum of 1,000 feet above the highest point within that segment, of the glideslope, the runway surface, or the missed approach course, whichever attains the highest altitude.

From the definition of the NTZ, it is clear that PRM coverage is required throughout the extent of the NTZ. However, a special flight inspection conducted by the Flight Inspection Policy and Standards Branch, revealed that because of certain siting considerations at MSP, a wedge beginning at the radar site and extending toward runway 12L/30R is without radar coverage. When flown at an altitude of 50 feet, the wedge subtended an angle of approximately 15 degrees. This resulted in a loss of coverage of approximately 600 feet along the runway centerline of runway 12L/30R. When flown at 100 feet, the wedge subtended an angle of approximately 3 degrees resulting in a loss of coverage of approximately 120 feet. It is the purpose of this paper to determine whether the loss of coverage during the missed approach will result in an increase of collision risk during simultaneous missed approaches from both runways and whether the risk of collision is acceptably low.

2.0 ANALYSIS PROCEDURE

The Flight Procedure Standards Branch Airspace Simulation and Analysis for TERPS (ASAT) computer system was modified to conform to the MSP conditions, including runway spacing, localizer alignment and siting, and decision height. The size of the radar blockage wedge was treated as a parameter. The scenario that was simulated involved simultaneous missed approaches from runways 12L and 12R and runways 30L and 30R. The sequence of events that constituted the scenario were as follows:

a. Aircraft types were selected according the anticipated traffic mix;

b. The aircraft were situated on the approaches to runways 22L and 22R;

c. Two aircraft were simultaneously flown along the final approaches of runways 12L and 12R or runways 30L and 30R;

d. Simultaneous missed approaches were initiated at DH;

e. Each aircraft climbs;

f. Each aircraft turns;

g. The separation distance between the two aircraft is monitored and the Closest Point of Approach (CPA) is logged; and

h. If the CPA distance is less than 500 feet then a Test Criterion Violation (TCV) is said to have occurred and logged as a TCV.

In order to simulate realistically the action of each aircraft, critical parameters along with their probability distributions were determined and were varied according to their probability distributions in each run of the simulation. Table 1 lists the critical parameters.

PARAMETER	UNITS	REMARKS
AC_TYPE	[-]	Aircraft category: B, C or D
IAS_APP	[Kts]	IAS at which the missed approach is initiated.
DH	[Ft]	The altitude at which the pilot initiated the missed approach
DELTA_HEAD	[Deg]	Track deviation from runway heading during missed approach climb
ROC_ACCEL	[FPM/Sec]	The rate of change of rate of climb.
ROC	[FPM]	The aircraft rate of climb.
IAS_ACCEL	[Kts/Sec]	Acceleration. The rate of change of air speed
IAS_CLIMB	[Kts]	The IAS at which the aircraft climbs
HTURN	[Ft]	The altitude at which the pilot initiates the turn outbound
BANK_RATE	[Deg/Sec]	The bank rate at which the aircraft banks to the angle BANK
BANK	[Deg]	The bank angle at which the aircraft executes the turn outbound.

Table 1: CRITICAL PARAMETERS VARIED FOR EACH RUN

Multiple sets of 50,000 runs were performed. Each set was run under a different size of radar coverage blockage. The blockage size ranged from 0 to 2,400 feet in increments of 300 feet bringing the total number of runs to 900,000: Only cases where the missed approach course deviation of the two aircraft were toward each other were run. Using this approach, the number of runs was effectively 4 times higher than the actual number of runs performed. Figure 1 depicts a typical run. In this run the radar blockage is a sector of 33.7 degrees that equates to a 1,200-foot radar blockage over runway 12L/30R.

3.0 SIMULATION RESULTS

The results of the Monte Carlo simulation runs are compiled in table 2. The first two columns of values refer to the percentage of TCVs when sets of 50,000 runs were performed on runways 12L and 12R and on runways 30L and 30R. The second two columns of values refer to the percentage of TCVs when the sets of 50,000 runs were converted to sets of 200,000 runs. The table indicates that the length of the radar blockage has no significant affect on the number of TCVs. The lack of sensitivity of risk to the radar blockage can be explained by the location of the blockage. Aircraft will initiate the turn at a nominal altitude of 400 feet AGL (Above Ground Level). Below 400 feet, the pilot will most likely not initiate any evasion maneuver. Since the aircraft performing a missed approach will be below 400 feet in the area of the radar blockage, the blockage has no appreciable effect on the risk of collision.

	% TCVs (50,000 runs)		**% of TCVs (200,000 runs)**	
Blockage [Ft]	**12L & 12R**	**30L & 30R**	**12L & 12R**	**30L & 30R**
0	0.0660	0.0820	0.0165	0.0205
300	0.0660	0.0850	0.0165	0.0213
600	0.0680	0.0800	0.0170	0.0200
900	0.0680	0.0820	0.0170	0.0205
1200	0.0680	0.0850	0.0170	0.0213
1500	0.0680	0.0680	0.0170	0.0170
1800	0.0640	0.0820	0.0160	0.0205
2100	0.0660	0.0800	0.0165	0.0200
2400	0.0680	0.0850	0.0170	0.0213

Table 2: ASAT RESULTS FOR 50,000 AND 200,000 RUNS

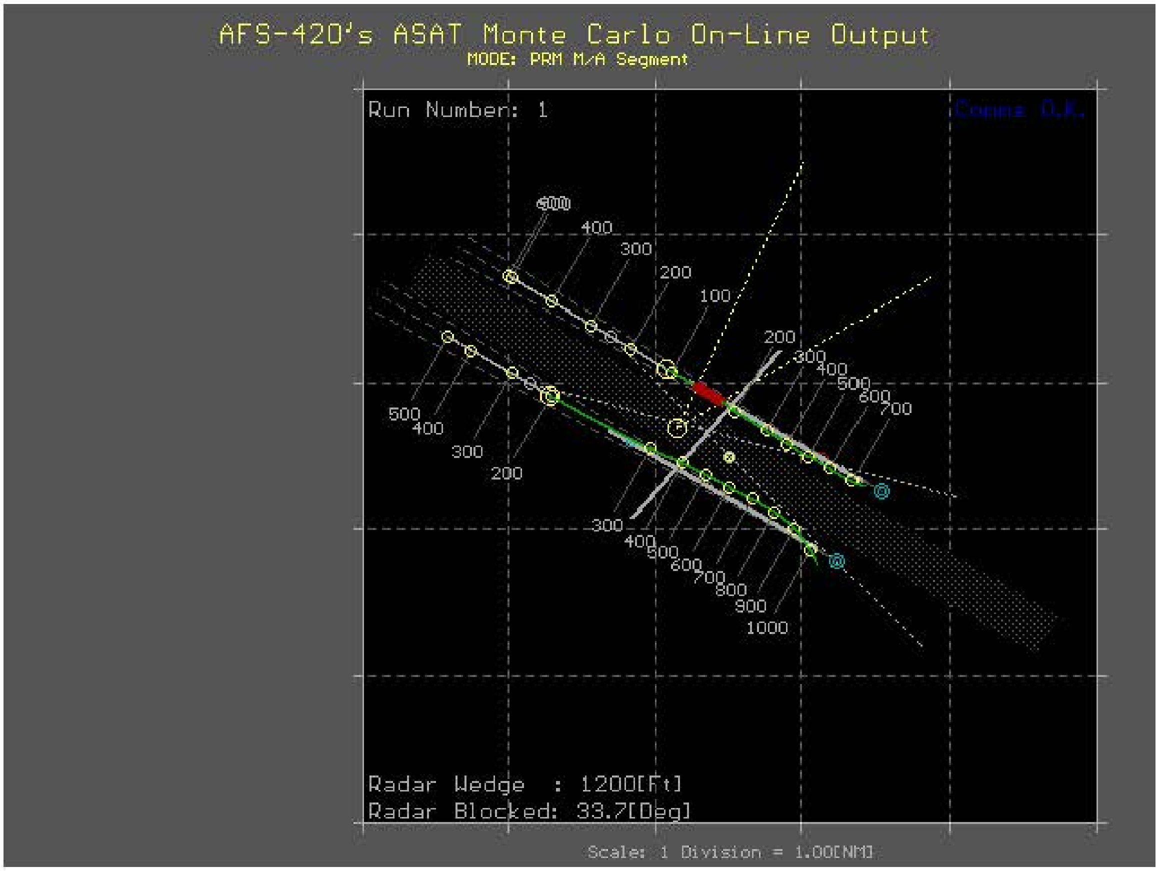

Figure 1: TYPICAL ASAT RUN

4.0 RISK ANALYSIS

In order to evaluate properly the simulation results presented in table 2, it is necessary to convert the percentage of TCVs that occurred with the radar blockage into the probability of a TCV. A TCV can only occur if the two aircraft perform missed approaches simultaneously and they are properly aligned at the beginning of the missed approaches so that a TCV will occur without controller intervention. Therefore the probability of a TCV can be represented by equation (1).

$$P(TCV) = P(TCV \text{ and Aligned and Miss1 and Miss2}) \qquad (1)$$

Using the principle of conditional probability, equation (1) becomes equation (2).

$$P(TCV) = P(TCV \mid \text{Aligned and Miss1 and Miss2}) \times P(\text{Aligned} \mid \text{Miss1 and Miss2}) \times P(\text{Miss2} \mid \text{Miss1}) \times P(\text{Miss1}) \qquad (2)$$

The vertical line in each term of equation (2) is read "given". Thus, P(Miss2|Miss1) is read " the probability of a missed approach on runway 2 given a missed approach occurred on runway 1".

In order to compute P(TCV), it is necessary to assign values to each term of the right-hand-side of equation 2. From table 2, the percentage of TCVs, with radar blockage of 600 feet along runway 12L/30R with the dual missed approaches on runways 12L and 12R, was found to be 0.0165. The 99 percent upper confidence limit of this number was found to be 0.02544 percent. During the simulations performed by the Multiple Parallel Approach Program, a conservative estimate of the probability of alignment was found to be 1/17. The probability of a missed approach given in the ICAO Collision Risk Model is 1/100. A value of the probability of a missed approach on runway 2 given a missed approach occurred on runway 1 has not been determined. If the occurrence of a missed approach on runway 2 is independent of the occurrence of a missed approach on runway 1, then P(Miss2|Miss1) would also be equal to 1/100. However, the occurrence of a missed approach on runway 2 is likely to be dependent on the occurrence of a missed approach on runway 1. Dependence is likely because whatever caused the missed approach on runway 1 may tend to cause a missed approach on runway 2. Thus, P(Miss2|Miss1) could be as high as 1/10.

Substituting these values into equation (2), and assuming that the occurrence of a missed approach on runway 2 is independent of the occurrence of a missed approach on runway 1, results in equation (3).

$$P(TCV) = 0.0002544 \times 1/17 \times 1/100 \times 1/100 = 1.5 \times 10^{-9} \qquad (3)$$

If it is assumed that the occurrence of a missed approach on runway 2 is dependent on the occurrence of a missed approach on runway 1, then the result is equation (4).

$$P(TCV) = 0.0002544 \times 1/17 \times 1/10 \times 1/100 = 1.5 \times 10^{-8} \qquad (4)$$

From equations (3) and (4), it follows that P(TCV), for a radar blockage of 600 feet on 12L/30R with the dual missed approaches on runways 12L and 12R, is between 1.5×10^{-9} and 1.5×10^{-8}. Table 3 presents the lower and upper ranges of risk for runways 12L and 12R and for runways 30L and 30R.

	TCV Risk 12L & 12R		**TCV Risk 30L & 30R**	
Blockage [Ft]	**Lower Limit**	**Upper Limit**	**Lower Limit**	**Upper Limit**
0	1.50×10^{-9}	1.50×10^{-8}	1.78×10^{-8}	1.78×10^{-8}
300	1.50×10^{-9}	1.50×10^{-8}	1.85×10^{-8}	1.85×10^{-8}
600	1.53×10^{-9}	1.53×10^{-8}	1.75×10^{-8}	1.75×10^{-8}
900	1.53×10^{-9}	1.53×10^{-8}	1.78×10^{-8}	1.78×10^{-8}
1200	1.53×10^{-9}	1.53×10^{-8}	1.85×10^{-8}	1.85×10^{-8}
1500	1.53×10^{-9}	1.53×10^{-8}	1.53×10^{-8}	1.53×10^{-8}
1800	1.46×10^{-9}	1.46×10^{-8}	1.78×10^{-8}	1.78×10^{-8}
2100	1.50×10^{-9}	1.50×10^{-8}	1.75×10^{-8}	1.75×10^{-8}
2400	1.53×10^{-9}	1.53×10^{-8}	1.85×10^{-8}	1.85×10^{-8}

Table 3: TCV RISK LOWER AND UPPER LIMITS

Although a Target Level of Safety (TLS) has not been determined for the missed approach segment of dual parallel approaches, it will be comparable to the TLS of the final approach segment. The range of the possible values of P(TCV) encompasses the final approach TLS and is considered to be acceptably low for each radar blockage tested. Therefore, the radar blockage, as simulated, does not adversely affect the safety of dual parallel operations at MSP and Category I operations, with a 200 foot decision height, are acceptable at MSP. However, radar blockage with different runway spacing and/or different siting or angular wedge would require additional simulation.