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Analysis of Missed Approach Radar Coverage at the John F. Kennedy International Airport

Dr. David N. Lankford
Dr. James Yates, DataCom
Shahar Ladecky, DataCom
Donna Templeton, Editor

U.S. Department of Transportation
Federal Aviation Administration
Mike Monroney Aeronautical Center
Oklahoma City, OK 73125

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ANALYSIS OF MISSED APPROACH RADAR COVERAGE AT THE JOHN F. KENNEDY INTERNATIONAL AIRPORT

Reviewed by:

Donald P. Pate 10-4-99

Donald P. Pate — Date
Manager, Flight Procedure
Standards Branch

Released by:

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for Robert A. Wright — Date
Manager, Flight Technologies and
Procedures Division

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12. Abstract

The parallel runways, 22L and 22R at John F. Kennedy International Airport (JFK) are separated by 3000 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 JFK, a wedge beginning at the radar site, extending toward runway 22R, and subtending an angle of 1.8 degrees is without radar coverage. The FAA/AFS-420 Airspace Simulation and Analysis for TERPS (ASAT) computer system was modified to conform to the JFK conditions and simulated simultaneous missed approaches were conducted the equivalent of 400,000 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 JFK.

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EXECUTIVE SUMMARY

The parallel runways, 22L and 22R at John F. Kennedy International Airport (JFK) are separated by 3,000 feet. According to FAA Order 8260.39A, Close Parallel ILS/MLS Approaches, simultaneous instrument approaches may be conducted at JFK 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, because of certain siting considerations at JFK, a wedge beginning at the radar site, extending toward runway 22R, and subtending an angle of 1.8 degrees is without radar coverage. This resulted in a loss of coverage of 219 feet along the runway centerline of runway 22R. 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 JFK conditions, including runway spacing, localizer alignment and siting, decision height, and radar blockage wedge. The scenario that was simulated involved simultaneous missed approaches from each of the runways 22L and 22R. The simulation was performed the equivalent of 400,000 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 6.4×10^{-9} and 6.4×10^{-8}. 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 JFK. However, radar blockage with different runway spacing and/or different siting or angular wedge would require additional simulation.

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1.0 INTRODUCTION

The parallel runways, 22L and 22R at John F. Kennedy International Airport (JFK) are separated by 3,000 feet. According to FAA Order 8260.39A, Close Parallel ILS/MLS Approaches, simultaneous instrument approaches may be conducted to runways spaced 3,000 feet apart if the following conditions, among others, are satisfied:

a. The localizers/azimuth transmitters must be aligned at least 2.5 degrees divergent from each other, but not more than 3.0 degrees.

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

c. The Decision Height (DH) must be no lower than 250 feet.

d. 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, because of certain siting considerations at JFK, a wedge beginning at the radar site, extending toward runway 22R, and subtending an angle of 1.8 degrees is without radar coverage. This resulted in a loss of coverage of 219 feet along the runway centerline of runway 22R. 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

Using the Flight Procedure Standards Branch Airspace Simulation and Analysis for TERPS (ASAT) computer system, it was modified to conform to the JFK conditions, including runway spacing, localizer alignment and siting, decision height, and radar blockage wedge. The scenario that was simulated involved simultaneous missed approaches from each of the runways 22L and 22R. 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 22L and 22R;

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

Table 2 depicts the radar settings used in the ASAT simulation. These values were held constant throughout the simulation.

Angular resolution	mRad	1
Range resolution	Ft	30

Radar predictor	Sec	10
Alpha tracker	N/A	0.3
Beta tracker	N/A	0.245
Scanning time	Sec	1
Processing Delay	Sec	0.5
Miss rate	per 1k	20
Radar X location	Ft	4068
Radar Y location	Ft	1834
Blockage heading	Deg	329.16
Blockage angle	Deg	1.8

Table 2. RADAR SETTINGS HELD CONSTANT FOR ALL RUNS

Two sets of 50,000 runs were performed. The first was generated using no radar blockage at all, while the second set of runs was generated using the 1.8 degrees radar blockage wedge. This was done to determine the increase in risk due to the radar blockage. 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 pair of typical trajectories generated by ASAT during the simulation. The radar blockage used was a sector of 1.8 degrees, resulting in a loss of coverage of 219 feet on the runway.

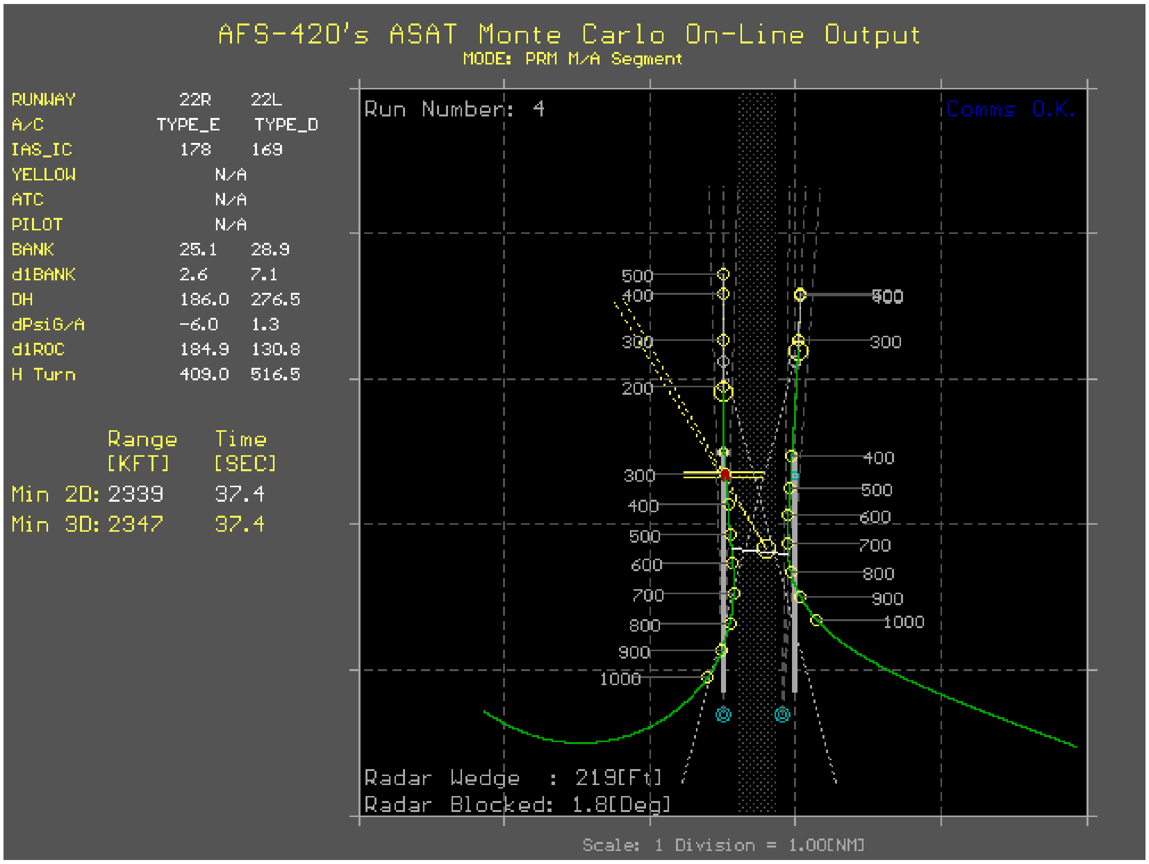

Figure 1: TYPICAL ASAT RUN

3.0 SIMULATION RESULTS

Table 3 presents the results of the simulation. The first column of values represents the percentage of 50,000 runs which resulted in a TCV. The second column represents the percentage of TCVs after conversion to 200,000 runs. Table 3 indicates that there is no significant effect caused by the PRM radar blockage. 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 to runways 22L and 22R will be below 400 feet in the area of the radar blockage, the blockage has no appreciable effect on the risk of collision.

	Ruways 22L & 22R	
Blockage [Deg]	**% TCVs (50,000 runs)**	**%TCVs (out of 200,000 runs)**
0	0.32	0.08
1.8	0.36	0.09

Table 3: ASAT RESULTS FOR 50,000 AND 200,000 RUNS

4.0 RISK ANALYSIS

In order to evaluate properly the simulation results presented in table 3, 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 3, the percentage of TCVs, with radar blockage, was found to be 0.09. The 99 percent upper confidence limit of this number was found to be 0.10875 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).

$$\begin{aligned} P(TCV) &= 0.0010875 \times 1/17 \times 1/100 \times 1/100 \\ &= 6.4 \times 10^{-9} \qquad (3) \end{aligned}$$

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).

$$\begin{aligned} P(TCV) &= 0.0010875 \times 1/17 \times 1/10 \times 1/100 \\ &= 6.4 \times 10^{-8} \qquad (4) \end{aligned}$$

From equations (3) and (4), it follows that P(TCV) is between 6.4×10^{-9} and 6.4×10^{-8}.

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. Therefore, the radar blockage, as simulated, does not adversely affect the safety of dual parallel operations at JFK. However, radar blockage with different runway spacing and/or different siting or angular wedge would require additional simulation.