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Flight Procedure Standards Branch  
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**Analysis of Operations  
Using Runway 22R at  
Detroit Metro Wayne County  
International Airport**

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Technical Report



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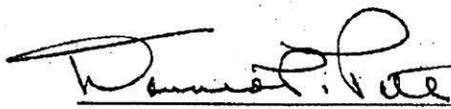
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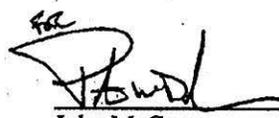
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**ANALYSIS OF OPERATIONS UTILIZING RUNWAY 22R AT  
DETROIT METRO WAYNE COUNTY INTERNATIONAL AIRPORT**

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Technical Report

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12. Abstract A fourth parallel runway, designated 22R, was opened in December 2001 at Detroit Metro Wayne County International Airport (DTW) resulting in three parallel runways, runway 22R, 22L, and 21L for arrivals and departures. There are three possible parallel runway configurations involving runways 22R, 22L, and 21L. The first option would be to conduct dependent, staggered approaches to runways 22R and 22L with independent operations between 21L and 22L. The second option would be to conduct independent approaches to runways 22R and 21L with independent departures from 22L. The third option would be to conduct triple simultaneous independent approaches to runways 22L, 22R, and 21L. The Flight Procedure Standards Branch, AFS-420, was tasked to develop and conduct a Monte Carlo simulation using its Airspace Simulation and Analysis for TERPS (ASAT) computer system to evaluate the options. The target level of safety (TLS) was set at $4 \times 10^{-8}$ for the triple approach configuration and $1 \times 10^{-8}$ for the other configurations. The first option met the TLS. The second option will meet the TLS if the probability of a missed approach does not exceed $1 \times 10^{-2}$ . The third option met the target level of safety.		
13. Key Words Detroit Metro Wayne County International Airport (DTW) Precision Runway Monitor (PRM) Staggered Approaches Missed Approaches Parallel Approaches		14. Distribution Statement Controlled by AFS-420
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## EXECUTIVE SUMMARY

A fourth parallel runway, designated 22R, was opened in December 2001 at Detroit Metro Wayne County International Airport (DTW). The addition of runway 22R will provide three parallel runways, runway 22R, runway 22L, and 21L for arrivals and departures. The spacing between the centerlines of runways 22R and 22L is 3,000 feet and the spacing between the centerlines of runways 22L and 21L is 5,900 feet. Each configuration requires a merging of current procedures. Airport capacity will be significantly increased if appropriate procedures can be developed to fully utilize the new runway.

There are three possible parallel runway configurations involving runways 22R, 22L, and 21L. The first option would be to conduct dependent, staggered approaches to runways 22R and 22L, with independent operations between 21L and 22L. The second option would be to conduct independent approaches to runways 22R and 21L with independent departures from 22L. The third option would be to conduct triple simultaneous independent approaches to runways 22L, 22R, and 21L. Each of the three configurations is a merging of currently approved operations and would require waivers for either implementation. A waiver can only be issued if an equivalent level of safety can be demonstrated.

The Flight Procedure Standards Branch, AFS-420, was tasked to develop and conduct a Monte Carlo simulation of certain critical scenarios involving blunders and missed approaches using its Airspace Simulation and Analysis for TERPS (ASAT) computer system. Six scenarios were simulated.

The target level of safety (TLS) for the triple approach configurations was set at  $4 \times 10^{-8}$ . The TLS for the other configurations was set at  $1 \times 10^{-8}$ . The results of the first scenario and the second scenario indicate that the target level of safety was met for staggered approaches to runways 22R and 22L with independent approaches to 21L.

The third scenario was a simulation of simultaneous departures and missed approaches from a parallel localizer course. The departures were from runway 22L. The probability of two aircraft passing within 500 feet was found to be less than  $7.5 \times 10^{-9}$ . Therefore the target level of safety was met for simultaneous missed approaches and departures between runways 22R and 22L.

The fourth scenario was a simulation of simultaneous departures and missed approaches from a 3 degree offset localizer approach. The missed approach runway was runway 22R and the departure runway was runway 22L. In order for the target level of safety to be met, the probability that a departure occurs, given that a missed approach occurs, must not be greater than  $1 \times 10^{-2}$ .

The fifth and sixth scenarios were a simulation of simultaneous independent approaches to runways 22R and 22L with PRM, and the localizer for 22R offset 3 degrees from the extended runway centerline. It was shown that the target level of safety was met by triple simultaneous independent approaches to runways 22R, 22L, and 21L with PRM for 22R and 22L, and the localizer for 22R offset 3 degrees from the extended runway centerline.

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## 1.0. INTRODUCTION

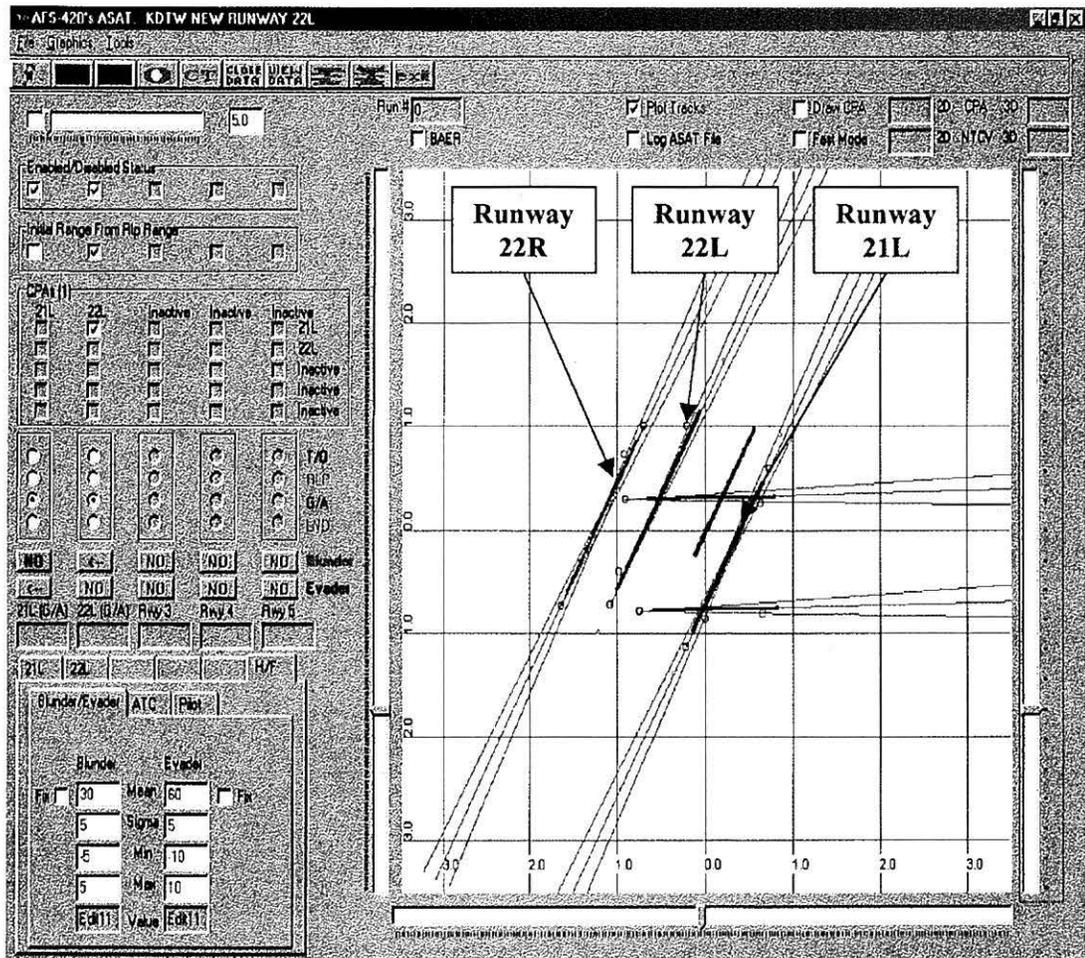
A fourth parallel runway, designated 22R, was opened in December 2001 at Detroit Metro Wayne County International Airport (DTW) (see figure 1). The addition of runway 22R provides three parallel runways, runway 22R, runway 22L, and runway 21L for arrivals and departures. The spacing between the centerlines of runways 22R and 22L is 3,000 feet and the spacing between the centerlines of runways 22L and 21L is 5,900 feet. Airport capacity will be significantly increased if appropriate procedures can be developed to fully utilize the new runway.

Three possible operational scenarios were studied for parallel runway configurations involving runways 22R, 22L, and 21L. Each of them is a merging of currently approved operations and requires waivers for their implementation. A waiver can be issued if an equivalent level of safety can be demonstrated. The purpose of this report is to evaluate and document the level of safety for each configuration option.

The first option would be to conduct dependent, staggered approaches to runways 22R and 22L with independent operations between 21L and 22L. Dependent dual approaches at 3,000 feet separation using currently installed equipment are authorized under current orders. Independent approaches between runways 22L and 21L are also authorized under current orders. However, the merging of the two dual operations into a triple approach operation is not addressed in current orders. Therefore, triple approach operations of this type would require a waiver from Air Traffic Planning and Procedures Program (ATP) and Flight Standards Service (AFS).

The second option would be to conduct independent approaches to runways 22R and 21L with independent departures from 22L. Independent approaches and departures from parallel runways are addressed by FAA Order 7110.65, paragraph 5-8-5, *Departures and Arrivals on Parallel or Nonintersecting Diverging Runways*. Since the arriving aircraft is approaching the farther runway threshold, simultaneous operations between aircraft departing on a runway and an aircraft on final approach to another parallel are authorized if the following condition, among others, is satisfied:

“The runway centerlines separation exceeds 2,500 feet by at least 100 feet for each 500 feet the landing thresholds are staggered.”



**Figure 1: ASAT GRAPHICS OUTPUT SHOWING THE AIRPORT CONFIGURATION**

Since the stagger between runways 22R and 22L is 3,700 feet, the minimum required spacing between runways 22L and 22R to allow independent arrivals to runway 22R and departures from runway 22L, is 3,240 feet. The calculation requires three steps as shown in (1), (2), and (3):

- (1)  $3,700/500 = 7.4$
- (2)  $7.4 \times 100 = 740$  feet
- (3)  $2,500 + 740 = 3,240$  feet

Since the two runways are 3,000 feet apart, a waiver is needed to conduct independent arrivals to runway 22R and departures from runway 22L.

The third option would be to conduct triple simultaneous independent approaches to runways 22L, 22R, and 21L. Runways 22L and 21L have the required spacing to conduct simultaneous instrument approaches with existing radar equipment. However, since the centerline of runway 22R is located only 3,000 feet from the centerline of 22L, the localizer for 22R would have to be offset and Precision Runway Monitor (PRM) system would have to be operative. Dual parallel approaches spaced 3,000 feet apart are only approved with an offset localizer and PRM. The addition of a third parallel approach to runway 22L would require either a change in Order 8260.39A or a waiver.

The Flight Procedure Standards Branch, AFS-420, was tasked to develop and conduct a safety evaluation of the three proposed options involving blunders and missed approaches using its Airspace Simulation and Analysis for TERPS (ASAT) computer system.

## **2.0. DEPENDENT STAGGERED APPROACHES TO 22R AND 22L WITH INDEPENDENT APPROACHES TO 21L**

The principal focus of this part of the study is the possible occurrence of a worst-case blunder (WCB) by one of the three aircraft during dependent staggered approaches to 22R and 22L with independent approaches to 21L.

### **2.1. BLUNDER SCENARIOS FOR DEPENDENT STAGGERED APPROACHES TO 22R AND 22L WITH INDEPENDENT APPROACHES TO 21L**

The Multiple Parallel Approach Program (MPAP) Working Committee (TWG) determined that the most critical event that could occur during parallel approaches is the WCB. A WCB is defined to be an unexpected 30 degree turn by one aircraft toward the approach path of an adjacent aircraft, in which the turning aircraft does not respond to air traffic control (ATC) instructions to return to its localizer course. A WCB could result from any one of the following events:

1. The aircraft approaching runway 22R blunders left, and the other two aircraft approaching runways 22L and 21L each perform an evasion maneuver.
2. The aircraft approaching runway 21L blunders right, and the other two aircraft approaching runways 22L and 22R each perform an evasion maneuver.
3. The aircraft approaching runway 22L blunders right, and the aircraft approaching runway 22R performs an evasion maneuver.
4. The aircraft approaching runway 22L blunders left, and the aircraft approaching runway 21L performs an evasion maneuver.

Since the aircraft approaching runways 22R and 22L are dependent, the stagger distance nullifies the possibility of a conflict between aircraft on 22R and 22L.

Therefore, in events 1 and 2, the risk of a conflict between the aircraft approaching 22R and 22L is considered to be negligible. Because of the magnitude of the separation of runways 22R and 21L, the risk of a conflict between the aircraft approaching 22R and 21L is also considered to be negligible. Therefore, the blunder analysis for dependent operations will focus on blunders between 22L and 21L. Should a blunder occur on one of the approaches to either 22L or 21L, there is no reason to believe that the risk of a blunder starting from the approach to 22L is different from the risk of a blunder starting from the approach to 21L. Therefore, all simulated blunders were initiated from the approach to 22L toward the approach to runway 21L. Figure 2 illustrates this blunder scenario.

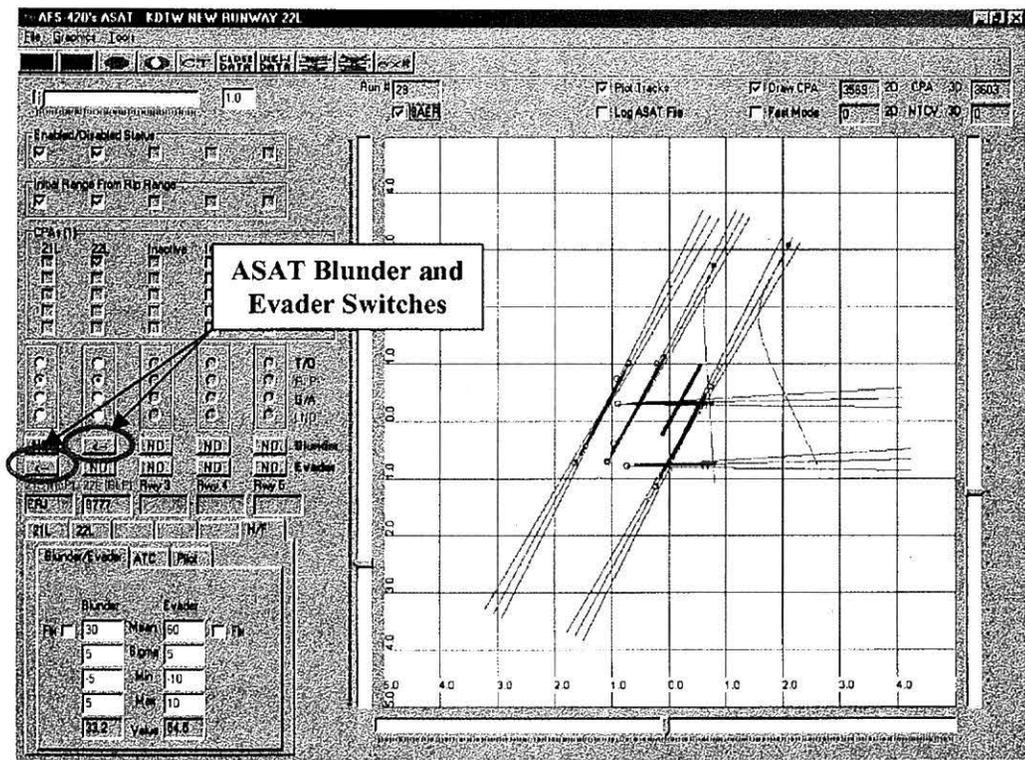


Figure 2: SAMPLE OF A SINGLE PAIR OF TRACKS (BLUNDER AND EVADER)

## 2.2. EVASION MANEUVERS

As in the study of triple simultaneous independent approaches, another potential source of risk during dependent operations occurs when a blundering aircraft from 22R forces evasion maneuvers by the aircraft approaching runways 22L and 21L.

During the evasion maneuvers, the aircraft approaching 21L is threatened by the aircraft approaching 22L. If the blundering aircraft was approaching 22R, then the two aircraft approaching 22L and 21L will both be issued evasion instructions at approximately the same time.

Since both aircraft are evading the blundering aircraft from the approach to runway 22R, the aircraft turning from the approach to 22L turns through an angle of approximately 60 degrees toward the aircraft approaching runway 21L. The issuance of evasion maneuvers at approximately the same time should increase the safety of the event; however, the 60-degree turn toward the adjacent approach path could possibly increase the risk. Therefore, a second aspect of the analysis focused on dual evasion maneuvers from runways 22L and 21L.

### **2.3. TARGET LEVEL OF SAFETY FOR DEPENDENT STAGGERED APPROACHES TO 22R AND 22L WITH INDEPENDENT APPROACHES TO 21L**

The standard criterion used for the evaluation of the risk of collision is the Test Criterion Violation (TCV). During the simulation of a WCB that affects the flight of two aircraft, the closest point of approach (CPA) of the aircraft is recorded. In other words, the distance between the centers of gravity of the two aircraft is continually monitored and when the run is completed, the smallest value, the CPA, is recorded. If the CPA is less than or equal to 500 feet, a TCV is said to have occurred. If one assumes that a TCV represents a collision, then the TCV rate observed in a simulation is an estimate of the risk 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. Previous testing has shown that blunders other than WCBs 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., it must be *at-risk*). If all of the above events develop, a TCV will occur if the controller and pilots cannot react in sufficient time to separate the blundering and the evading aircraft.

The TWG agreed to an analysis that relates to the collision rate observed in a simulation to the test criterion of less than 1 fatal accident per 25 million approaches ( $4 \times 10^{-8}$ ). Therefore, the target level of safety (TLS) for dual and triple approaches was determined to be 1 fatal accident per 25 million approaches ( $4 \times 10^{-8}$ ). The TWG also agreed to an analysis that relates the TLS to the TCV rate. If the TCV rate for triple approaches, given that an at-risk Worst-Case Blunder (WCB) has occurred, is less than 5.1 percent, and the collision rate for each adjacent runway pair is less than 6.8 percent, then the overall risk of a collision accident resulting from the triple simultaneous instrument approach procedure will be less than the target level of safety. Since the risk of collision between aircraft approaching runways 22R and 22L is considered to be negligible, the only risk of collision due to a blunder is between aircraft approaching runways 22L and 21L.

Therefore, this operation is equivalent to dual independent approaches and the target level of safety will be met if the TCV rate between aircraft approaching runways 22L and 21L is less than or equal to 6.8 percent.

### **3.0. SIMULTANEOUS MISSED APPROACH AND DEPARTURE**

The conditions described in FAA Order 7110.65, paragraph 5-8-5, that relate runway separation to runway stagger, were designed to reduce the risk of a conflict should an approaching aircraft to a parallel runway perform a missed approach simultaneously with a departure from the other parallel runway. Therefore, a third aspect of the analysis focused on independent arrivals to runway 22R and departures from 22L. The arriving aircraft performs a missed approach or balked landing while the other aircraft departs. The localizer for 22R may be aligned with the extended runway centerline or, if a PRM is installed to support independent approaches to runways 22R and 22L, the localizer for 22R may be offset at a 3-degree angle away from runway 22L.

#### **3.1. TARGET LEVEL OF SAFETY FOR SIMULTANEOUS MISSED APPROACH AND DEPARTURE**

A formal target level of safety for this situation has not been developed. However, since the fatal accident rate for precision approaches is on the order of  $10^{-7}$ , every component of a precision approach must have an accident rate on the order of  $10^{-8}$ . Therefore, the target level of safety for a missed approach from runway 22R with a simultaneous departure from runway 22L is  $1 \times 10^{-8}$ .

### **4.0. TRIPLE SIMULTANEOUS INDEPENDENT APPROACHES USING PRM**

The principal focus of this part of the study is the possible occurrence of a worst-case blunder (WCB) by one of the three aircraft during independent parallel operations to all three runways while using PRM.

#### **4.1. BLUNDER SCENARIOS DURING PARALLEL APPROACHES USING PRM**

The Multiple Parallel Approach Program (MPAP) Working Committee (TWG) determined that the most critical event that could occur during parallel approaches is the WCB. A WCB could result from any one of the following events:

1. The aircraft approaching runway 22R blunders left and the other two aircraft approaching runways 22L and 21L each perform an evasion maneuver.
2. The aircraft approaching runway 21L blunders right and the other two aircraft approaching runways 22L and 22R each perform an evasion maneuver.
3. The aircraft approaching runway 22L blunders right and the aircraft approaching runway 22R performs an evasion maneuver.

4. The aircraft approaching runway 22L blunders left and the aircraft approaching runway 21L performs an evasion maneuver.

Since the approaches are conducted independently, each of the four WCB scenarios must be considered. In a similar fashion to staggered approaches covered in section 2.0, if the aircraft approaching runway 22R blunders left, the controller must issue a left turn instruction to the pilot of the aircraft approaching 22L. Then the two aircraft approaching 22L and 21L will both be issued evasion instructions at approximately the same time. As in section 2.1, the evading aircraft will normally be instructed to turn 60 degrees to avoid the blundering aircraft. Since both aircraft are evading the blundering aircraft from the approach to runway 22R, the aircraft turning from the approach to 22L turns through an angle of approximately 60 degrees toward the aircraft approaching runway 21L. The issuance of evasion maneuvers at approximately the same time should increase the safety of the event; however, the 60-degree turn toward the adjacent approach path could possibly increase the risk of a TCV. Therefore, a second aspect of the analysis focused on dual evasion maneuvers from runways 22L and 21L.

Because of the close proximity of runways 22L and 22R, a blunder from runway 21L toward 22L will cause the controller to issue a right turn toward runway 22R. Again, the evading aircraft will normally be instructed to turn 60 degrees to avoid the blundering aircraft. The 60-degree turn toward the adjacent approach path could possibly increase the risk of a TCV. Therefore, a second aspect of the analysis focused on dual evasion maneuvers from runways 22L and 22R.

In a similar fashion, if the aircraft approaching 21L blunders to the right, then the controller must issue a right turn instruction to the pilot of the aircraft approaching 22L. This in turn forces the controller to issue a second right turn instruction to the pilot of the aircraft approaching 22R. Therefore, there is a possibility of a TCV occurring between the aircraft from 22R and 22L. Similarly, there is a possibility of a TCV occurring between the aircraft from 22L and 21L. A simulation of a WCB between runways 22L and 21L is illustrated in figure 2.

#### **4.2. TARGET LEVEL OF SAFETY FOR INDEPENDENT PARALLEL APPROACHES**

The target level of safety for independent simultaneous parallel approaches was determined from accident data for precision instrument landing system (ILS) approaches. The target level of safety was found to be  $4 \times 10^{-8}$ . The target level of safety can be stated in terms of the observed TCV rate found by simulation. The acceptable TCV rate must be less than or equal to 5.1 percent of the at-risk blunders for triple operations with TCV rates less than or equal to 6.8 percent of the at-risk blunders for the adjacent dual pairs.

## **5.0. ASAT MODEL DEVELOPMENT**

The Flight Procedure Standards Branch, AFS-420 ASAT system was used to generate the statistical database necessary to derive the risk figures associated with the operations described in the previous sections. The ASAT system was modified to include geodetic data of the airport runways and facilities and to emulate certain operational aspects unique to DTW (Figure 1).

The modifications were developed with close cooperation of DTW air traffic controllers. Two meetings between AFS-420 personnel and DTW air traffic controllers took place. The first meeting was convened at the FAA Mike Monroney Aeronautical Center in Oklahoma City and the second meeting convened at DTW. The first meeting helped AFS-420 understand critical details of the proposed operation. Using the data gathered during the first meeting and with regular interaction with DTW air traffic controllers, ASAT models customized for the DTW proposed operational modes were developed. After the models were developed and ASAT software customizations had been finalized, a second meeting took place. This meeting was convened at DTW with AFS-420 personnel and DTW air traffic controllers. During the meeting, AFS-420 presented the model to the air traffic controllers for their assessment. Suggestions for fine-tuning the model were subsequently incorporated into the model.

### **5.1. BLUNDER SCENARIO IMPLEMENTATION**

Several parameters were randomly varied to obtain realistic replications of the scenarios. Each simulation is ultimately based on aircraft, pilot, and controller parameters. Aircraft parameters are governed by flight dynamics models, i.e., mathematical models of specific aircraft models. During a simulation, aircraft models are randomly selected for a particular run according to the aircraft traffic mix at the particular airport. Although the AFS-420 collection of aircraft models is extensive, there are still many aircraft in operation at a given airport for which models are not available. For those aircraft types for which flight dynamics models were not available, another aircraft type from the AFS-420 model collection with similar performance was substituted.

The traffic mix distribution was based upon a MITRE report. Table 1 shows the actual traffic mix, as well as the traffic mix after suitable substitutions, that were used for this study. Table 2 shows the percentage of each aircraft type at DTW.

#### **5.1.1. PARAMETER SELECTION FOR 22L AND 21L BLUNDERS**

The parameters and the manner of selection for a simulation run of a blunder from 22L toward 21L during dependent staggered were randomly selected as follows:

- a. The aircraft types were randomly selected according to Table 2.

- b.** Flight dynamics parameters such as maximum bank angles and bank angle rates for the blundering aircraft were selected from probability distributions associated with the specific aircraft type.
- c.** The distance of each aircraft from its respective threshold was selected from a uniform distribution. The possible distances ranged from 1 to 4 NM from threshold.
- d.** The lateral and vertical distances of each aircraft about its localizer and glideslope were randomly selected from ICAO Collision Risk Model distributions.
- e.** The angle of deviation (blunder angle) is randomly selected. The value for each run is determined from a normal distribution with a mean of -30 degrees, a standard deviation of  $\sigma = 5$  degrees and bounded to between -35 degrees to -25 degrees. (Negative values denote an aircraft blundering to the left).
- f.** The evading aircraft will perform a left turn resulting in a nominal deviation of 60 degrees from its original track. The value for each run is determined from a normal distribution with a mean of -60 degrees, a standard deviation of  $\sigma = 5$  degrees and bounded to between -65 degrees to -55 degrees.
- g.** Flight dynamics parameters for the evading aircraft's climb and turn are randomly selected from probability distributions associated with the specific type of aircraft.
- h.** Air Traffic Control response time is randomly selected from a probability distribution.

### **5.1.2. EVASION MANEUVER PARAMETER SELECTION**

The parameters and the manner of selection for a simulation run of the evasion maneuvers during dependent staggered approaches to 22R and 22L with independent approaches to 21L are described as follows:

- a.** The aircraft types were randomly selected according to Table 2.
- b.** Flight dynamics parameters such as maximum bank angles and bank angle rates for the blundering aircraft were selected from probability distributions associated with the specific aircraft type.
- c.** The distance of each aircraft from its respective threshold was selected from a uniform distribution. The possible distances ranged from 1 to 4 NM from threshold.
- d.** The lateral and vertical distances of each aircraft about its localizer and glideslope were randomly selected from the ICAO Collision Risk Model distributions.
- e.** The angle of deviation (blunder angle) is randomly selected. The value for each run is determined from a normal distribution with a mean of 30 degrees, a standard deviation of  $\sigma = 5$  degrees and bounded to between 25 degrees to 35 degrees.
- f.** The evading aircraft will perform a turn resulting in a nominal deviation of 60 degrees from its original track.

The value for each run is determined from a normal distribution with a mean of 60 degrees, a standard deviation of  $\sigma = 5$  degrees and bounded to between 55 degrees to 65 degrees.

**g.** Flight dynamics parameters for the evading aircraft's climb and turn are randomly selected from probability distributions associated with the specific type of aircraft.

**h.** Air Traffic Control response time is randomly selected from a probability distribution.

Actual A/C Type	Type used in ASAT	Comments
DC9Q	B732	
SF34	DH8	
BA46	F100	
B72Q	B727	
MD80	MD80	
B733	B732	
B73Q	B732	
Other Large	A320	From the MITRE Report
Medium	B732	From the MITRE Report
Small	GLF2	From the MITRE Report
DC10	DC8	
B744	B744	
DC8Q	DC8	
Other Heavy	DC8	From the MITRE Report
B752	B752	

**Table 1: TRAFFIC MIX AT DTW**

Aircraft Type	Percentage
A320	9
ATR42	13
B732	12
B752	14
B777	14
ERJ	24
MD88	14

**Table 2: AIRCRAFT DISTRIBUTION AT DTW**

### 5.1.3. PARAMETER SELECTION FOR MISSED APPROACHES AND DEPARTURES

For missed approaches or bailed landings from runway 22R with simultaneous departures from runway 22L, the parameters and manner of selection are described as follows:

- a. The aircraft types were randomly selected according to Table 2.
- b. Flight dynamics parameters such as maximum bank angles and bank angle rates for the missed approach aircraft were selected from probability distributions associated with the specific aircraft type.
- c. The initial headings for the missed approaches or bailed landings were selected from a truncated normal distribution with mean of 0 degrees and standard deviation of 5 degrees in the range -15 to +15 degrees. However, if a positive heading was selected, signifying a right turn, then the run was not completed since the probability of a TCV was 0.
- d. The lateral and vertical distances of the initial position of the aircraft approaching runway 22R about its localizer and glideslope were randomly selected from the ICAO Collision Risk Model distributions.
- e. The initial headings for the missed approaches or bailed landings were selected from a truncated normal distribution with mean of 0 degrees and standard deviation of 5 degrees in the range -15 to +15 degrees. However, if a positive heading was selected, signifying a right turn, then the run was not completed since the probability of a TCV was 0.
- f. The altitude that the missed approach aircraft climbed to before making a right turn was selected from a truncated normal distribution with mean 400 feet and standard deviation of 50 feet in the range 325 to 475 feet.
- g. The right turn of the missed approach aircraft was chosen from a truncated normal distribution with mean 20 degrees and standard deviation 5 degrees in the range 10 to 30 degrees
- h. The initial headings for the departing aircraft were selected from a truncated normal distribution with mean 0 degrees and standard deviation of 5 degrees in the range -15 to +15 degrees. If a negative angle was selected, indicating a left turn, the run was not completed since the probability of a TCV was 0.
- i. The altitude that the departing aircraft climbed to before making a left turn was selected from a truncated normal distribution with mean 800 feet and standard deviation 50 feet in the range from 700 to 900 feet.
- j. The left turn of the departing aircraft was chosen from a truncated normal distribution with mean -15 degrees and standard deviation 5 degrees in the range -25 to -5 degrees.

#### **5.1.4. PRM MODEL PARAMETER SELECTION**

The model parameters for the blunder scenarios and the methods used to randomly select them are very similar to those described in the preceding paragraphs. The parameters and the manner of selection for a PRM simulation run are described as follows:

- a. The aircraft types were randomly selected according to Table 2.
- b. Flight dynamics parameters such as maximum bank angles and bank angle rates for the missed approach aircraft were selected from probability distributions associated with the specific aircraft type.
- c. The aircraft approaching runway 22L and 22R were placed along the final approach path at a distance from the threshold ranging from 1.5NM to 10NM using a uniform distribution.
- d. The simulation determined which of the three aircraft would be the blunderer. Each aircraft has the same probability of being the next blunder aircraft.
- e. Once the blundering aircraft and other initial conditions were randomly selected for the next run, the aircraft that the blunder was directed toward was placed "at-risk." An aircraft is said to be at-risk if collision with a blundering aircraft is certain unless action is taken by the controller to direct the at-risk aircraft away from the path of the blundering aircraft.
- f. Monitor controller response times are generated from a statistical database of controller monitoring a similar PRM operation.
- g. Pilot response times are generated from a statistical database of pilot performing similar evasion maneuvers on PRM operations.
- h. In addition, the bank angle, bank rate, rate of climb, and rate of change of rate of climb are generated using probability distributions associated with the specific aircraft type being simulated.

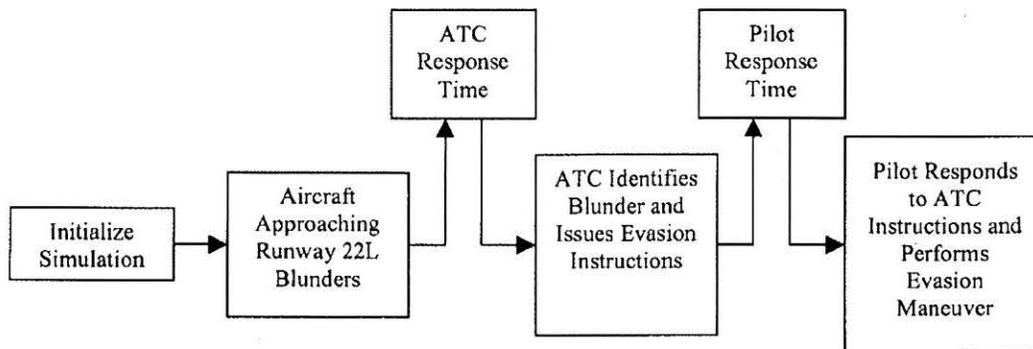
#### **5.2. SIMULATION OF BLUNDERS FROM 22L TOWARD 21L**

The sequence of events for each run was as follows:

1. The simulation was initialized by randomly selecting parameters as described in paragraph 5.1.1.
2. The aircraft approaching runway 22L blunders toward the aircraft approaching runway 21L.
3. Air Traffic Control identifies the blunders and issues an evasion instruction to the pilot approaching runway 21L.
4. The pilot approaching runway 21L responds to Air Traffic Control instruction and performs an evasion maneuver.

A flow chart of the sequence of events that occur during a blunder is shown in Figure 3.

Figure 2 shows a typical pair of tracks consisting of a blunder (aircraft approaching to runway 22L blunders left) and an evader (Aircraft approaching runway 21L evading with a left turn and a climb).



**Figure 3: BLUNDER FROM 22L TOWARD 21L FLOW CHART**

### 5.3. SIMULATION OF 22L AND 21L EVASION MANEUVERS

The sequence of events for each run was as follows:

1. The simulation was initialized by randomly selecting parameters as described in paragraph 5.1.2.
2. The aircraft approaching runway 22L blundered toward the aircraft approaching runway 21L.
3. Air Traffic Control identified the blunders and issued an evasion instruction to the pilot approaching runway 21L.
4. The pilot approaching runway 21L responded to Air Traffic Control instruction and performed an evasion maneuver.

The simulation of the dual evasion maneuvers from runways 22L and 21L is essentially the same as for a blunder from one of the approaches toward the other discussed in sections 2.0 and 3.0. The differences lie in the selection of turn angles and the controller response time. The nominal turn angle of the first aircraft is 60 degrees and that of the second is 90 degrees. Controller instructions are issued to both aircraft almost simultaneously. A screen capture of a simulation run is shown in Figure 5.

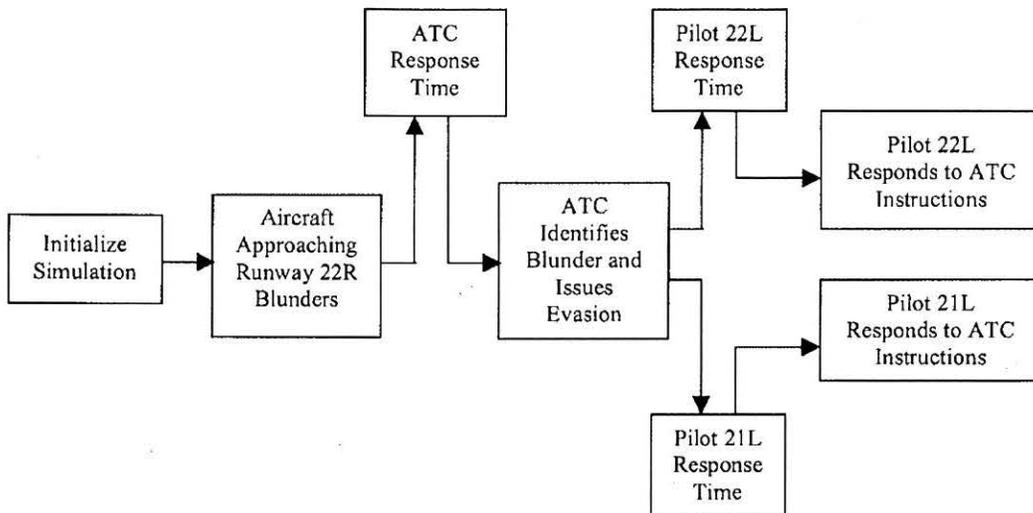


Figure 4: EVASION SCENARIO FLOW CHART

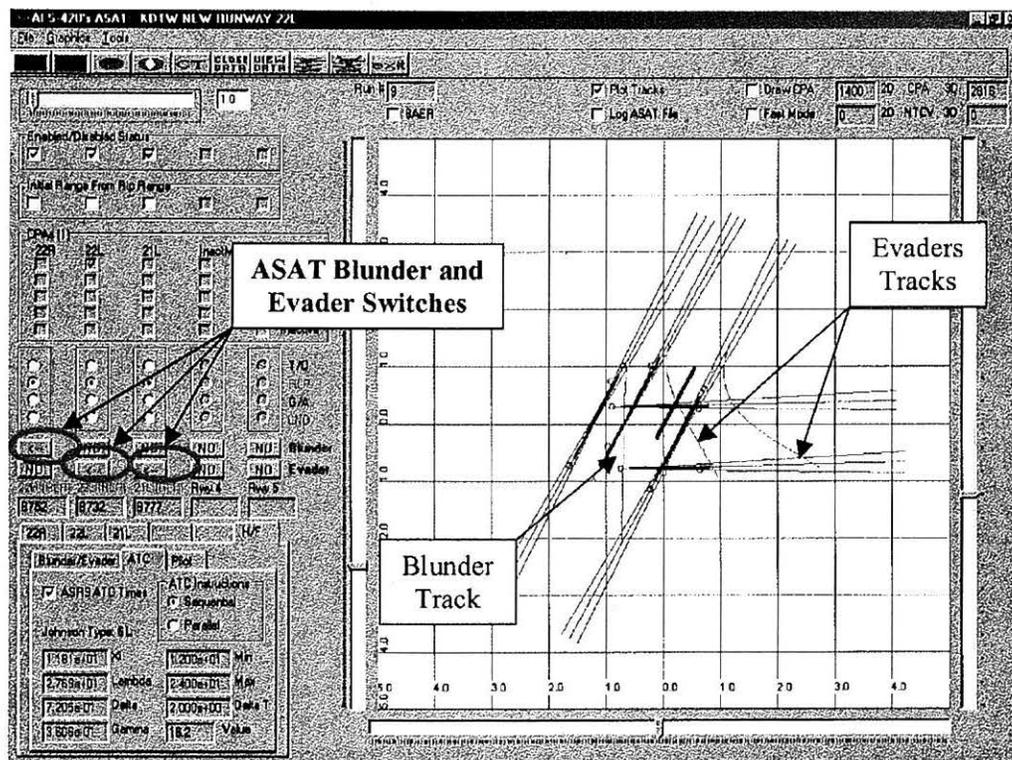


Figure 5: SAMPLE OF A SINGLE SET OF TRACKS (22R BLUNDERS, 22L AND 21L EVADES)

#### 5.4. SIMULATION OF SIMULTANEOUS MISSED APPROACH FROM 22R AND DEPARTURE FROM 22L.

This scenario assumes that approaches are conducted to runway 22R and departures are conducted from runway 22L. The approach to 22R is parallel to the extended runway centerline of runway 22L. The sequence of events for each run was as follows:

1. The aircraft are initialized at their starting points by selecting parameters as described in 5.1.3. The missed approach aircraft is initialized at the missed approach point for runway 22R, and the departing aircraft is initialized at the departure end of runway 22L.
2. The missed approach aircraft begins the missed approach and simultaneously the departing aircraft begins its takeoff roll.
3. Each aircraft climbs to its respective turn altitude and performs its turn.

Figure 6 shows a sample of 1,000 runs executed under the scenario described above. The tracks are color-coded and show dispersion of take off tracks (in **green** color) departing runway 22L and dispersion of go around tracks (in **fuchsia** color).

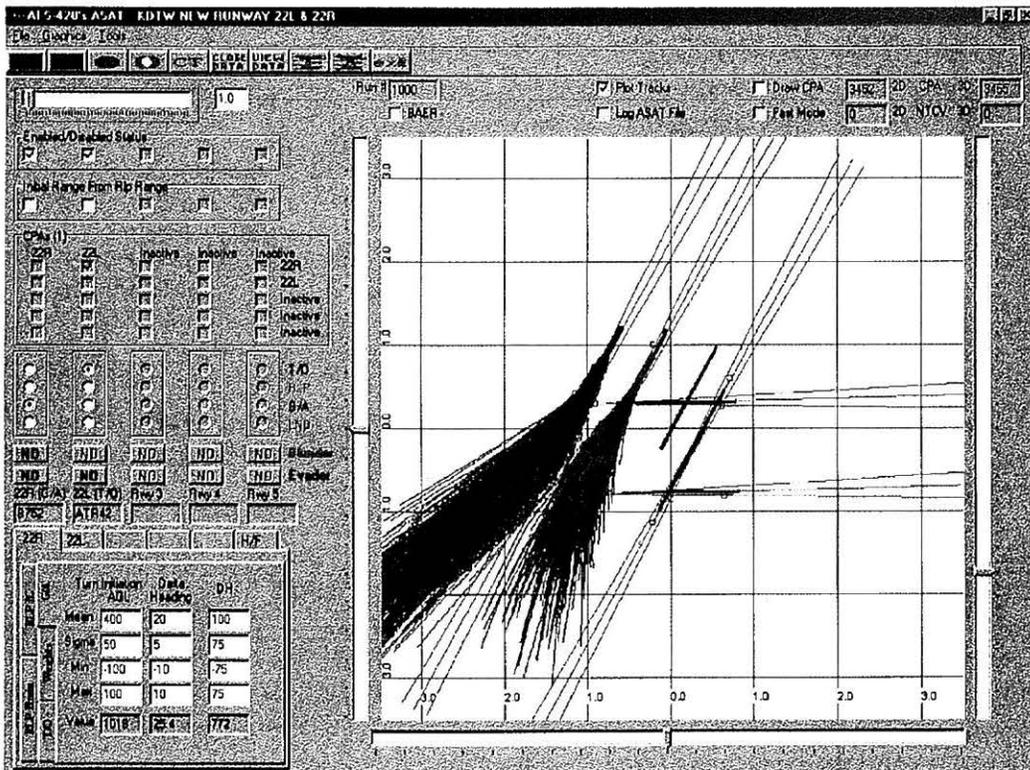


Figure 6: SAMPLE OF 1000 ASAT MONTE-CARLO SIMULATION RUNS

## 5.5. SIMULATION OF SIMULTANEOUS MISSED APPROACH AND DEPARTURE WITH PRM

This simulation differs from the simulation of Section 5.4, because the localizer to runway 22R had to be offset 3 degrees (see Figure 7) to support simultaneous independent approaches to runways 22L and 22R using PRM. The offset 22R localizer results in increased distances between the approaches to runway 22L and 22R, and should decrease the risk of a TCV, should a blunder occur. This case is similar to the one described in Section 5.4 with the following exceptions:

1. A PRM system was used.
2. The localizer associated with runway 22L was shifted outward (offset) 3 degrees.

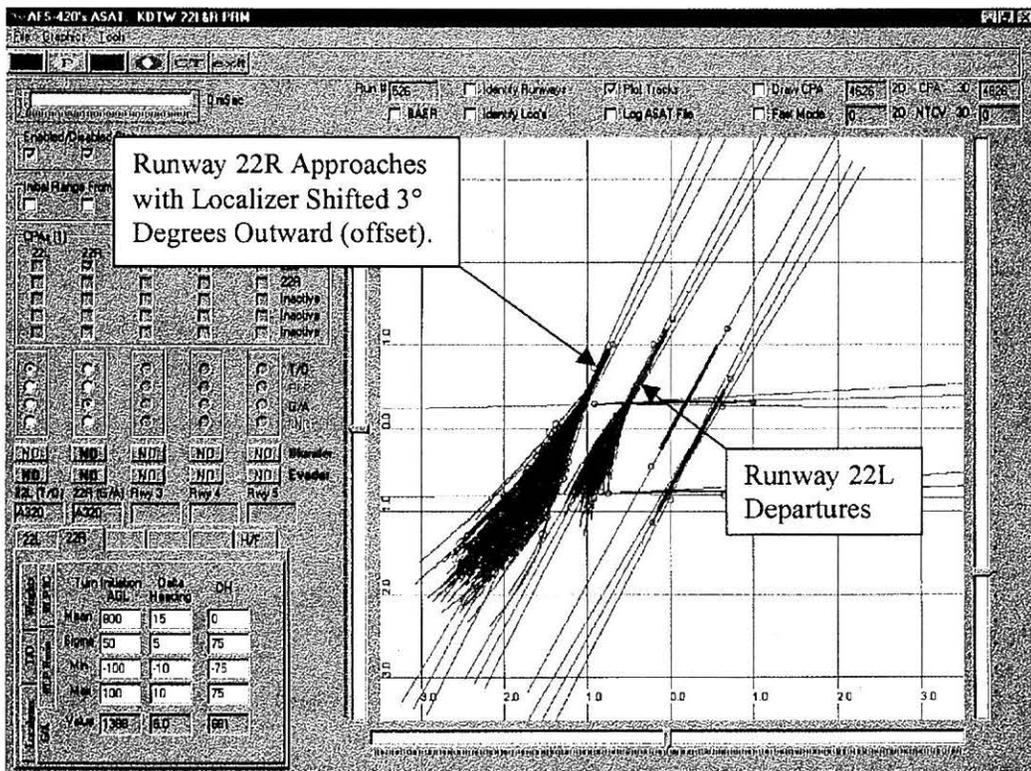


Figure 7: SAMPLE OF ASAT MONTE-CARLO SIMULATION RUNS SHOWING RUNWAY 22R LOCALIZER SHIFTED OUTWARD 3 DEGREES.

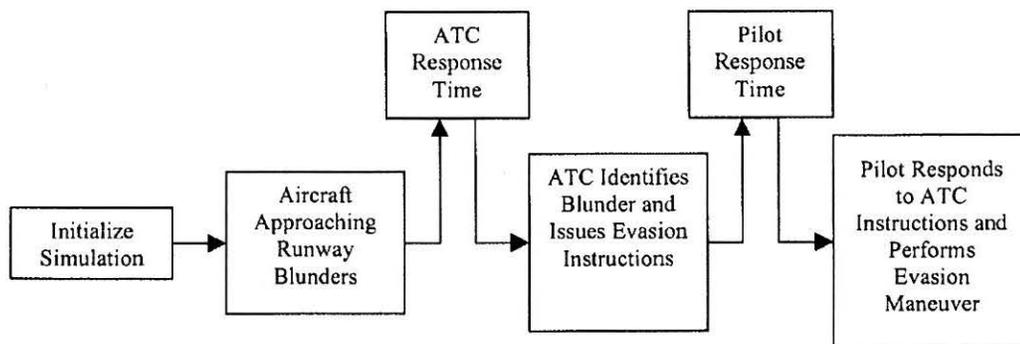
## 5.6. SIMULATION OF BLUNDERS USING PRM

Figure 9 illustrates the PRM blunder scenario that was evaluated for simultaneous independent approaches to runways 22L and 22R. The spacing between the runway centerlines is 3,000 feet. The localizer associated with runway 22R was offset 3 degrees. Figure 9 depicts the tracks of a blundering aircraft and an evading aircraft, as well as the Non Transgression Zone (NTZ) between runways 22L and 22R and the offset localizer to runway 22R. The 5 dots leading each one of the tracks are the PRM 10 seconds predictor that was also modeled for this analysis.

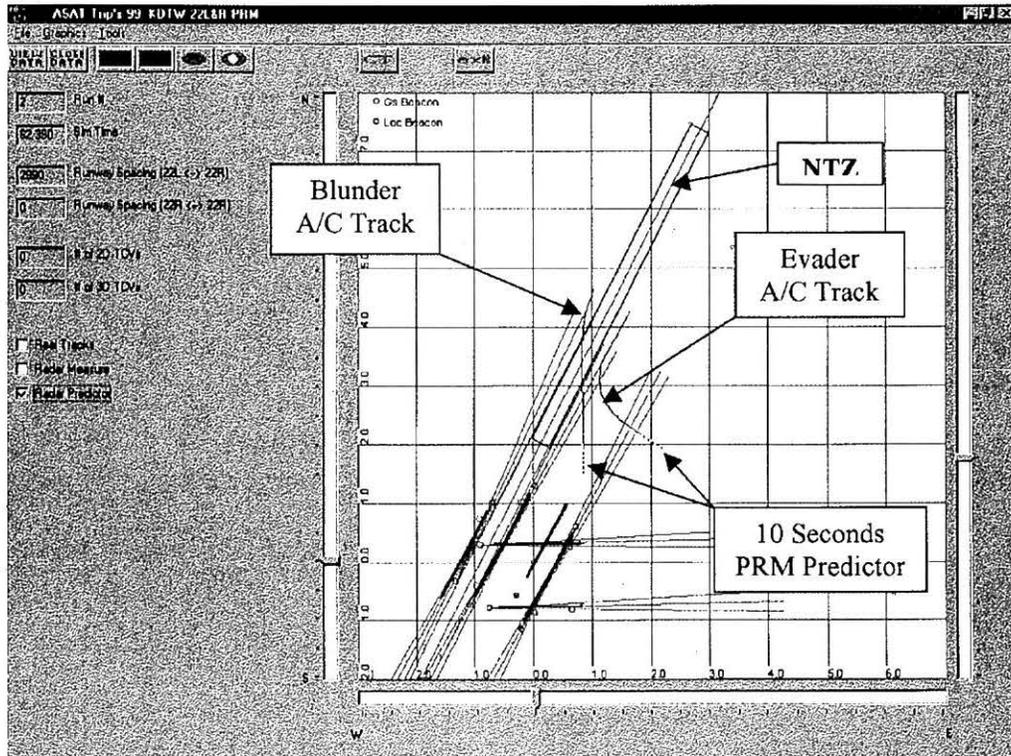
The sequence of events for each simulation run using PRM was as follows:

1. The simulation was initialized by randomly selecting parameters as described in paragraph 5.1.4.
2. The simulation started with the blundering aircraft initiating a blunder towards the adjacent aircraft.
3. The blunder aircraft triggered a PRM alarm.
4. The controller issued evasion instructions to the pilot of the aircraft being threatened.
5. The pilot of the threatened aircraft responded by simultaneously climbing and executing a turn away from the blundering aircraft.
6. The simulation program records the closest point of approach (CPA) between aircraft.
7. The simulation was terminated 30 seconds after the CPA was determined.

A flow chart of the sequence of events that occur during a blunder is shown in Figure 8.



**Figure 8: BLUNDER SCENARIO FLOW CHART USING PRM**



**Figure 9: SAMPLE OF A SINGLE PAIR OF TRACKS  
(22R BLUNDERS, 22L EVADES)**

## 6.0. SIMULATION RESULTS

The data provided by the simulations were analyzed to determine whether the target level of safety was met by the scenarios.

### 6.1. DEPENDENT STAGGERED APPROACHES TO 22R AND 22L WITH INDEPENDENT APPROACHES TO 21L

At-risk blunders were simulated from runway 22L toward runway 21L. Since there is no reason to believe that the risk of a TCv is any different for blunders directed from 21L toward 22L, and any different from the risk of a TCv for blunders directed from 22L toward 21L, all blunders were directed from runway 22L toward runway 21L. Two hundred thousand blunders were simulated and zero TCvs were observed. The absence of observed TCvs does not imply that the risk of a TCv is zero, but it does imply that the risk is very low. A 99 percent confidence interval for the TCv rate was computed assuming that the probability of a TCv is constant. The confidence interval indicated that with 99 percent confidence, the TCv rate due to blunders from 22L toward 21L lies between 0.0 and 0.00265 percent.

One hundred thousand simulation runs of evasion maneuvers from runway 22L toward 21L were conducted and zero TCVs were observed. The absence of observed TCVs does not imply that the risk of a TCV is zero, but it does imply that the risk is very low. A 99 percent confidence interval for the TCV rate was computed assuming that the probability of a TCV is constant. The confidence interval indicated that with 99 percent confidence the TCV rate for evasion maneuvers from runway 22L toward 21L lies between 0.0 and 0.00530 percent.

The analysis indicates that the combined TCV rate is between 0.0 and 0.00265 + 0.00530 percent. Since 0.00795 percent is less than 5.1 percent, the maximum allowable TCV rate for triple approaches, and TCV rate for blunders between runways 22L and 21L is less than 6.8 percent, the target level of safety is met for dependent staggered approaches to runway 22R and 22L with independent approaches to 21L.

## 6.2. SIMULTANEOUS DEPARTURES AND MISSED APPROACHES FROM A PARALLEL LOCALIZER COURSE

Simultaneous departures and missed approaches from a parallel localizer course were simulated 100,000 times. A probability curve was fitted to the resulting set of CPAs. The probability of a TCV, under the conditions of the simulation, was estimated to be  $3 \times 10^{-6}$ . However, this number does not represent the actual probability of a TCV during a missed approach since it does not account for the probability of a missed approach, and it does not account for the probability that one or the other of the planes will turn toward the other. In the simulation, only those runs where the aircraft initially turned towards each other were simulated. Therefore, a TCV can only occur when a missed approach occurs, a departure occurs, the aircraft turn toward each other, and the CPA is less than 500 feet. If we let  $H$  represent the event the headings converge,  $M$  represent a missed approach,  $D$  represent a departure, and  $C$  represent a CPA less than 500 feet, the probability of a TCV,  $P(TCV)$ , can be found from the following formula:

$$\begin{aligned} P(TCV) &= P(M \cap D \cap C \cap H) \\ &= P(C|M \cap D \cap H)P(H|M \cap D)P(D|M)P(M) \end{aligned} \quad (1)$$

where the vertical line, '|', is read 'given', and the symbol  $\cap$  is read 'and.'

The first factor in equation (1) is the probability that the CPA is less than 500 feet given that a missed approach occurred, a departure occurred, and the aircraft turned toward each other. This is the number estimated from the simulation. Therefore,

$$P(C|M \cap D \cap H) = 3 \times 10^{-6}. \quad (2)$$

The second factor in equation (1) is the probability that the aircraft headings converge given that a simultaneous missed approach and departure occurred.

The probability that each heading will be in the direction of the other is .5. Since the headings of the two aircraft are independent, the probability that the headings converge is:

$$P(H|M \cap D) = .5 \times .5 = .25 \quad (3)$$

The third factor in equation (1) is the probability that an aircraft will depart almost simultaneously with a missed approach. This probability is not known, but must be much less than one.

The fourth factor in the equation is the probability of a missed approach. This number is internationally considered to be  $1 \times 10^{-2}$ . Therefore,

$$P(M) = 1 \times 10^{-2} \quad (4)$$

Substituting (2), (3), and (4) into equation (1) results in the following equation:

$$\begin{aligned} P(TCV) &= (3 \times 10^{-6}) \times (2.5 \times 10^{-1}) \times P(D|M) \times (1 \times 10^{-2}) \\ &= (7.5 \times 10^{-9}) \times P(D|M) \end{aligned} \quad (5)$$

Since  $P(D|M)$  is less than one,  $P(TCV)$  is less than  $7.5 \times 10^{-9}$ . Therefore, the target level of safety is met for simultaneous departures and missed approaches with a parallel localizer course.

### 6.3. SIMULTANEOUS DEPARTURES AND MISSED APPROACHES FROM AN OFFSET LOCALIZER COURSE

This situation is very similar to that of section 6.2. Simultaneous missed approaches and departures from an offset localizer course were simulated 100,000 times. A probability curve was fitted to the resulting set of CPAs. The probability of a TCV, under the conditions of the simulation, was estimated to be  $5 \times 10^{-4}$ . Therefore equation (2) becomes:

$$P(C|M \cap D \cap H) = 5 \times 10^{-4} \quad (6)$$

Since the two courses converge at a 3-degree angle, the probability that the aircraft performing the missed approach turns toward the departing aircraft is estimated to be  $93/180 = 0.52$ . The probability that the departing aircraft turns toward the missed approach aircraft is also estimated to be 0.52. Therefore, equation (3) becomes:

$$P(H|M \cap D) = .52 \times .52 = .27 \quad (7)$$

The fourth factor, the probability of a missed approach remains the same. Therefore, equation (5) becomes:

$$\begin{aligned} P(TCV) &= (5 \times 10^{-4}) \times (2.7 \times 10^{-1}) \times P(D|M) \times (1 \times 10^{-2}) \\ &= (1.35 \times 10^{-6}) \times P(D|M) \end{aligned} \quad (8)$$

As before, the probability of a departure given a missed approach occurs is unknown. However, examination of equation (8) indicates that  $P(D|M)$  must not be greater than  $1 \times 10^{-2}$  in order for the target level of safety to be met.

#### **6.4. TRIPLE SIMULTANEOUS INDEPENDENT APPROACHES USING PRM**

One hundred thousand independent simulated approaches to runways 22R and 22L were conducted using PRM and an offset localizer for runway 22R. The observed TCV rate was 2.563 percent. Because of the random nature of Monte Carlo simulation, the actual TCV rate may be larger than the observed rate. Therefore, a 99 percent confidence interval was computed for the TCV rate. A 99 percent confidence interval is an interval that is 99 percent certain to contain the actual TCV rate. The upper bound of the 99 percent confidence interval was found to be 2.695 percent. This indicates that with a 99 percent certainty, the actual TCV rate is less than 2.695 percent for the runway pair 22R and 22L.

One hundred thousand simulated evasion maneuvers from runway 22L toward 22R were simulated. The observed TCV rate was 0 percent. The upper bound of the 99 percent confidence interval of the TCV rate was found to be 0.00265 percent. In addition, one hundred thousand simulated evasion maneuvers from runway 22L toward runway 21L were simulated. Again the observed TCV rate was 0 percent. As before, the upper bound of the 99 percent confidence interval of the TCV rate was found to be 0.00265 percent.

For this report, no simulated approaches were conducted between runways 22L and 21L. However, a report (reference 2) will be published this year describing a simulation of parallel simultaneous independent instrument approaches to runways spaced 4,300 FT and 5,000 FT apart. The report indicates that the 99 percent upper confidence interval limit for the TCV rate of the runway pair separated by 5,000 FT is 0.0149 percent. Since runways 22L and 21L are spaced 5,900 FT apart, the 99 percent upper confidence limit for these two runways will be less than 0.0149 percent.

The combined TCV rates for blunders between runways 22R, 22L, and 21L can be shown to be less than 1.36 percent. Therefore, since the TCV rate for each adjacent runway pair is less than 6.8 percent and the combined TCV rate is less than 5.1 percent, the proposed operation meets the target level of safety.

## 8.0. CONCLUSION

The Flight Procedure Standards Branch, AFS-420, was tasked to develop and conduct a safety evaluation of certain critical scenarios involving blunders and missed approaches at the Detroit Metro Wayne County International Airport using its Airspace Simulation and Analysis for TERPS (ASAT) computer system. Six scenarios were simulated.

The first scenario was a simulation of blunders between runways 22L and 21L. These are parallel runways spaced 5,900 feet apart. The target level of safety for dual parallel approaches was determined by the Multiple Parallel Approach Program to be  $4 \times 10^{-8}$ . The simulation indicated that the target level of safety was met for blunders between runways 22L and 21L.

The second scenario was a simulation of dual evasion maneuvers by the two aircraft approaching runways 21L and 22L. Since the aircraft were originally flying dual approaches, the target level of safety for dual approaches was used. The simulation indicated that the probability of two aircraft passing within 500 feet is much less than  $4 \times 10^{-8}$ . Since this probability is less than the target level of safety, the target level of safety was met for evasion maneuvers between runways 22L and 21L.

The results of the first scenario and the second scenario indicate that the target level of safety was met for staggered approaches to runways 22R and 22L with independent approaches to 21L.

The third scenario was a simulation of simultaneous departures and missed approaches from a parallel localizer course. The departures were from runway 22L. An investigation of accident data during missed approaches has not been conducted. However, because the historical fatal accident rate due to all causes is about  $4 \times 10^{-7}$ , the accident rate due to any particular event must be at least one order of magnitude less. Therefore, the TLS for the simultaneous missed approach and departure event was conservatively set at  $1 \times 10^{-8}$ . The probability of two aircraft passing within 500 feet was found to be less than  $7.5 \times 10^{-9}$ . Therefore the target level of safety was met for simultaneous missed approaches and departures between runways 22R and 22L.

The fourth scenario was a simulation of simultaneous departures and missed approaches from a 3 degree offset localizer approach. The missed approach runway was runway 22R and the departure runway was runway 22L. The TLS for the simultaneous missed approach and departure event was also conservatively set at  $1 \times 10^{-8}$ . The probability of two aircraft passing within 500 feet was found to be less than  $1.35 \times 10^{-6}$ . This number is decreased by multiplication with the probability that a departure occurs given that a missed approach occurs. In order for the target level of safety to be met, the probability that a departure occurs given that a missed approach occurs, must not be greater than  $1 \times 10^{-2}$ .

The fifth scenario was a simulation of simultaneous independent approaches to runways 22R and 22L with PRM and the localizer for 22R offset 3 degrees from the extended runway centerline. The TLS of this scenario was  $4 \times 10^{-8}$ . The sixth scenario was related to the fifth scenario since it was designed to determine the probability that a TCV would occur between an evading aircraft from 22L toward 22R. The target level of safety was met by both of these scenarios. By reference to a report by Magyarits and Ozmore, it was shown that the target level of safety was met by triple simultaneous independent approaches to runways 22R, 22L, and 21L with PRM for 22R and 22L and the localizer for 22R offset 3 degrees from the extended runway centerline.

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2. Magyarits, Sherri M., Ozmore, Richard E., *Evaluation of Triple Independent Instrument Landing System Approaches to Runways Spaced 4,000 FT and 5,300 FT Apart Using A Precision Runway Monitor System*, ACT-540, William J. Hughes Technical Center, Atlantic City, NJ, 2002.