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Simulation of Quadruple Simultaneous Parallel ILS Approaches at D/FW - Phase III

Test Report

August 1990

Final Report

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16. Abstract

This study was part of an ongoing effort to evaluate plans for increasing air traffic capacity in the Dallas/Fort Worth (D/FW) area. The objective was to evaluate the traffic handling ability of controllers during Instrument Meteorological Conditions (IMC) for D/FW's proposed quadruple parallel approach airport configuration using a real-time air traffic control (ATC) simulation.

Both dual and quadruple simultaneous parallel Instrument Landing System (ILS) approaches were simulated with controllers monitoring approach traffic. Blunders were introduced by having simulated aircraft deviate toward adjacent localizers. Some of the blundering aircraft also simulated a loss of radio communication. The ability of the controllers to maintain distance between blundering aircraft and aircraft on parallel approaches was the central issue in the study. Additionally, a few runs evaluated the missed approach procedures with the controllers monitoring the departing and missed approach aircraft.

Based upon the findings of the simulation, it was concluded that the quadruple simultaneous parallel ILS approach procedures are safe and workable for the airport configuration (D/FW) tested. Therefore, the operations at D/FW were recommended.

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EXECUTIVE SUMMARY

This study was part of an ongoing effort to evaluate plans for increasing air traffic capacity in the Dallas/Fort Worth (D/FW) area and to evaluate multiple parallel approaches in general. The objective of this study was to evaluate the traffic handling ability of controllers during Instrument Meteorological Conditions (IMC) for D/FW's proposed quadruple parallel runway airport configuration using a real-time air traffic control (ATC) simulation. The proposed changes to the existing D/FW airport configuration included the addition of two additional runways parallel to the four existing runways. Runway 16L was 8500 feet (ft) long located 5000 ft east of 17L with the threshold offset to the south. Runway 16R was 9900 ft long located 5800 ft west of 18R with the threshold offset to the north. Runways 17L and 18R are 11,388 ft long and are spaced 8800 ft apart.

Both dual and quadruple simultaneous parallel Instrument Landing System (ILS) approaches were simulated with controllers monitoring traffic on the approach localizers. Blunders were introduced, according to predetermined scenarios, by having simulated aircraft deviate off the localizer at 10, 20, or 30 degree angles. Some of the blundering aircraft also simulated loss of radio communication with the controllers. The ability of the controllers to maintain distance between blundering aircraft and aircraft on parallel approaches was the central issue in the study. Additionally, a few runs evaluated the missed approach procedures with the controllers monitoring the departing and missed approach aircraft. Missed approaches were initiated to evaluate the controller's ability to maintain distance between missed approach aircraft and departing aircraft. Four questions were to be answered:

1. Can the controllers maintain miss distances of greater than 500 ft between aircraft, in response to blunders, for the proposed approach configuration?

2. Are there statistical differences between the miss distances achieved in the dual and quadruple operations? If so, are the differences operationally significant?

3. In the event of a missed approach, can the controllers maintain miss distances of greater than 500 ft between departing aircraft and the missed approach aircraft for the proposed airport configuration?

4. Do the controllers, controller observers, and ATC management observers view the quadruple approach operation as acceptable, achievable, and safe?

All of the blunders in both the dual and quadruple approach operations resulted in slant range miss distances that were greater than 900 ft. While manning the departure monitor positions, controllers maintained a minimum miss distance of 3765 ft between missed approach aircraft and other aircraft. These values were both greater than the 500 ft test criterion used in the simulation.

Analysis of the CPA and the API metrics indicated that the quadruple approach operation resulted in miss distances that were statistically less than the miss distances that occurred in the dual approach operation. The miss distances between the aircraft in the quadruple approach operation were generally large (average miss distance = 7763 ft). The difference between the average miss distances for dual and quadruple approaches was small (1216 ft) relative to the average miss distance, therefore, it was determined that there were no operational differences between the dual and quadruple approach conditions.

The controllers who participated in the simulation found the quadruple approach operation to be a "safe, efficient, and workable procedure."

The Multiple Parallel Technical Work Group (TWG), composed of air traffic control, flight safety, flight standards, and operations personnel, participated in the simulation and evaluated the simulation findings. Based upon the TWG's understanding of (1) daily operations, (2) the knowledge and skills of controllers, and (3) the contingencies which must be accounted for, the TWG found the quadruple approaches, simulated for D/FW, as acceptable, achievable, and safe.

Based upon the findings of the statistical analysis, the Administrative Assessment, the Controllers Report, and the Industry Observer comments, it was concluded that the quadruple simultaneous parallel ILS approach procedures are safe and workable for the airport configuration (D/FW) tested in this simulation. Therefore, the TWG recommended the implementation of quadruple simultaneous parallel ILS approach operations at D/FW. The TWG further recommends:

1. There shall be one monitor controller for each runway. Personnel and equipment shall be provided to support the procedure.

2. All monitor positions should be located together and near their respective arrival and departure positions.

3. Radar coverage must be provided through the missed approach point to a point 7 nautical miles (nmi) beyond the departure end of the runway. Coverage shall be as low as 50 ft above the runway surface or as approved by flight standards. Approach minimums will be dependent upon the lowest point at which radar coverage can be provided, e.g., CAT II minimums if radar coverage can be accomplished as low as 50 ft above the runway surface, etc.

4. The No Transgression Zone (NTZ) needs to be extended through the missed approach to a point 7 nmi beyond the departure end of the runways.

5. The Implementation Strategy used prior to conducting quadruple approaches to the lowest authorized minimum for D/FW shall include a phase-in period, 60 days or 1000 approaches, with a minimum visibility of 1500 ft/3 nmi.

1. INTRODUCTION.

1.1 OBJECTIVE.

The Federal Aviation Administration (FAA) is evaluating the capability of multiple (triple and quadruple) parallel runways to increase airport capacity without degrading safety. The goal is to develop national standards for using multiple simultaneous parallel Instrument Landing System (ILS) approaches with both existing and new technology radar and display equipment. Dallas/Fort Worth (D/FW) International Airport has proposed an expansion which would permit quadruple simultaneous parallel ILS approaches and quadruple simultaneous departures/missed approaches on parallel runways separated by at least 5000 feet (ft). The objective of this simulation was to evaluate the traffic handling ability of controllers during Instrument Meteorological Conditions (IMC) at D/FW's proposed quadruple parallel airport configuration using a real-time air traffic control (ATC) simulation.

In an effort to develop procedures for simultaneous departures/ missed approaches on four parallel runways at D/FW, No Transgression Zones (NTZ) were established to a point 7 nautical miles (nmi) from the runway departure end. Aircraft were monitored until standard separation was achieved, i.e., 1000 ft vertical and/or a 15 degree course divergence.

1.2 BACKGROUND.

The ability of the National Airspace System (NAS) to handle the projected increase in air traffic is a serious problem. Efforts to alleviate the problem include redesign of the airways, central flow management, and automation of the ATC system. There has been a long-term effort to increase the capacity of the NAS, both to reduce air traffic delays and to handle the anticipated increase in demand. The FAA is investigating the use of triple and quadruple parallel runways as one means by which to increase airport capacity while maintaining the high level of safety.

1.2.1 Airport Limitations.

The number of aircraft that can land at an airport during IMC is a significant limitation on system capacity. An area for improvement concerns the number of simultaneous parallel ILS approaches that can be made during IMC. The present limit is two, but there has been interest in triple and quadruple simultaneous ILS approaches for more than 10 years. [1, 2]

The implementation of multiple parallel approaches would require an analysis of current procedures to determine their applicability in conducting triple and quadruple simultaneous ILS approaches.

The following procedures apply to dual parallel approaches as per "Air Traffic Control," FAA Order 7110.65F, Paragraph 5.126 (September 1989):

a. When parallel runways are at least 4300 ft apart, authorize simultaneous ILS, Microwave Landing System (MLS), or ILS and MLS approaches to parallel runways if:

1. Straight-in landings will be made.

2. ILS, MLS, radar, and appropriate frequencies are operating normally.

b. Clear the aircraft to descend to the appropriate glide slope/glidepath intercept altitude soon enough to provide a period of level flight to dissipate excess speed. Provide at least 1 nmi of straight flight prior to the final approach source intercept.

c. Vector the aircraft to intercept the final approach course at an angle not greater than 30 degrees.

d. Provide a minimum of 1000 ft vertical or a minimum of 3 nmi radar separation between aircraft during turn-on to parallel final approach. Provide the minimum applicable radar separation between aircraft on the same final approach course.

Note: Aircraft established on a final approach course are separated from aircraft established on an adjacent parallel final approach course provided neither aircraft penetrates the depicted NTZ.

e. When assigning the final heading to intercept the final approach course, issue the following to the aircraft:

1. Position from a fix on the localizer course or the MLS azimuth course.

2. An altitude to maintain until established on the localizer course or the MLS azimuth course.

3. Clearance for the appropriate ILS/MLS runway number approach.

f. Monitor all approaches regardless of weather. Monitor local control frequency to receive any aircraft transmission. Issue control instructions and information necessary to ensure separation between aircraft and to ensure aircraft do not enter the NTZ.

Note 1: Separate monitor controllers, each with transmit/receive and override capability on the local control frequency, shall ensure aircraft do not penetrate the depicted NTZ. Facility directives shall delineate responsibility for providing the minimum applicable longitudinal separation between aircraft on the same final approach course.

Note 2: An NTZ, 2000 ft wide, is established equidistant between runway centerlines extended and is depicted on the monitor display. The primary responsibility for navigation on the final approach course rests with the pilot. Therefore, control instructions and information are issued only to ensure separation between aircraft and that aircraft do not penetrate the NTZ. Pilots are not expected to acknowledge those transmissions unless specifically requested to do so.

Note 3: For the purposes of ensuring an aircraft does not penetrate the NTZ, the "aircraft" is considered the center of the primary radar return for that aircraft.

(1) When aircraft are observed to overshoot the turn-on or to continue on a track which will penetrate the NTZ, instruct the aircraft to return to the correct final approach course immediately.

(2) When an aircraft is observed penetrating the NTZ, instruct aircraft on the adjacent final approach course to alter course to avoid the deviating aircraft.

(3) Terminate radar monitoring when one of the following occurs:

(a) Visual separation is applied.

(b) The aircraft reports the approach lights or runway in sight.

(c) The aircraft is 1 mile or less from the runway threshold, if procedurally required and contained in facility directives.

(4) Do not inform the aircraft when radar monitoring is terminated.

g. When simultaneous ILS, MLS, or ILS and MLS approaches are being conducted to parallel runways, consideration should be given to known factors that may in any way affect the safety of the instrument approach phase of flight, such as surface wind direction and velocity, wind shear alerts/reports, severe weather activity, etc. Closely monitor weather activity that could impact the final approach course. Weather conditions in the vicinity of the final approach course may dictate a change of approach in use. [3, 4]

These requirements have been studied by the FAA for a number of years. Operations research based models of the system have been used to study various safety restrictions and capacity limitations.

[1, 5, 6, 7, 8, 9, and 10] Analyses have considered controller and pilot response times, navigational accuracy on the localizers, radar accuracy, and update rates, etc. [11]

1.2.2 ATC Standards Modification Requirements.

The requirement for modifying ATC standard procedures is the demonstration of safety. Evidence supporting safety as a result of proposed system changes can be obtained in a number of ways:

a. Demonstrate, through the collection and analysis of operational data, that present standards are unnecessarily restrictive.

b. Conduct flight tests proving the feasibility and safety of proposed changes.

c. Conduct operations research, math modeling, or fast-time simulation and examine the impact of proposed changes on a variety of operational parameters and contingencies.

d. Conduct real-time ATC simulation studies of the changed system, introduce errors and failures, and compare the results with those of present operations.

These approaches are neither independent nor mutually exclusive. Reliable field data are the basis for successful modeling and for simulation. Real-time ATC simulation, flight simulation, and flight testing are needed to generate estimates of the operational parameters used for modeling and fast-time simulation. Modeling provides a framework for collecting and analyzing field data.

The desire to provide absolute certainty in the outcome of an extremely rare event may reduce system capacity below acceptable limits. Ultimately, it falls to experienced system users (e.g., controllers, pilots, and operations personnel) to weigh the evidence and decide upon the proposed change, based on (1) their understanding of daily operations, (2) the knowledge and skills of controllers, and (3) the contingencies to which the system must respond.

1.2.3 Previous Multiple Parallel Runway Studies.

Early studies of multiple runways concentrated on reducing separation between aircraft during simultaneous parallel approaches. [1, 2, 5, 6, 7, 8, 9, and 10] These studies have indicated that the reduction of separation between aircraft is dependent upon many factors, including, e.g., pilot/aircraft navigational accuracy (flight technical error (FTE)), radar update, radar accuracy, and controller displays.

A simulation conducted in 1984 investigated runway spacing, modified radar displays, improved radar accuracy, and higher radar update rates. [11] The study established the importance of navigational accuracy in determining system capacity and showed the relationships between a number of system (radar) parameters and the controllers' abilities to cope with blunders.

Since the 1984 simulation was completed, navigational error data has been collected for Memphis International Airport and the Chicago O'Hare facility. [12 and 13, respectively] The data from these surveys, which directly considered simultaneous parallel approaches under IMC, were used in the development of the FTE model for the present simulation.

Additional real-time ATC simulations were conducted at the FAA Technical Center to investigate parallel runway questions. [14, 15] These studies complement the models cited above since they generate estimates of the model parameters and, more importantly, allow direct observation and recording of criterion measures related to safety and capacity. The 1988 and 1989 D/FW simulations constituted Phases I and II of a six phase program designed to develop procedures for triple and quadruple simultaneous ILS approaches.

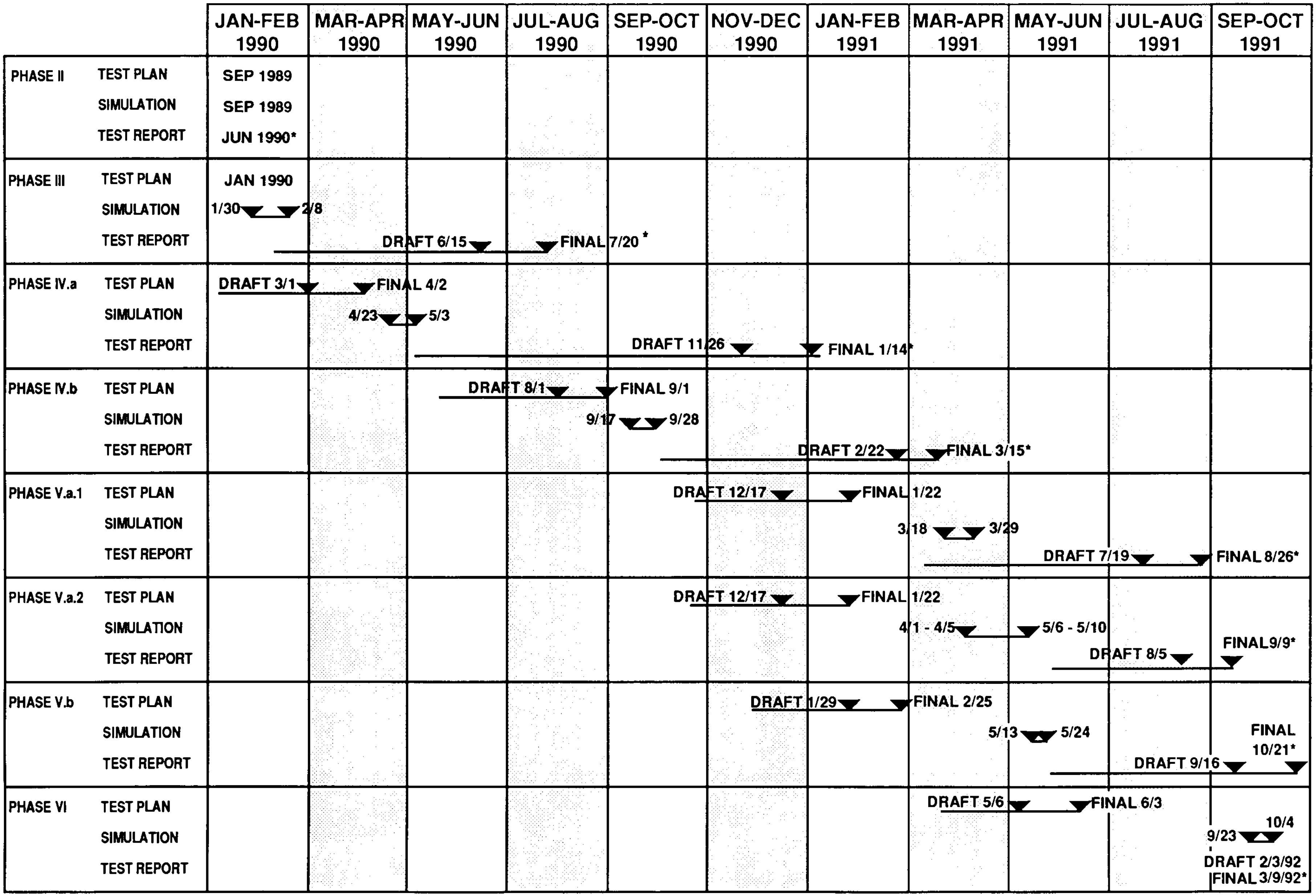
1.2.4 Triple and Quadruple Simultaneous ILS Approach Procedural Development Program.

This is a six phase program designed to develop procedures for triple and quadruple simultaneous ILS approaches. Real-time ATC simulations of triple and quadruple approaches will be used to assess their acceptability, achievability, and safety and to develop ATC procedures. The schedule is shown in figure 1.

1.2.4.1 Phase I.

The D/FW Phase I simulation was conducted at the FAA Technical Center from May 16 to June 10, 1988. This was a two-part study designed to test selected aspects of the quadruple approach operation. The first part of the simulation evaluated concepts for using additional routes, navigational aids, runways, en route and Terminal Radar Approach Control Facility (TRACON) traffic flows in the implementation of quadruple approaches.

The second part of the simulation focused on the quadruple ILS parallel approach operation. The runway configuration consisted of the two existing 11,388 ft runways (17L and 18R), which have a centerline spacing of 8800 ft, and two new 6000 ft runways. The first, 16R, was 5800 ft west of the 18R centerline, and the second, 16L, was 5000 ft east of the 17L centerline.



* ALLOW 2 MONTHS FOR PUBLISHING

FIGURE 1. AIRPORT CAPACITY IMPROVEMENT PROGRAM SIMULATION SCHEDULE

The analyses indicated that blunders which threatened more than one approach were no more dangerous than blunders which threatened only one approach. Additionally, the controllers agreed that the new configuration maximized the en route airspace. [16] Based upon this simulation, triple parallel ILS approaches were approved for D/FW with only turboprop aircraft landing on 16L.

1.2.4.2 Phase II.

This simulation was conducted from September 25 to October 5, 1989, at the FAA Technical Center. The simulation assessed the D/FW triple simultaneous ILS approach operation. The airport configuration used a new 8500 ft runway, 16L, located 5000 ft east of the runway 17L centerline.

Analyses indicated that controllers were able to intervene in the event of a blunder and provide distances between conflicting aircraft in the triple approach condition that were comparable to the distances achieved in the dual approach condition. No blunder in either the dual or triple condition resulted in a slant range miss distance of 1100 ft or less. Additionally, the controllers, controller observers, and ATC management observers concluded that the proposed triple approach operation at D/FW was acceptable, achievable, and safe. [17] Results from this simulation supported the approval of turbojets operating on all runways.

1.2.4.3 Phase III.

This is the simulation currently being reported. The Phase III simulation reconsidered the D/FW quadruple simultaneous ILS approach and departure/missed approaches operation assessed in Phase I with changes in runway lengths and traffic samples. Runway 16L was 8500 ft long and 16R was 9900 ft long. The traffic samples included props, turboprops, and turbojets on the outer runways and turbojets only on the inside runways.

1.2.4.4 Phase IV.

The purpose of the Phase IV simulations is to develop national standards for triple simultaneous ILS approach operations using a current radar system, Airport Surveillance Radar (ASR)-9 and display, and Automated Radar Terminal Systems (ARTS) IIIA. Phase IV will be conducted in two simulations:

a. Phase IV.a (conducted April 24 to May 3, 1990) assessed triple simultaneous ILS approaches with 4300 ft between runway centerlines with even thresholds. This simulation included the integration of a Phase II CAT-121 B-727 flight simulator and a General Aviation Trainer (GAT) flight simulator. The results of this simulation are currently being assessed.

b. Phase IV.b will assess triple simultaneous ILS approaches with 5000 ft between runway centerlines with even thresholds. This simulation will include the integration of three Phase II CAT-121 flight simulators and one GAT flight simulator. This simulation is scheduled to be conducted at the FAA Technical Center from September 18 to 27, 1990.

1.2.4.5 Phase V.

The purpose of the Phase V simulations is to assess runway spacing in the triple simultaneous ILS approaches operations using the Sony 20x20 inch color displays and controller aids. Additionally, high update radar and other new technology systems will be assessed in future simulations. The results of these simulations will be used for the development of national standards for multiple parallel approach airport configurations using the new technology equipment. The first Phase V simulation is currently scheduled to be conducted from March 19 to April 5, 1991, at the FAA Technical Center.

1.2.4.6 Phase VI.

The Phase VI simulations will assess quadruple simultaneous ILS approaches with not less than 4300 ft between centerlines with even thresholds. These simulations will be developed based upon the results of both Phases IV and V simulations.

2. PHASE III - SIMULATION OF QUADRUPLE SIMULTANEOUS ILS APPROACHES AT D/FW.

This section describes the simulation performed January 29 through February 9, 1990, at the FAA Technical Center. An overview of the simulation, a description of the controllers, facilities, experimental design and procedures, as well as a discussion of the various approaches utilized in data analysis are presented in sections 2.1 through 2.6.

2.1 SIMULATION OVERVIEW.

The Phase III simulation evaluated quadruple independent ILS parallel approaches at the D/FW airport. The simulation was designed to examine operational issues relative to implementing quadruple independent parallel approaches to the D/FW facility.

The participating controllers manned the approach or departure monitor positions to monitor traffic movement in accordance with established procedures. [3] The controllers issued instructions, via voice communications, which caused the pilot to respond appropriately unless scripted otherwise. The controllers' task was to maintain adequate distances between aircraft at all times.

Aircraft began the simulation on the ILS, approximately 20 nmi from the threshold, and flew approximately 180 knots until intercepting the glide slope. The aircraft began the approach with the standard aircraft separation distance as determined by aircraft type. Every 1 to 5 minutes an aircraft was randomly chosen to execute a blunder. The blunder was a deviation of 10, 20, or 30 degrees from the ILS heading toward an adjacent ILS. The controllers issued vector and/or altitude changes to aircraft which were affected directly or indirectly by the blundering aircraft.

The simulation addressed four questions:

a. Can the controllers maintain the test criterion miss distance of greater than 500 ft between aircraft, in response to blunders, for the proposed approach configuration?

b. Are there statistical differences in the achieved miss distances between the dual and quadruple operations? If so, are the differences operationally significant.

c. Do the controllers, controller observers, and ATC management observers view the quadruple approach operation as acceptable, achievable, and safe?

d. In the event of a missed approach, can the controllers maintain the test criterion miss distance of greater than 500 ft between departing aircraft and the missed approach aircraft, for the proposed airport configuration?

2.1.1 Controller Activities.

Separate monitor controllers, each with transmit/receive and override capability on the local control frequency, monitor the final approach courses to ensure that aircraft did not penetrate the NTZ. When aircraft penetrated the NTZ, controllers issued instructions necessary to achieve longitudinal, lateral, and/or vertical separation between aircraft. Facility directives delineated responsibility for providing the minimum applicable longitudinal separation between aircraft on the same final approach course. An NTZ 2000 ft wide, established equidistant between extended runway centerlines, was depicted on the monitor display. Coordination among the controllers also ensured effective responses to the potential conflict situation.

2.1.2 Blunders.

Blunders occurred when an aircraft established on the localizer deviated from its intended course. Deviations usually resulted in aircraft coming into conflict with each other. Depending on the degree of blunder from the localizer, the controller (1) instructed the blundering aircraft to rejoin the localizer or (2) instructed the blundering aircraft and aircraft on adjacent runways to make changes in heading and/or altitude. Thus, aircraft were vectored away from the blundering aircraft to ensure adequate miss distances between the aircraft.

2.1.3 Airport Configuration.

The Phase III simulation evaluated independent quadruple parallel approaches at the D/FW airport. Runways modeled were the existing 17L and 18R, a proposed east runway (16L) 8500 ft long and 5000 ft from 17L, and a proposed 9900 ft west runway (16R), located 5800 ft from 18R. The distance between the existing 18R and 17L runways was 8800 ft. Traffic consisted of turbojets, props, and turboprops on the outer runways and only turbojets on the inner runways (see figure 2).

Aircraft started on the localizers and maintained the altitude at which they were cleared until intercepting the glide slope, as shown in table 1. Only the monitor controller positions were manned during the simulation.

The airport layout, runways, arrival frequencies, and displays emulated D/FW except for modifications necessary for test purposes. Patch-in telephone communications and computer links were used during the simulation.

2.1.4 Traffic Samples.

Traffic samples were based on flight strips and computer printouts from the D/FW TRACON and consisted of representative aircraft types and identifiers. The samples permitted the exercise of maximum system capacity.

Five traffic samples were developed for the quadruple runs. The number of traffic samples for the dual runs is three since the small number of dual runs greatly reduced the possibility of controllers learning to predict the traffic and blunders.

The Phase III simulation included two to three speed overtakes during each run. These were accomplished by introducing small variations in the speed at which aircraft turned on to the localizer.

2.1.5 Navigational Error Model.

A review of the Chicago O'Hare Radar Data (ORD), by the FAA ATC Technology Branch, ACD-340, showed that many aircraft gradually home in on the localizer (i.e., follow paths that are asymptotic to the localizer), rather than oscillating around the localizer with reductions in oscillation amplitude as they proceed to the threshold. To accurately model the actual motion of aircraft, a concept of pseudoroutes was employed. A pseudoroute was defined as a route starting at one of several fixes offset from the extended

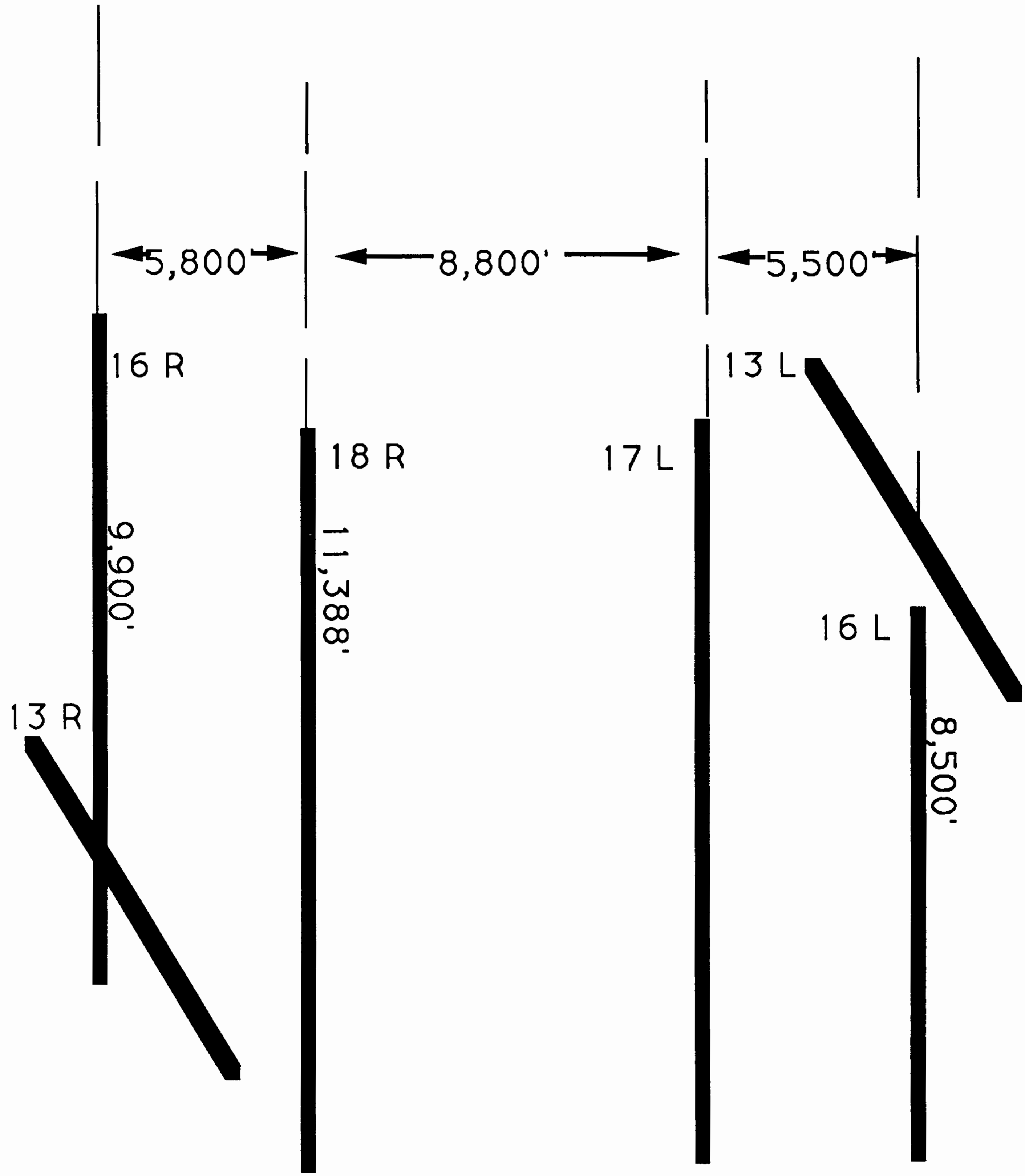


FIGURE 2. AIRPORT CONFIGURATION

TABLE 1. ILS RUNWAY TURN ON ALTITUDES

Runway	Turn On Altitude (ft)	Glide Slope Intercept (nmi from threshold)
16L	5000	15.7
17L	7000	22.0
18R	6000	18.8
16R	5000	15.7

ILS centerline and joining the ILS at the threshold, as shown in figure 3. Each aircraft was assigned to fly the localizer or one of four pseudoroutes. These pseudoroutes were offset from the localizer by + 0.2 degrees and + 0.35 degrees. Forty percent of the aircraft flew on the localizer; 20 percent flew each inside pseudoroute, and 10 percent flew the outside pseudoroutes.

The navigational error model generated FTE on the ILS localizer by creating an occasional "wandering"[1] aircraft. The computer program considered each aircraft currently on the localizer at regular intervals and determined whether to give it a deviation off the localizer. Only aircraft travelling on the center pseudoroute were subject to "wandering." This decision was made on a random basis, with a fixed probability at each "look." If there was to be a deviation, tables of random values were used to determine the angle and length of time the aircraft would stay on the deviated course before returning to the localizer. The combination of frequency of deviation, size of deviation, and duration of deviation determined the accuracy of the sample.

The selection of parameters for these variables, mean and standard deviation, or range, are based on two criteria:

a. The flightpaths of individual aircraft should look reasonable to the controllers (i.e., deviations from the localizer centerline should be typical of "wandering" aircraft).

b. The aggregate errors should reflect the accuracy typical of aircraft in the traffic sample (i.e., the ORD data).

Controller intervention is permitted to correct FTE or "wandering."

[1]A "wanderer" is an aircraft whose navigation performance is so poor that it may deviate into the NTZ unless a controller takes corrective action. If no action is taken, the aircraft will return o its own to the localizer.

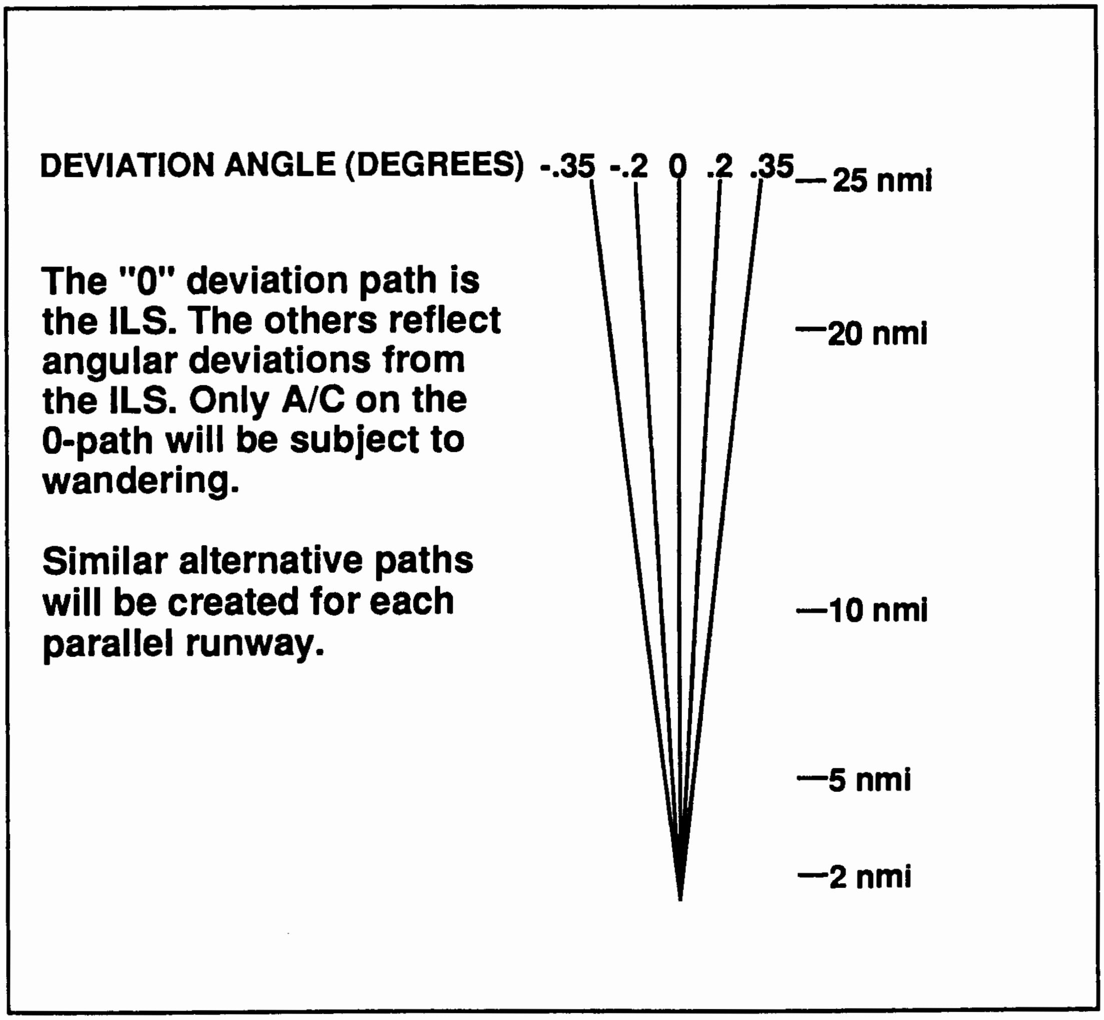


FIGURE 3. PSEUDOROUTE DIAGRAM

2.2 CONTROLLERS.

Seven controllers from D/FW participated in this simulation. All seven were current full performance level air traffic controllers. They had an average of 12.2 years of career experience and an average of 7.2 years experience working parallel approaches. Controller assignments to runs and runway positions are shown in table 2, which also shows the schedule for the simulation. The controller assignments were determined by the following restrictions:

a. No controller would participate in more than two consecutive runs per day, and a total of no more than three runs in 1 day.

b. Controller assignments would be balanced among dual, departure control, and quadruple runs.

c. Each controller's assignments were to be equally divided with respect to inner and outer runways in the quadruple and departure control conditions.

2.3 SIMULATION FACILITY.

The simulation was conducted in the National Airspace System Simulation Support Facility (NSSF) ATC Laboratory at the FAA Technical Center. Sections 2.3.1 through 2.3.3 describe the ATC Laboratory, the simulator pilot, and the computer facilities used in the simulation.

2.3.1 ATC Laboratory.

In the controller laboratory, the controllers monitored Plan View Displays (PVDs) and directed traffic movement in accordance with established procedures. As in the real world, the controller in the NSSF Laboratory had voice communications with the aircraft under his control in order to issue instructions or clearances which cause the aircraft to respond accordingly. There was also a controller-to-controller voice interface that allowed a coordination of actions among the various control positions. In addition, there is a digital interface to the central computer facility that consisted of a keyboard and trackball, as in the real world, which controlled the presentation of data on the controller's display.

2.3.2 NSSF Simulator Pilot Facility.

The NSSF simulator pilot facility housed the simulator pilots. The simulator pilots did not actually fly the aircraft but converted verbal clearances into data entry messages via a keyboard. The messages were then transmitted to the Central Computer Complex (CCC) where the appropriate responses were generated. As in the

TABLE 2. CONTROLLER/RUNWAY ASSIGNMENTS

Date	Run	Quads/Departures* Runway 16R	Quads/Departures* Runway 18R	Quads/Departures* Runway 17L	Quads/Departures* Runway 16L	Duals A1 Runway 16R	Duals A1 Runway 18R	Duals A2 Runway 18R	Duals A2 Runway 17R	Duals A2 Runway 17L	Duals A2 Runway 16L
1/30		Abbreviated Practice Runs of Dual and Quad Approaches									
	1							E	G	F	C
	2					B	F			A	E
1/31	3	A	G	D	B						
	4	E	C	F	A						
	5					C	G			D	B
	6	F	B	G	E						
	7	D	A	E	C						
2/1	8	G	D	C	A						
	9					F	A	B	E		
	10	E	F	B	G						
	11	D	A	G	C						
	12	B	D	C	F						
2/2	13	F	C	A	D						
	14	B	G	D	E*						
	15	A	E	C	F*						
	16	C	D	G	A						
	17	B	E	F	G						
2/5	18	A	E	B	F						
	19	C	G	D	E						
	21	F	B	E	A						
	22	G	F	C	D						
	20	G	C	A	D*						
2/6	23	F	D	A	B						
	24	C	F	B	G*						
	25	E	G	D	C						
	26	B	A	E	D						
	27					E	C	F	G		
2/7	28	E	A	C	F						
	29	D	F	B	G						
	30					A	E			G	D
	31							A	C	B	G
	32	B	D	F	E*						

* Departure runs using runways 16R, 18L, 17R, and 16L completed.

real world, these simulator pilots were in voice communications with the controllers. This voice link allowed the controllers to issue clearances to the simulator pilots as if they were real pilots.

It was possible for the controllers to use existing ATC clearances and procedures, thereby, keeping the interface between the pilot and the controller as realistic as possible. Each simulator pilot usually controlled several aircraft and was provided a display of data concerning the current status of each aircraft. This data, which would have been available to a real pilot, included the aircraft's speed, heading, and altitude.

2.3.3 Computer Facility.

The CCC also simulated all other aspects of the air traffic system. These included the aircraft model and the functions of the ATC ground facility. The aircraft model actually controlled the aircraft by dynamically updating each aircraft's position based upon its last position and current status (i.e., turning, climbing, and accelerating). An aircraft's status was constantly monitored to reflect changes caused by predetermined flight plans, maneuvers, and/or controller directions.

In providing the functions of the ATC ground facility, the central computer simulated the radar-beacon, target detection system, and maintained and updated information on the controller displays.

2.3.4 Software.

Target Generation Programs (TGPs) performed the basic aircraft simulation functions which included target initialization, target update, navigation, holding, approach simulation, simulator pilot processing, radar processing, and data collection.

Data Reduction and Analysis Routines provided a means of extracting and analyzing the data measures related to the concept under study. The reports provided such data as: lists of all violations of ATC separation standards including the position and motion characteristics of each aircraft at the start and end of the violation, the duration of the violation, the horizontal and vertical separation of the closest point of approach, and a categorization of the instructions (e.g., speed commands and vectors) issued to each aircraft.

2.3.5 Voice Communications.

Controller and NSSF simulator pilot voice communications were recorded using a 20-channel audio recorder at the FAA Technical Center. Controller and NSSF simulator pilot verbal response times to blunders were extracted and statistically analyzed. Synchronization of the audio, video, and computer data was accomplished through the insertion of a "time hack," corresponding to simulator run time, onto the video and audio recordings.

2.3.6 Video Recording.

Continuous video recordings, with sound and time synchronization, were made to assist in the interpretation of events and the analysis of computer recorded data. One radar display, showing the four monitor positions, was dedicated to video recording using an S-VHS format video recorder. Two microphones were used to record controllers' voices during each run. There was one microphone for each pair of controllers. This would permit the analysis of interaction between controllers where it was deemed necessary.

2.4 CONTROLLER AND INDUSTRY OBSERVER QUESTIONNAIRES.

Following each run, a questionnaire and a workload rating scale was administered to the controllers. The questionnaire assessed their opinions concerning run realism, difficulty, controllability, and their recommendations for operational use. The workload rating scale was derived from the Modified Cooper-Harper Scale. The work load rating scale was used to assess mental workload.

Information from industry observers was acquired through a questionnaire. Observers were queried about their perception of simulation realism and the workability of the approaches.

2.5 SIMULATION PROCEDURES.

During the simulation, 7 runs employed dual approaches, 25 runs used the proposed four-runway operation, and 5 runs served to assess the effects of scripted missed approaches on departure control operations. All runs were 60 minutes in length, with a 10 to 20 minute turnaround between runs. To maximize data collection, three independent two-runway airports were modeled (5000, 5800, and 8800 ft spacing) with two of the three configurations used for any given dual approach run. Thus, four controller workstations were used for the Phase III simulation.

The first morning of the simulation was used to familiarize controllers with the NSSF Laboratory and the equipment. Additionally, practice runs using dual and quadruple simultaneous parallel ILS approaches were conducted to familiarize the controllers with the strategies involved in the control of aircraft for the runway configurations. The practice runs were abbreviated in length, and the data from these runs were not subjected to formal analysis. Two dual simultaneous parallel ILS approach runs were conducted during the afternoon of the first day of simulation. These runs were not abbreviated in length and were subjected to formal analysis. Five more dual runs were interspersed among the quadruple and missed approach runs.

The five departure control runs were conducted with an automatic simulation of arriving traffic on runways 16R, 18R, 17L, and 16L. Twenty percent of the aircraft executed missed approaches. The missed approaches were scripted by personnel from the Technical Programs Division, AFS-400, and the Aviation Standards National Field Office, AVN-540. A member of the Southwest Regional Office Air Traffic Division cleared aircraft for takeoff. Controllers were assigned to monitor the departure runways and keep missed approach aircraft from entering the NTZ. Finally, AFS-400 and AVN-540 personnel instructed a number of missed approach aircraft (i.e., approximately 17 per run) to drift 15 degrees right or left of the centerline, which simulated adverse wind effects. Assignments to drift to the left or right were made on a random basis. This resulted in aircraft drifting toward each other or drifting toward non-drifting aircraft. The airport configuration used for the departure control runs is shown in figure 2.

2.5.1 Blunder Scripts.

The test director and his assistant used scripts when issuing turns to aircraft established on the localizer to create blunders. Turns were 10, 20, or 30 degrees, always toward at least one other localizer, and blundering aircraft were individually instructed (according to the script) as to whether they could acknowledge and respond to any controller communications.

For the four-runway airport, 50 percent of the blunders on the center approaches occurred to the left and 50 percent occurred to the right of the localizer centerline. Blundering aircraft on the outside approaches (16R and 16L) moved toward the inside localizers. In the two-runway system, blunders from each localizer were initiated toward the other localizer. Blunders commenced 16 nmi or less from threshold, after the glide slope intercept for all approaches.

The blunder scripting for Phase III is one which (1) included a sufficient number of blunders and (2) provided sufficient variability in the blunder distribution. The scripting of blunders was as follows:

The scripting of blunders established an average interval of 3 minutes between blunders, with maximum and minimum blunder intervals of 5 minutes and 1 minute, respectively. The blunders were random and uniformly distributed. This scripting scheme yielded an average of 17 blunders per hour. The total number of blunders in the 22 quadruple scenarios was approximately 370.

The blunders were scripted so that aircraft randomly maintained altitude or descended following a blunder. Each scenario included one or two blunders which occurred within 2 miles of the threshold. A scenario was created for each run in the simulation.

2.6 ANALYSIS APPROACHES.

2.6.1 Experimental Assessment.

This assessment focuses on statistical analysis of the computer data from the simulation, and an interpretation of the results in light of the safety related questions posed in the study. The Closest Point of Approach (CPA) is the smallest slant range distance occurring between two aircraft while in conflict. The CPA and the Aircraft Proximity Index (API) were used to evaluate the observed aircraft miss distances as an estimate of the relative safety of the conditions employed in this study (see appendix A).

Among the questions answered using the Experimental Assessment were the following:

a. Were there differences in CPA and API as a function of approach condition or the number of runways threatened by a blunder?

b. Was there a quantitative difference in CPA and API between blunders threatening only one runway in the quadruple runway condition and blunders observed in the two-runway condition?

c. What was the impact of the degree of blunder and communication/no communication conditions during a blunder on CPA and API?

d. Did controllers' response time to a blunder vary as a function of degree of blunder, runway separation, and the number of runways (i.e., dual versus quadruple approach)?

2.6.2 Operational Assessment.

The operational assessment approach evaluated each incident that met criteria spelled out in figure 4, "Operational Assessment Decision Tree," as if it had occurred in an operational environment. The analysis of each event considers data from many sources, including controller and technical observer reports, computer data, and video and audio tape materials. This approach provides a systematic review of the results of each blunder. Should a comprehensive review be necessary (i.e., a blunder has resulted in a slant range distance of 500 ft or less), the review will be conducted by the Multiple Parallel Technical Work Group (TWG) composed of representatives of each of the FAA organizations involved in the study. A detailed report will present the finding of this review.

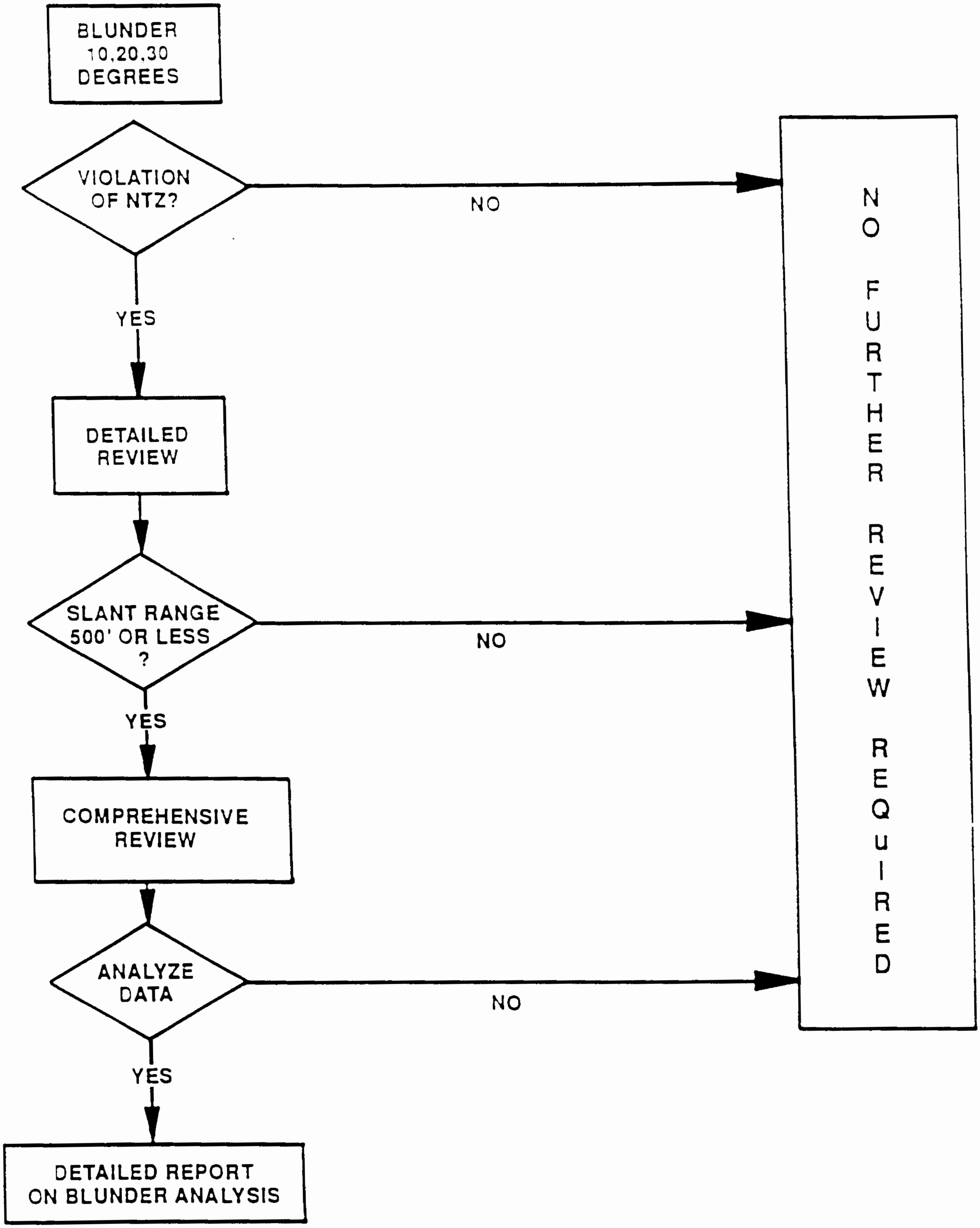


FIGURE 4. OPERATIONAL ASSESSMENT DECISION TREE

2.6.3 Administrative Assessment.

This approach provided the overview analysis and documentation of the simulation. This is performed by the TWG. The material used by the TWG for the overview analysis included:

a. Controller evaluation and comment reports.

b. Industry observer written evaluations and comments.

c. The Quadruple Parallel Runway Simulation Controller Report which included comments, evaluations, and recommendations (see appendix G).

3. PHASE III - ATC SIMULATION OF QUADRUPLE RUNWAYS AT D/FW.

This section describes the findings of the Phase III Simulation. Section 3.1 presents the results of the statistical analyses performed on the aircraft miss distance data. The next section, 3.2, describes the controller questionnaire results. The controller and pilot/aircraft response time data are presented in section 3.3.

3.1 AIRCRAFT MISS DISTANCE ANALYSES.

The blunder event may result in more than one conflict. Generally, a blunder in the dual approach condition will result in two conflicts and a blunder in the quadruple approach condition will result in three or more conflicts. Usually, only the conflict involving the blundering aircraft and aircraft on the adjacent approach is of a serious nature. Therefore, the analyses conducted on aircraft miss distances considered only the worst conflict caused by each blunder. If all conflicts were considered, the quadruple approach condition data would contain a disproportionate number or nonserious conflicts.

In addition to the descriptive statistics reported (e.g., means, standard deviations), the analyses of the aircraft miss distance data utilized a number of inferential statistics, including analysis of variance and t-tests for independent samples.

With regard to the analysis of variance technique, two types of effects are considered: main effects and interactions. A main effect is the effect of a variable considered in isolation. For example, the main effect of communication condition would consider the effect of having (or not having) radio communication between controller and simulator pilot, on a system performance measure, such as API. Other variables which might influence this effect (e.g., runway separation, degree of blunder) are ignored.

An interaction, on the other hand, represents the joint effect of two or more variables considered together. A significant interaction occurs when either (1) a variable has disproportionate effects at different levels of the other variable(s), or (2) a variable has opposite effects at different levels of the other variable(s). As an example, if API values increased from the dual to the triple approach condition for the with radio communication condition, but decreased from the dual to triple approach condition for the no radio communication condition, an interaction would exist in the data.

Main effects and interactions in an analysis of variance are denoted by F statistic values. The presentation of these values is exemplified by $F(1,21) = 19.05$, $MSE = 2.43$, $p. < .01$, where the numbers in parentheses following the F signify the numerator and denominator degrees of freedom. MSE stands for mean square error, the error term used in the F test.

In order to compare the means of two independent samples, T-tests are used in this report. The format used to report the "t" is exemplified by ($t(5) = 2.14$, $p. < .01$), where the number in parentheses following the "t" signifies the degree of freedom for the test.

It should be noted that these tests are used to assess statistical differences between samples. The differences found between samples should then be evaluated to determine if the statistical difference would have an operational effect on the procedure.

3.1.1 Dual Versus Quadruple Approach Data.

The data analysis reported in this section compares the dual and quadruple approaches with regard to the safety issues.

3.1.1.1 CPA Analysis.

A total of 495 of the 514 blunders generated in the Phase III simulation resulted in a conflict situation. Of these, 194 occurred in the dual approach condition, and 301 occurred in the quadruple approach condition. The average CPA for the dual approach condition was 8979 ft (s.d. = 3858 ft, minimum = 1482 ft). The quadruple approach condition had a smaller average CPA of 7763 ft (s.d. = 3055 ft, minimum = 914 ft). The distribution of CPA values for dual and quadruple approaches is shown in figure 5.

An Analysis of Variance (ANOVA) was performed on the CPA data to assess the effects of approach condition, degree of blunder, and radio communication on CPA. The approach condition was shown to have a significant effect on the controller's ability to maintain distance between conflicting aircraft ($F(1,482) = 14.78$, $MSE = 0.16E+9$, $p. < 0.0005$). As indicated earlier, the average CPA for the dual approach condition was larger than the average CPA for the quadruple approach condition.

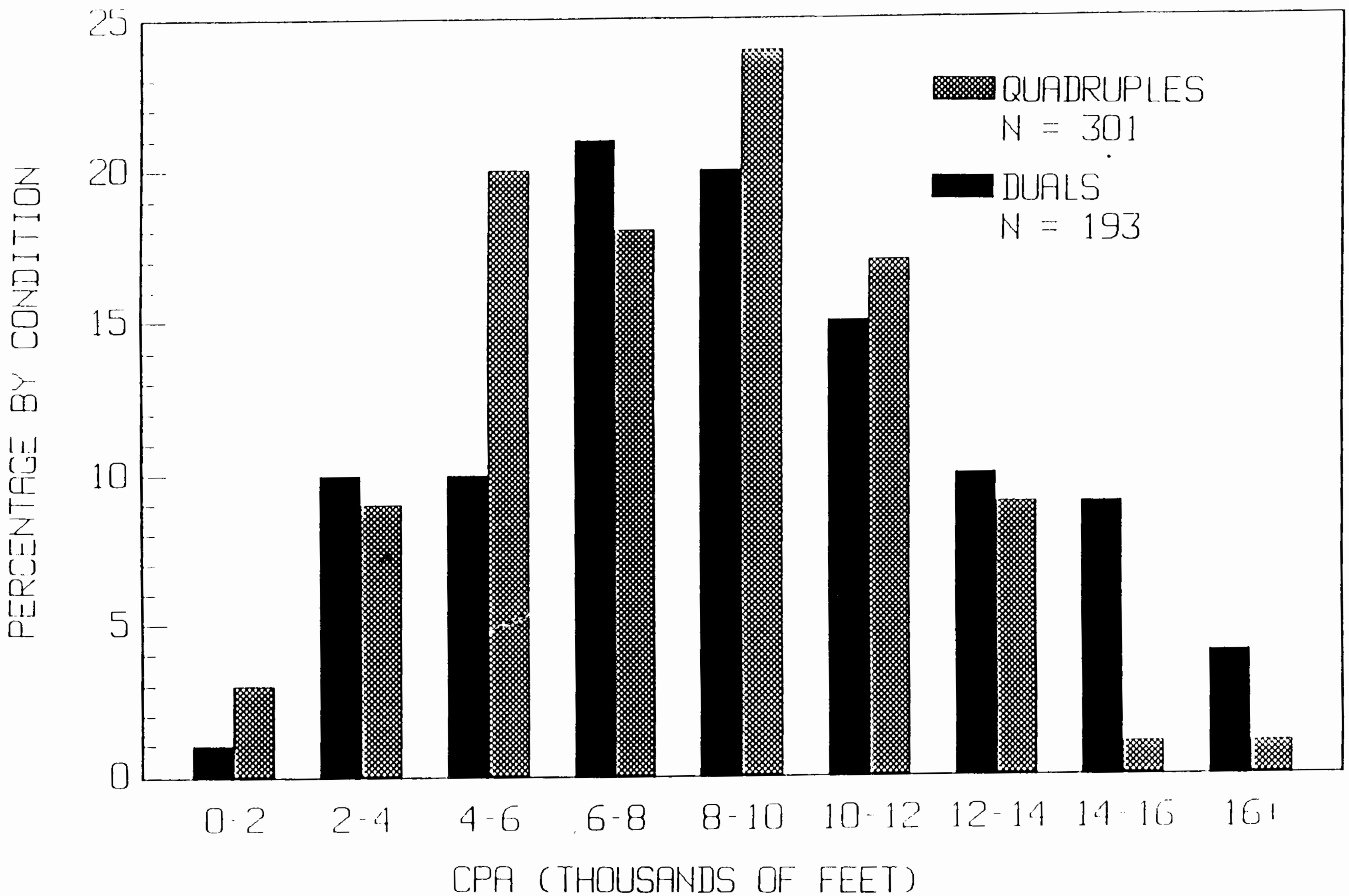


FIGURE 5. DISTRIBUTION OF CPA VALUES

The blunder degree was a significant factor ($F(2,482) = 4.50$, MSE = .50E+8, $p. < 0.05$) in the controller's ability to resolve conflicts due to blunders. The average CPA for 30 degree blunders was the smallest (mean = 7687 ft, s.d. = 3432 ft, n = 242), followed by 10 degree blunders (mean = 8558 ft, s.d. = 2978 ft, n = 99) and 20 degree blunders (mean = 8929 ft, s.d. = 3602, n = 153).

Radio communication was a significant factor ($F(1,482) = 8.18$, MSE = .91E+8, $p. < 0.005$) in the controller's ability to maintain distance between conflicting aircraft. Without communication (NORDO) the average CPA was 7722 ft (s.d. = 358 ft, n = 260). The average CPA for blunders with communication (RDO) was 8811 ft (s.d. = 3266 ft, n = 235). Additionally, the ANOVA did not indicate an interaction between any of the main effects in this analysis.

Analysis was performed on the data which controlled for differences in the spacing between the blundering aircraft's approach and the adjacent approach. The results again indicated statistically significant differences ($F(1, 484) = 16.4$, MSE = .19E+9, $p. < 0.0005$) in controller performance between the dual and quadruple approach conditions.

3.1.1.2 API Analysis.

Of the 514 blunders in Phase III, 493 blunders had an API greater than 0. The average API was 15.7 (s.d. = 15.5, n = 193) for the dual approach condition and 23.6 (s.d. = 18.6, n = 300) for the quadruple approach condition. The largest API was 82 for the dual approach and 84 for the quadruple approach conditions. The distribution of API values is shown in figure 6.

An ANOVA performed on the API data assessed the effects of approach condition, degree of blunder, and radio communication on the controllers ability to maintain distance between the blundering aircraft and other aircraft. The approach condition was shown to have a significant effect ($F(1,480) = 19.24$, MSE = 5648, $p. < 0.0001$) on controller performance. As detailed earlier, the dual approach condition had a smaller average API value.

Blunder degree was also shown to have a significant effect ($F(2,480) = 3.06$, MSE = 897, $p. < 0.05$) on the controller's ability to maintain distance between the blundering aircraft and other aircraft. The mean 30 degree blunder condition had the highest average API ($mean_{30} = 23.3$, s.d. = 19.8) followed by mean 20 degree blunders ($mean_{20} = 18.2$, s.d. = 16.3) and 10 degree blunders ($mean_{10} = 17.0$, s.d. = 14.1).

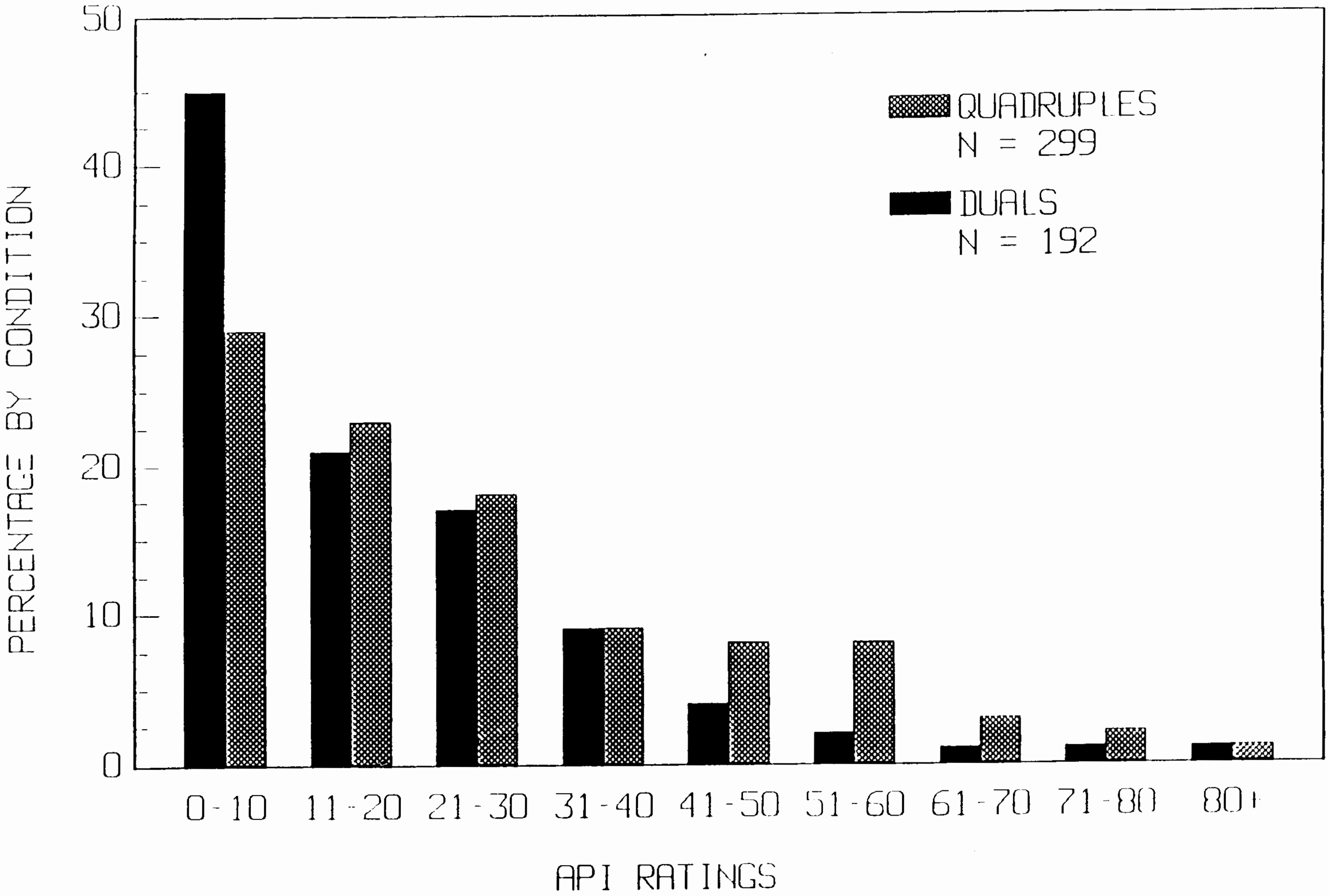


FIGURE 6. DISTRIBUTION OF API VALUES

The communication condition significantly affected the controller's ability to separate aircraft ($F(1,480) = 7.47$, MSE = 2194, $p. < 0.01$). The NORDO condition had an average API of 23.1 (s.d. = 19.5, n = 259), the RDO condition had an average API of 17.5 (s.d. = 15.3, n = 234). There were no interactions between any of the main effects.

Analysis was performed on the data which controlled for differences in the spacing between the blundering aircraft's approach and the adjacent approach. The results again indicated statistically significant differences ($F(1, 482) = 22.99$, MSE = 7041, $p. < 0.00005$) in controller performance between the dual and quadruple approach conditions.

3.1.1.3 Analysis of the Worst Blunders (5 Percent).

The generation of blunders was done to develop worst case situations. Still, as can be seen by the distribution of CPA and API values, some blunders resulted in more severe conflicts. The evaluation of blunders required an analysis which examined only the worst conflicts generated during the simulation. Therefore, an assessment was made of the worst 5 percent of the blunder induced conflicts. Two samples were chosen separately based upon the CPA and the API ratings, 10 conflicts were chosen from the dual approach condition and 15 were chosen from the quadruple approach condition. The data were assessed using a nonparametric test (Kruskal-Wallis ANOVA by Ranks) to determine differences between the samples.

The Kruskal-Wallis test indicated that there was a significant difference between the CPA values in the dual approach sample and the quadruple approach sample ($H(1, 25) = 4.214$, $p. = 0.04$). The dual approach sample had an average CPA of 2249 ft (s.d. = 445 ft). The quadruple approach sample had an average CPA of 1832 ft (s.d. = 479 ft).

Conversely, the Kruskal-Wallis test did not indicate a significant difference between the API values in the dual and quadruple samples. The average API for the dual approach was 58.8 and the average API was 68.4 for the quadruples.

3.1.1.4 Predicted API and CPA Analyses.

An analysis of the predicted API (PAPI) and the predicted CPA (PCPA) was performed to compare the initial blunder conditions for the dual and quadruple approaches (see appendix H for the calculation of PCPA). Significant differences between the dual and quadruple approaches may have indicated an inherent performance bias (i.e., larger PAPIs in one condition may have resulted in larger APIs for the same condition).

The analysis of the PAPI data indicated that there were no significant differences between PAPI values in the dual and quadruple approach conditions. The average PAPI was 16.4 (s.d. = 20.3) for the dual condition and 16.2 (s.d. = 20.9) for the quadruple condition.

Likewise, the PCPA analysis indicated that there were no significant differences between the PCPA values in the dual and quadruple approach conditions. The average PCPA for the dual approach condition was 8178 ft (s.d. = 4879 ft). The average PCPA for the quadruple approach condition was 8819 ft (s.d. = 4866 ft).

3.1.2 Number of Runways Threatened Analysis.

This section assesses the effect of multiple runways on the controllers ability to maintain distance between the blundering aircraft and nonblundering aircraft. Section 3.1.2.1 details the results of comparing dual and quadruple approach conditions when only one runway is threatened. Section 3.1.2.2 covers the analyses comparing the blunders which threatened one runway against the blunders threatening two and three runways using the quadruple approach runs only (see figure 7).

3.1.2.1 One Runway Threatened.

In the quadruple approach runs, the only blunders which threaten only one other approach were left turning blunders from 17L and right turning blunders from 18R. These two types of blunders differ in the spacing between the runways. The blunders from 17L have a spacing of 5000 ft and the blunders from 18R have a spacing of 5800 ft. To control for this difference, the analysis is blocked for separation and only the dual approaches for the east airport (5000 ft spacing) and the west airport (5800 ft spacing) are used in the analysis.

An ANOVA performed on the CPA data indicated that there was a significant difference ($F(1, 224) = 4.99$, $MSE = .72E+8$, $p. < 0.05$) in the controller's ability to maintain distance between aircraft between the dual and quadruple approach conditions. The average CPA in the dual approach condition was 8747 ft. The average CPA in the quadruple approach condition was 7579 ft.

The API data analysis had results similar to the CPA data results ($F(1,223) = 8.80$, $MSE = 3102.7$, $p. < 0.005$). The average API was 15.8 for the dual approach condition and 23.5 for the quadruple approach condition.

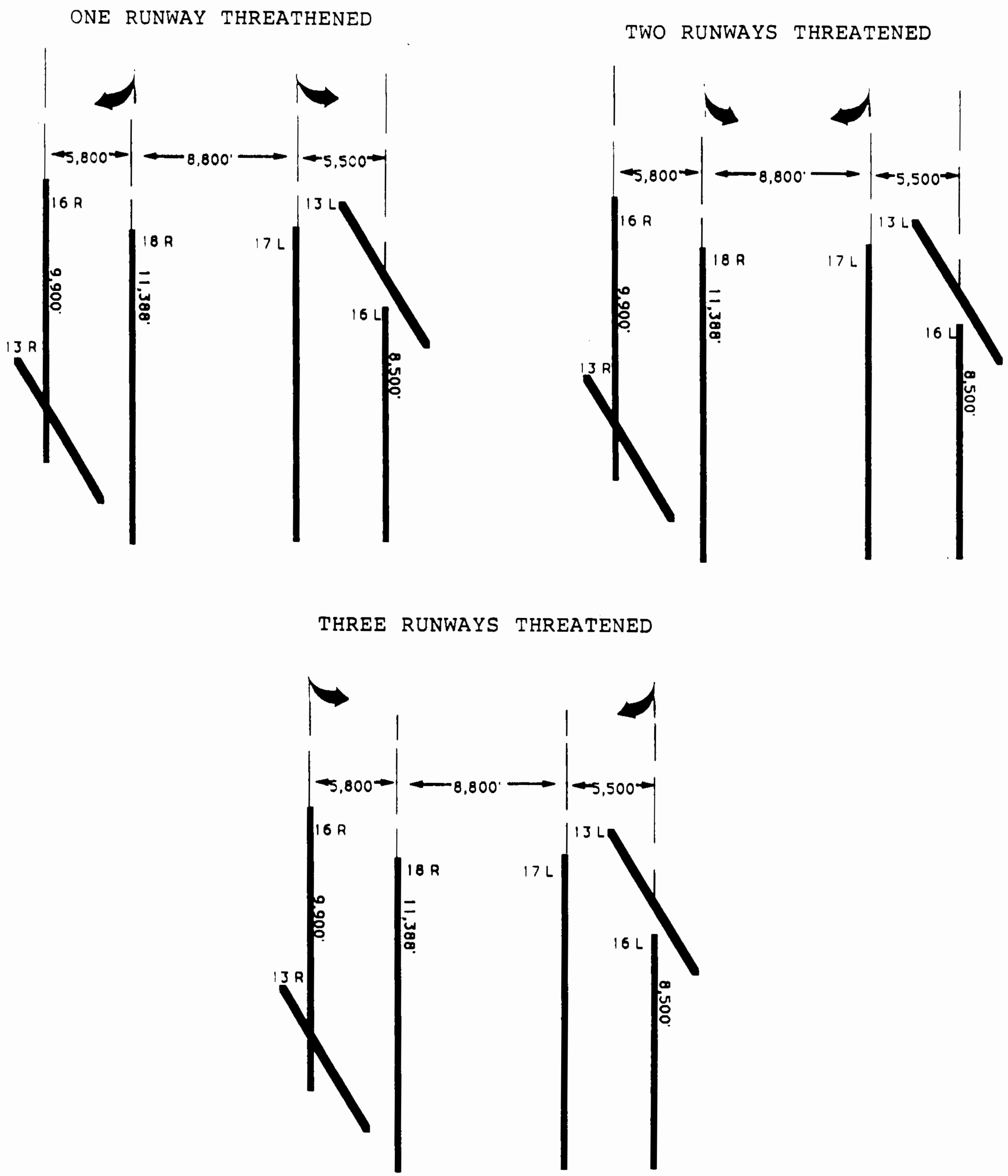


FIGURE 7. GRAPHICAL REPRESENTATION OF THE CONDITIONS IN THE RUNWAY THREATENED ANALYSES

3.1.2.2 One, Two, and Three Runway Threatened Analysis.

These analyses were performed using only the quadruple approach data. The analyses compared the one, two, and three runway threatened conditions to determine if this is an important factor in controller performance. The ANOVAs performed on the API and CPA data indicated that the number of runways threatened did not significantly influence controller performance. The average CPA was 7806 ft for the one runway threatened blunders, 8145 ft for the two runway threatened blunders, and 7875 ft for the three runway threatened blunders. The average API for the one, two, and three runway threatened blunders were 21.2, 22.2, and 22.9, respectively.

3.1.3 Runway Separation Analysis.

Analyses were conducted on the API and the CPA data to determine whether controllers performed differently as a function of the various runway spacings (5000, 5800, and 8800 ft). The data were categorized by the spacing between the blundering aircraft's approach and the adjacent approach.

The ANOVAs indicated no differences in CPA or API between the three spacing distances. The smallest average CPA was 8050 ft with 5000 ft spacing. The average CPA was 8214 ft for 5800 ft spacing, and 8829 ft for the 8800 ft spacing.

The API analysis followed the same pattern as the CPA analysis. The largest average API was 20.6 for the 5000 ft spacing, followed by 19.5 for the 5800 ft spacing and 18.8 for the 8800 ft spacing.

3.1.4 Departure Run Analysis (Including Missed Approaches).

The aircraft miss distance data from the departure control runs was assessed. It was determined that controllers maintained an average distance of 12,110 ft (s.d. = 3548 ft, minimum = 3765 ft, n = 249) between the missed approach aircraft and aircraft departing from adjacent runways. The average API for these conflicts was 6.0 (s.d. = 9.6, maximum = 54).

Similarly, the average CPA between missed approach aircraft and aircraft landing or departing on the same runway was 14,913 ft (s.d. = 2807 ft, minimum = 5160 ft, n = 112). These conflicts had an average API of 2.1 (s.d. = 4.1, maximum = 31).

3.2 CONTROLLER QUESTIONNAIRE ANALYSIS.

This section details the findings of the controller questionnaire and the workload rating scale. Each question is addressed separately in sections 3.2.1 through 3.2.7.

3.2.1 Traffic Handling.

The first question required controllers to assess the ease with which traffic could be handled during the run. The rating scale ranged from 1 (difficult) to 10 (effortless). Controllers rated the handling ability in both the dual (mean = 6.7, s.d. = 2.4, n = 24) and quadruple (mean = 6.0, s.d. = 2.3, n = 92) approach conditions as average (see figure 8). An ANOVA performed on the data indicated that there was no significant difference between the controller's ratings in the dual or quadruple approach conditions.

An ANOVA was performed on the dual approach data to assess the effect of runway separation on the controller's ratings. The runway spacing proved to be a significant factor ($F(2,21) = 3.90$, $MSE = 4.56$, $p. < 0.05$) in the controller's assessment of traffic handling ease. Controller's felt that traffic handling was easiest (mean = 8.7, s.d. = 1.0) with the 8800 ft separation distance, runways 18R and 17L (center airport). This was followed by the 5800 ft separation distance (mean = 6.4, s.d. = 2.4), runways 18R and 16R (west airport), and the 5000 ft spacing (mean = 5.5, s.d. = 2.4), runways 17L and 16L (east airport).

A similar ANOVA performed on the quadruple approach data indicated that controllers rated the traffic handling ease approximately equal regardless of which runway they were assigned (16R mean = 6.6, 18R mean = 5.3, 17L mean = 5.8, 16L mean = 6.3).

3.2.2 Activity Level.

The second question addressed the controller's activity level. Controller's were asked to rate their activity levels on a scale of 1 (minimal) to 10 (intense). Controllers rated the activity levels lower during dual runs (mean of 3.4, s.d. = 1.7), than in quadruple runs (mean of 4.5, s.d. = 2.3). An ANOVA indicated that these means were significantly different ($F = (1,114) = 4.84$, $MSE = 4.88$, $p. < 0.05$). Although the dual and quadruple approach responses were different, it should be noted that both rated the activity level as moderate (see figure 9).

Further investigation of dual approaches indicated that the ratings for the west (mean = 3.5), center (mean = 2.2), and east (mean = 4.2) airport approaches were not significantly different, indicating that the activity levels did not vary as a function of runway separation.

An examination of only the quadruple approach data indicated no significant differences in responses between monitor control positions. The average response was 4.0 for 16R, 4.9 for 18R, 4.6 for 17L, and 4.4 for 16L.

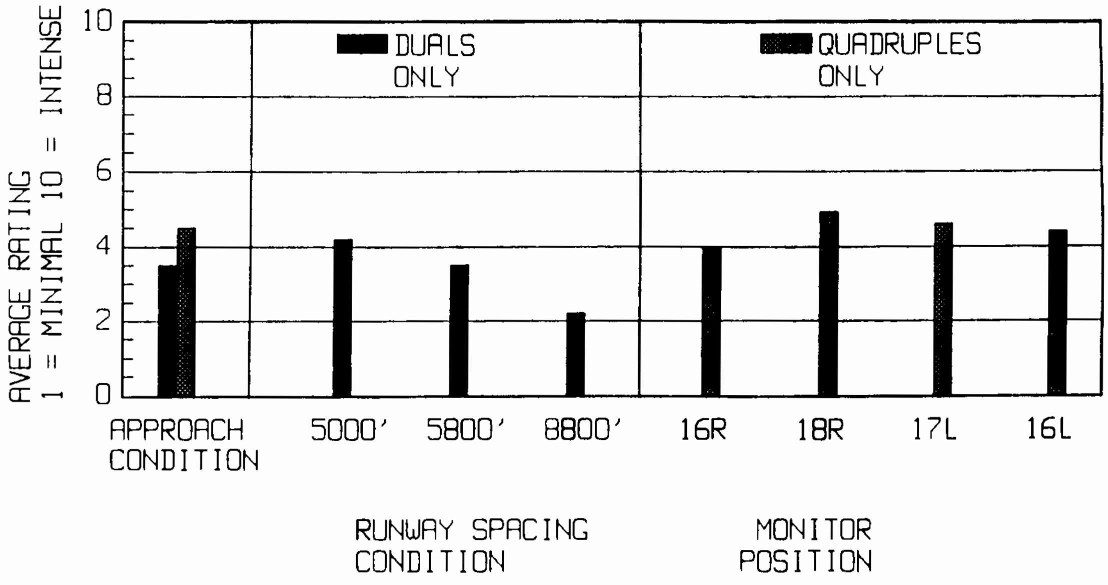


FIGURE 8. RATE THE EASE OF TRAFFIC HANDLING DURING THE PAST SESSION

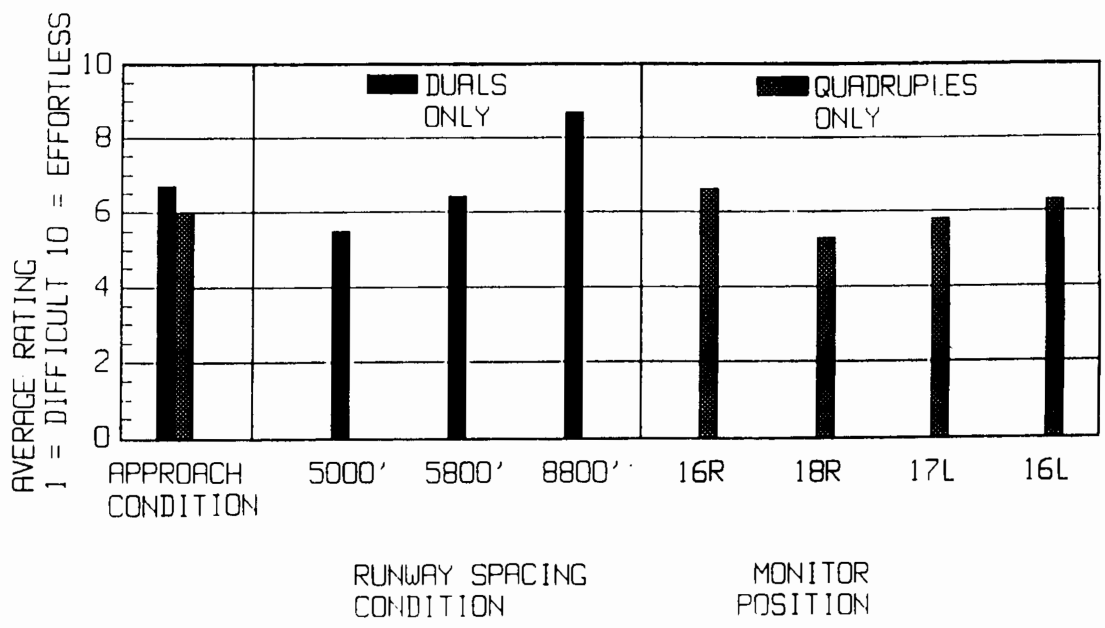


FIGURE 9. RATE THE LEVEL OF ACTIVITY REQUIRED DURING THE PAST SESSION

3.2.3 Stress Level.

Perceived stress levels were assessed in the third question. Controllers rated their stress level on a scale of 1 (slight) to 10 (extreme). The average rating for the dual approach condition was 3.5 and the rating for the quadruple approach condition was 4.1 (see figure 10). This represents a low to moderate stress level for both conditions. An ANOVA indicated no significant differences in the responses between the approach conditions.

Assessing stress levels for the dual approach runs indicated a significant difference in controller perception ($F(2,21) = 3.63$, $MSE = 3.26$, $p. < 0.05$) for the different runway spacings. Controllers experienced a higher level of stress working with the east airport (having the smallest runway spacing) (mean = 4.6, s.d. = 2.2), than with the west (mean = 3.5, s.d. = 1.9) or center (mean = 2.0, s.d. = 0.6) airports.

Controllers did not experience a difference in stress levels across runways within the quadruple approach runs. The average response was 3.6 for 16R, 4.5 for 18R, 4.2 for 17C, and 4.0 for 16L.

3.2.4 Workability.

Controllers assessed whether the simulated procedures would be workable in their present facility. The scale ranged from 1 (strong yes) to 10 (strong no). An ANOVA indicated that there was not a difference in workability ratings between the dual (mean = 1.9, s.d. = .8) and the quadruple (mean = 2.3, s.d. = 1.1) approach conditions (see figure 11).

In the dual approach runs, there were no significant differences in workability ratings between the different runway spacings (west mean = 2.0, center mean = 1.3, and east mean = 2.3). Additionally, no significant differences were found in the ratings, within the quadruple approach runs, between the different runways (16R mean = 2.2, 18R mean = 2.3, 17L mean = 2.3, and 16L mean = 2.5).

3.2.5 Mental Workload.

A rating scale based upon the Modified Cooper-Harper scale was utilized to assess the mental workload during the simulation runs. The scale ranged from 1 (very easy to perform with minimal mental effort) to 10 (impossible to perform). An ANOVA indicated controllers experienced no significant differences in mental workload between dual (mean = 2.7, s.d. = 1.2) and quadruple (mean = 3.2, s.d. = 1.4) approach runs (see figure 12). Overall, mental workload was rated as acceptable.

An analysis of the mental workload ratings in the dual approach runs indicated a significant difference in the ratings ($F(2,21) = 3.75$, $MSE = 1.09$, $P < .05$) between the different runway conditions.

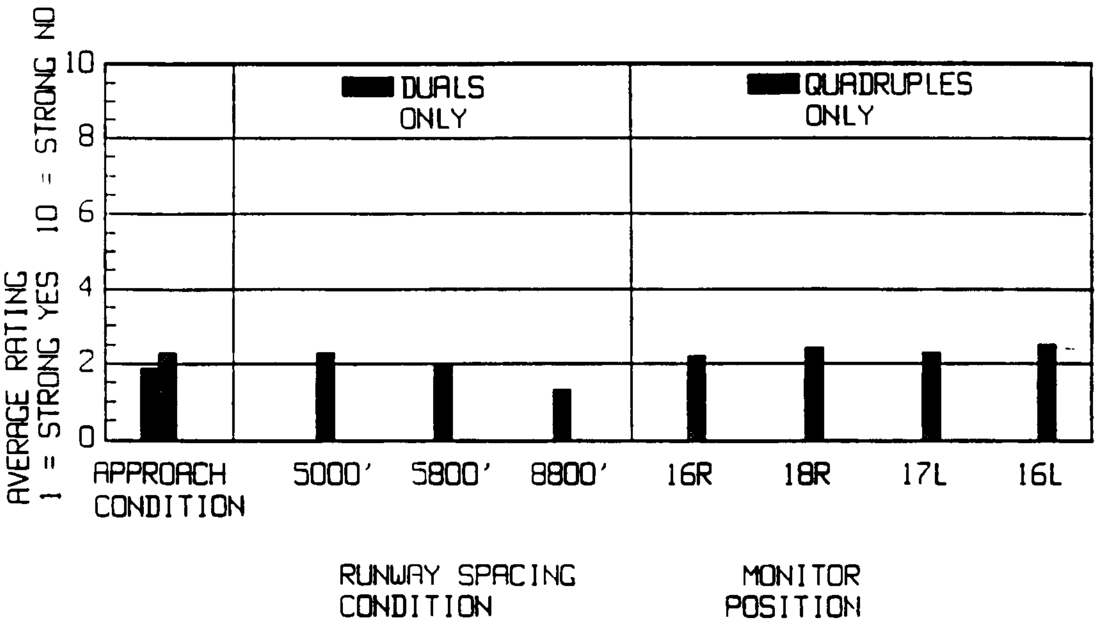
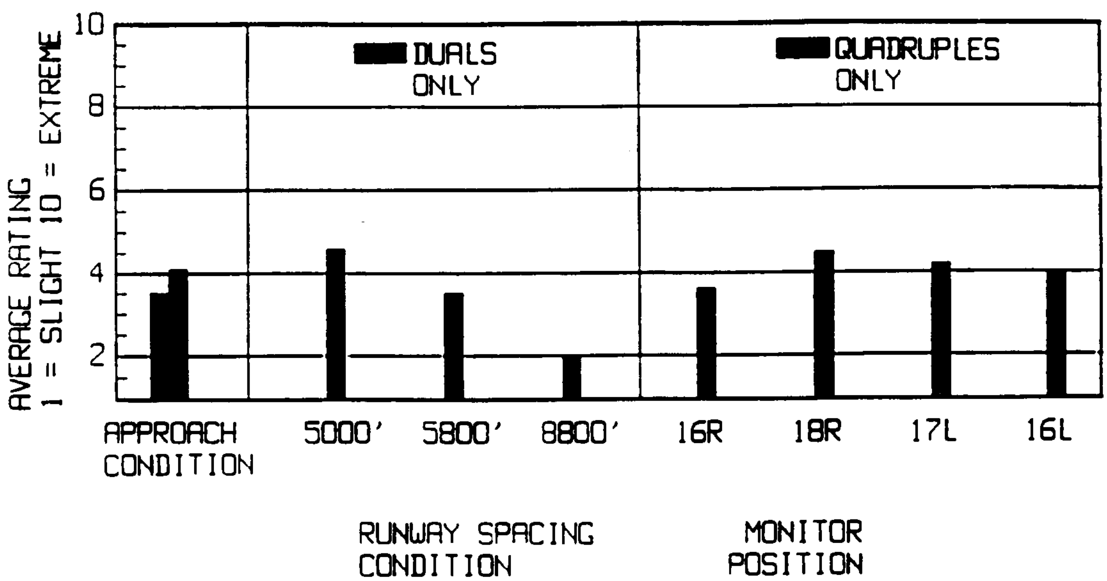


FIGURE 10. RATE THE LEVEL OF STRESS EXPERIENCED DURING THE PAST SESSION



*(traffic volume, procedures, geography, separation requirements..)

FIGURE 11. ARE THE CONDITIONS OF THIS PAST SESSION WORKABLE AT YOUR PRESENT FACILITY?*

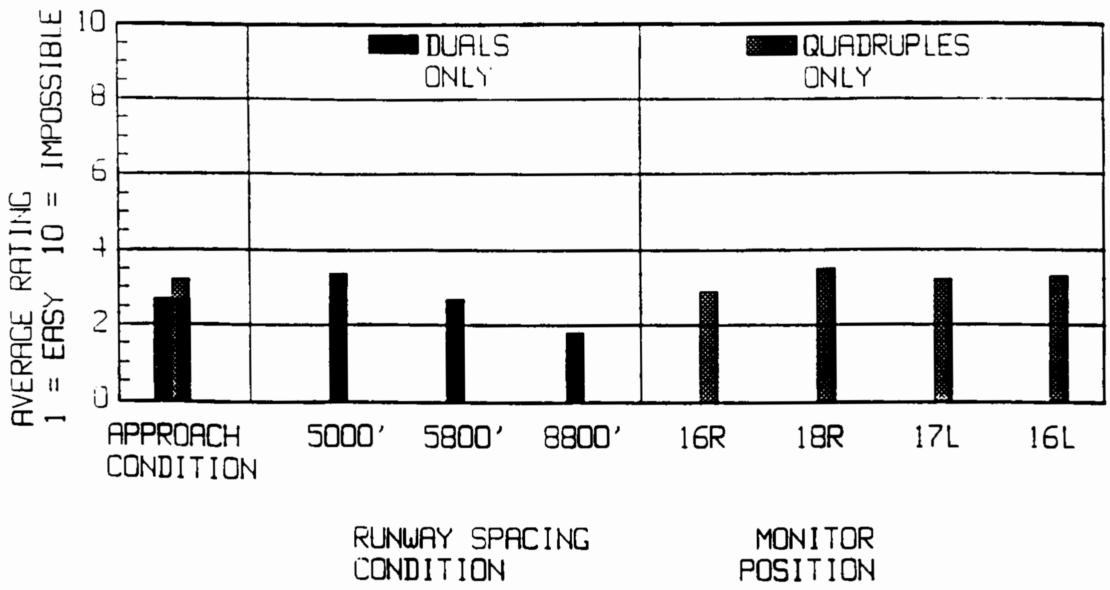


FIGURE 12. RATE THE MENTAL WORKLOAD DURING THE PAST SESSION

The east airport, with the smallest spacing, 5000 ft, resulted in the highest average rating of mental workload (mean = 3.4), followed by the west airport, 5800 ft (mean = 2.7), and the center airport, having the largest spacing, 8800 ft (mean = 1.8).

An ANOVA indicated no significant differences in the workload ratings between runways in the quadruple approach runs. The average rating was 2.9 for 16R, 3.5 for 18R, 3.2 for 17L, and 3.3 for 16L.

3.3 CONTROLLER AND SIMULATOR PILOT RESPONSE TIME ANALYSES.

The controller and pilot response times were assessed from four simulation runs (three quadruple runs and one dual run). Time of the controller messages were measured from the audio recordings. Controller response time to a blunder was assessed by comparing the time of the blunder initiation and the time of the controller's message. An ANOVA was performed on the data to assess the effects of approach condition and blunder degree on the controller's ability to detect a blunder. The analysis indicated that there were no significant differences in controller response time between the dual and quadruple approach conditions. The average controller response time was 12.2 seconds (s) in the quadruple approach runs and 11.9 s in the dual approach runs. The degree of blunder did significantly affect controller response times ($F(2,52) = 3.17$, $MSE = 459.33$, $p. < 0.05$). The average response time for the 30 degree blunders was the smallest, 10.3 s (s.d. = 10.5 s, n = 28), followed by 10 degree blunders, 15.3 s (s.d. = 7.7, n = 15), and the 20 degree blunders, 22.0 s (s.d. = 16.5, n = 15).

The simulator pilot response times were determined by subtracting the controller message time from the pilot message entry data time. The controller messages included altitude changes, heading changes, and heading changes with a change in altitude. The average NSSF simulator pilot response time was 11.1 s (s.d. = 9.1, n = 152). A correlational analysis was conducted on the data to determine the relationship between the number of keystrokes required to enter the message (message complexity) and the pilot response times. The results indicated that no relationship existed between the two variables.

4. DISCUSSION.

Analysis of the simulation computer data indicated that controllers were able to intervene in the event of a blunder to maintain slant range distances (CPAs) which were generally large. The average CPA was 9173 ft for the dual simultaneous approach runs and 7898 ft for the quadruple simultaneous approach runs. It should be noted that the smallest CPA, 914 ft, was well above the 500 ft test criterion miss distance. It was not necessary to conduct an operational assessment of conflicts since all of the miss distances were greater than the 500 ft test criterion.

Assessment of the CPAs indicated a statistically significant difference between the dual and quadruple approach conditions. The average CPA in the dual approach runs was 1216 ft larger than the average CPA in the quadruple runs. The operational significance of this difference is minimal when the size of the average CPA is considered.

An analysis performed on the worst 5 percent of the blunder induced conflicts for the dual and quadruple runs had results similar to those found in the overall analysis. The dual approach runs (2249 ft) had a larger average CPA than the quadruple approach runs (1832 ft). Again, the size of the averages must be considered when determining the operational significance of the difference between the two approach conditions.

Calculations of the API for each blunder resulted in generally low ratings for both the dual (15.3) and the quadruple (22.4) approach runs. There was a statistically significant difference between the dual and quadruple approach conditions. However, the difference is not operationally significant when the size of the average API is considered.

An analysis was performed which considered only the worst 5 percent of the blunder induced conflicts based upon API. This analysis did not indicate a significant difference between the dual and quadruple approach conflicts. The largest API was 82 in the dual approach runs and 84 in the quadruple approach runs.

To compare the miss distances between the dual and quadruple approach conditions, it is necessary that both conditions have the same potential for serious conflicts. A comparison of the PCPA and the PAPI for the dual and quadruple approach runs indicated no differences in conflict potential between the two conditions. This finding confirms the statistical reliability of the CPA and API analyses previously discussed.

A comparison between blunders which threatened only one runway in the quadruple approach runs and blunders in the dual approach runs which had the same runway separation (5000 and 5800 ft) was conducted. There was a statistical difference in the CPA values and the API ratings between the approach conditions. The quadruple approach blunders resulted in a smaller average CPA (7579 ft) than the dual approach blunders (8747 ft). Similarly, quadruple approach blunders resulted in statistically larger average API ratings (23.5) than the dual approach blunders (15.8). The difference between the approach conditions in this analysis is not operationally significant when the size of the average CPA and API are considered.

Within the quadruple approach condition, a blunder can threaten one, two, or three other approaches. Analyses were conducted to determine whether the number of runways threatened was related to the size of the CPA or API. There were no differences in the CPA or API between the blunders which threatened one, two, or three approaches.

An assessment of the effect of runway spacing (5000, 5800, and 8800 ft) on the controller's ability to maintain miss distances between aircraft was performed by comparing the three configurations used in the dual runs. The analysis did not find significant differences in average aircraft miss distances between runway spacing levels. However, there was a trend for increased miss distances with increased runway spacing.

Controllers were able to maintain an average CPA of 12,110 ft between aircraft executing missed approaches and departing aircraft. The smallest CPA for this type of conflict was 3765 ft. These values were well above the test criterion miss distance of 500 ft.

Although the controller questionnaires indicated slight differences between the dual and quadruple approach operations, all of the controller responses indicated that the quadruple approach was a safe operation. The questionnaires indicated that controllers rated the activity level as moderate in both the dual and quadruple approach runs, while the stress level was rated as low in both approach conditions. Responses by controllers indicated that the quadruple approach procedures were workable at D/FW. Finally, controllers rated the mental workload as being acceptable in both the dual and quadruple approach conditions.

The Controller's Report (appendix G) indicated that the arrival and departure monitor positions were functional for D/FW. Additionally, the controllers stated "We believe that quadruple ILS approaches as simulated, without regard to the interaction of adjacent airspace and traffic, is a safe, efficient, and workable procedure."

The Administrative Assessment (appendix I) conducted by the TWG found the quadruple approach and departure procedures for D/FW to be acceptable, achievable, and safe. Their findings were based on the large average miss distances maintained in the arrival and departure simulation runs; the ability of controllers to maintain distances between aircraft that were well above the test criterion miss distance of 500 ft; and their observations of controller performance during the simulation.

The analysis of responses to the Industry Observer Questionnaire indicated that they believed the simulation was realistic and that simultaneous quadruple approaches are workable (appendix D).

5. CONCLUSIONS.

The Dallas/Fort Worth (D/FW) Phase III simulation investigated the potential of quadruple simultaneous Instrument Landing System (ILS) approaches and departures/missed approaches. All of the blunders in both the dual and quadruple approach operations resulted in slant range miss distances that were greater than 900 feet (ft). While manning the departure monitor positions, controllers maintained a minimum miss distance of 3765 ft between missed approach aircraft and other aircraft. These values were both greater than the 500 ft test criterion used in the simulation.

Analysis of the Closest Point of Approach (CPA) and the Aircraft Proximity Index (API) metrics indicated that the quadruple approach operation resulted in miss distances that were statistically less than the miss distances that occurred in the dual approach operation. The miss distances between the aircraft in the quadruple approach operation were generally large (average miss distance = 7763 ft). The small difference between the average miss distances for dual and quadruple approaches was small (1216 ft) relative to the large average miss distance. Therefore, it was determined that there were no operational differences between the dual and quadruple approach conditions.

The controllers that participated in the simulation found the quadruple approach operation to be a "safe, efficient and workable procedure."

The Multiple Parallel Technical Work Group (TWG), composed of air traffic control, flight safety, flight standards, and operations personnel, participated in the simulation and evaluated the simulation findings. Based upon the TWG's understanding of (1) daily operations, (2) the knowledge and skills of controllers, and (3) the contingencies which must be accounted for, the TWG found the quadruple approaches, simulated for D/FW, as acceptable, achievable, and safe.

Observers for the Airline Industry indicated that the quadruple approach operation was workable.

Based upon the findings of the statistical analysis, the Administrative Assessment, the Controllers Report, and the Industry Observer comments, it was concluded that the quadruple simultaneous parallel ILS approach procedures are safe and workable for the airport configuration (D/FW) tested in this simulation. Therefore, the TWG recommended implementation of quadruple simultaneous parallel ILS approach operations at D/FW. The TWG further recommends:

a. There shall be one monitor controller for each runway. Personnel and equipment shall be provided to support the procedure.

b. All monitor positions should be located together and near their respective arrival and departure positions.

c. Radar coverage must be provided through the missed approach point to a point 7 nautical miles (nmi) beyond the departure end of the runway. Coverage shall be as low as 50 ft above the runway surface or as approved by flight standards. Approach minimums will be dependent upon the lowest point at which radar coverage can be provided, e.g., CAT II minimums if radar coverage can be accomplished as low as 50 ft above the runway surface, etc.

d. The No Transgression Zone (NTZ) needs to be extended through the missed approach to a point 7 nmi beyond the departure end of the runways.

e. The Implementation Strategy used prior to conducting quadruple approaches to the lowest authorized minimum for D/FW shall include a phase-in period, 60 days or 1000 approaches, with a minimum visibility of 1500 ft/3 nmi.

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APPENDIX A

AN AIRCRAFT PROXIMITY INDEX (API)

AN AIRCRAFT PROXIMITY INDEX (API)

BACKGROUND.

Air Traffic Control (ATC) simulation is an essential research tool for the improvement of the National Airspace System (NAS). Simulation can never offer all of the complexity and subtlety of the real world, with live radar, actual aircraft, full communications systems, and the rest of the ATC environment, but it can provide an intensive exercise of key portions of the system -- with controllers in the loop.

Proper use of simulation starts with carefully defining the questions to be answered and then developing a simulation environment which includes the features that could influence the process under study. The selection of a simulation environment, the development of scenarios, the choice of data to be recorded, and the method of analysis are part science, part art.

An important benefit of simulation is that it permits the exploration of systems, equipment failures, and human errors that would be too dangerous to study with aircraft, or that occur so rarely in the system that they cannot be fully understood and evaluated. A current example of this use has to do with the introduction of blunders[1] in parallel runway instrument approaches.

The introduction of large numbers of system errors is a useful way to study safety, but the analysis of the outcomes of these incidents is not always simple or clear cut.

SAFETY EVALUATION.

1. Conflicts.

The occurrence of a conflict in normal ATC operations is considered prima facie evidence of a human or system error. Identifying (and counting) conflicts under a variety of conditions is one way to expose a system problem.

> A conflict is defined as the absence of safe separation between two aircraft flying under Instrument Flight Rules (IFR). At its simplest, safe separation requires: (a) the aircraft must be laterally separated by 3 or 5 nautical miles (nmi) depending on distance from the radar, (b) vertical separation by 1,000 or 2,000 feet (ft), depending on altitude or flight level, or (c) that both aircraft are established on ILS localizers. There are refinements of the above rules that take into consideration the fact that one aircraft may be crossing behind another, or that an aircraft has begun to climb or descend from a previous altitude clearance. There are special "wakes and vortices" restrictions for aircraft in trail behind heavy aircraft.

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[1]A blunder is defined as an unexpected turn towards an adjacent approach by an aircraft already established on the Instrument Landing System (ILS).

Since actual conflicts are rare, every event leading up to them and all the information available on the onset and resolution is carefully analyzed. The emphasis is on the intensive investigation of the particular event.

In scientific investigation, the intensive study of a single individual or a particular event is called the **idiographic** approach. This is often contrasted with the **nomothetic** approach: the study of a phenomenon or class of events by looking at large numbers of examples and attempting to draw general conclusions through the application of statistics.

The idiographic approach is mandatory for accident or incident investigation where the goal is to get as much information as possible about a unique event in order to prevent future occurrences.

In a simulation experiment, where the goal is to make a comparison between two or more systems (2 vs 3 or 4 runways, 4300 vs 3000 ft runway spacing, etc.) and to generalize beyond the simulation environment, the nomothetic approach is most appropriate. This means generating a large numbers of events and statistically analyzing the outcomes with respect to the system differences.

There is much to be gained by studying the individual conflicts in a simulation as an aid to understanding the kinds of problems that occur and to generate hypotheses about how a system might be improved for subsequent testing. But the evaluation of the systems under test requires the use of all of the valid data, analyzed in as objective a manner as possible. Valid data in this context means that it was collected under the plan and rules of the simulation and was not an artifact, such as a malfunction of the simulation computer or distraction by visitors.

2. Slant Range.

If it is important to go beyond the counting of conflicts, measurement of the distance between the conflicting aircraft pair is required. The most obvious measure is slant range separation: the length of an imaginary line stretched between the centers of each aircraft. Over the course of the incident that distance will vary, but the shortest distance observed is one indication of the seriousness or danger of the conflict.

The problem with slant range is that it ignores the basic definition of a conflict and is insensitive to the different standards that are set for horizontal and vertical separation. A slant range distance of 1100 ft might refer to 1000 ft of vertical separation, which is normally perfectly safe, to less than 0.2 nmi of horizontal miss distance, which would be considered by most people to be a very serious conflict.

Slant range, per se, is too ambiguous a metric to have any real analytical value.

3. API.

The need exists for a single value that reflects the relative seriousness or danger. The emphasis here is on "relative," since with the nomothetic or statistical approach, an absolute judgment of dangerous or safe is useful, but for the different experimental conditions and determine whether one pattern indicates more, less, or the same degree of safety as another.

Such an index should have to have certain properties.

a. It should consider horizontal and vertical distancesseparately, since the ATC system gives 18 times the importanceto vertical separation (1000 ft vs 3 nmi).

b. It should increase in value as danger increases, and go to zero when there is no risk, since the danger in the safe systemis essentially indeterminate.

c. It should have a maximum value for the worst case (collision), so that users of the index can grasp itssignificance without tables or additional calculations.

d. It should make the horizontal and vertical risk or danger independent factors, so that if either is zero, i.e., safe, their product will be zero.

e. It should be a nonlinear function, giving additional weight to serious violations, since they are of more concern than anumber of minor infractions.

The API is designed to meet these criteria. It assigns a weight or value to each conflict, depending on vertical and lateral separation. API facilitates the identification of the more serious (potentially dangerous) conflictions in a data base where many conflictions are present. One hundred has been chosen, somewhat arbitrarily, for the maximum value of the API.

APPROACH.

During a simulation API can be computed whenever a conflict exists. For convenience, this is taken to be when two aircraft have less than 1000 ft of vertical separation AND less than 3.0 miles of lateral separation. It is computed once per second during the conflict. The API of the conflict is the largest value obtained.

API considers vertical and horizontal distances separately, then combines the two in a manner than gives them equal weight; equal in the sense that a loss of half the required 3.0 nmi horizontal separation has the same effect as the loss of half the required 1000 ft of vertical separation.

COMPUTATION.

The API ranges from 100 for a mid-air collision to 0 for the virtual absence of a technical confliction. A linear decrease in distance between the aircraft, either vertically or laterally, increases the APl by the power of 2.

Computation is as follows:

D^V = vertical distance between a/c (in ft)

D^H - horizontal distance (nmi (6076 ft)

API = $(1,000.DV)^2*(3.DH)^2/(90.000)$

To simplify its use, API is rounded off to the nearest integer, i.e.,

API =INT$((1,000-DV)^2*(3-DH)^2/(90,000)+.5)$

The rounding process zeros API's less than 0.5. This includes distances closer than 2 nmi AND 800 ft. The contour plot in figure A-1 demonstrates the cutoff for API = 1.

See tables A-1 and A-2 for typical values of API at a variety of distances.

Figure A-2 is a three-dimensional plot showing the relationship between API and vertical and horizontal separation graphically. Figure A-3 shows the same information in a slightly different way. Anything outside the contour at the base is "0." In figure A-4 a contour plot of API for horizontal and vertical distances from 0 to 500 feet is shown, with 300 and 500 ft slant range distances superimposed.

DISCUSSION.

The index is not intended as a measure of acceptable risk, but it meets the need to look at aircraft safety in a more comprehensive way than simply counting conflictions or counting the number of aircraft that came closer than 200 ft, or some other arbitrary value.

It should be used to compare conflicts in similar environments, i.e., an API of 70 in en route airspace with speeds of 600 knots is not necessarily the same concern as a 70 in highly structured terminal airspace with speeds under 250 knots.

Since the API is computed every second, it may be useful to examine its dynamics over time as a means of understanding the control process.

TABLE 1. TYPICAL VALUES

Vertical Distance (D_V) (in ft)	3	2.5	2.0	1.5	1.0	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	.05	.01	-0-
	Horizontal Distance in Nautical Miles (1 nmi = 6076 ft) (D_H)																
1000	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
900	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1
800	0	0	0	1	2	2	2	2	3	3	3	3	3	4	4	4	4
700	0	0	1	2	4	4	5	5	6	6	7	7	8	8	9	9	9
600	0	0	2	4	7	8	9	9	10	11	12	13	14	15	15	16	16
500	0	1	3	6	11	12	13	15	16	17	19	20	22	23	24	25	25
400	0	1	4	9	16	18	19	21	23	25	27	29	31	34	35	36	36
300	0	1	5	12	22	24	26	29	31	34	37	40	43	46	47	49	49
200	0	2	7	16	28	31	34	38	41	44	48	52	56	60	62	64	64
100	0	2	9	20	36	40	44	48	52	56	61	66	71	76	78	80	81
	0	3	11	25	44	49	54	59	64	69	75	81	87	93	97	99	100

TABLE 2. ADDITIONAL VALUES

D_H	D_V	API	D_H	D_V	API	D_H	D_V	API
3.0	1000	0	1.0	667	5	.05	667	11
3.0	0	0	1.0	500	11	.05	500	24
0	1000	0	1.0	333	20	.05	333	43
2.0	667	1	1.0	250	25	.05	250	54
2.0	500	3	1.0	100	36	.05	100	78
2.0	333	5	1.0	0	44	.05	0	97
2.0	250	6	.5	667	8	.01	667	11
2.0	100	9	.5	500	17	.01	500	25
2.0	0	11	.5	250	39	.01	333	44
1.5	667	3	.5	100	56	.01	250	56
1.5	500	6	.5	0	69	.01	100	80
1.5	333	11	.1	667	10	.01	0	99
1.5	250	14	.1	500	23	0	667	11
1.5	100	20	.1	250	53	0	500	25
1.5	0	25	.1	100	76	0	333	44
			.1	0	93	0	250	56
						0	100	81
						0	0	100

A/C PROXIMITY INDEX (API)

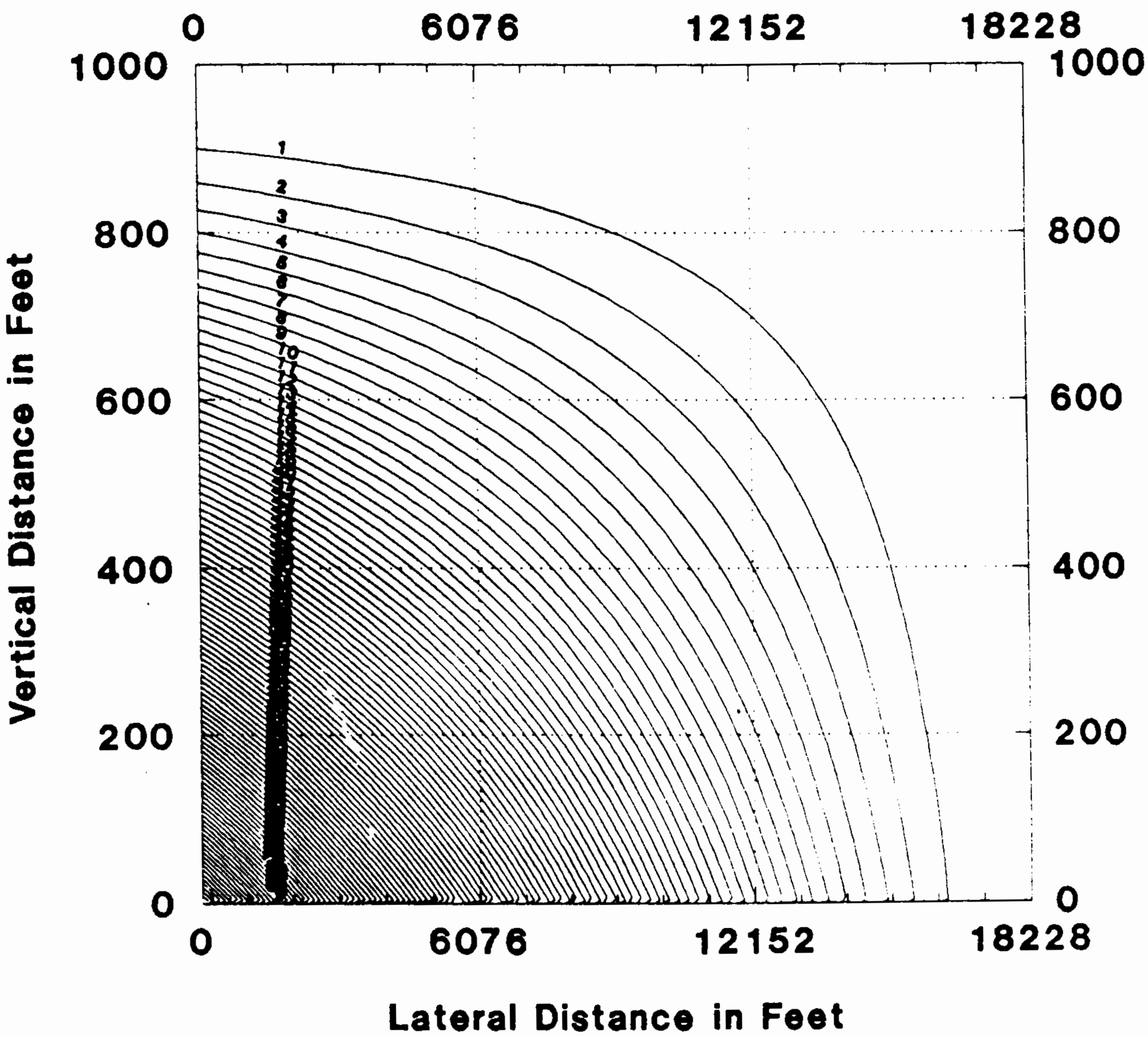

FIGURE A-1. CONTOUR PLOT

This is a contour plot of API showing the values of API for the horizontal separations of 0 to 3 nmi, and vertical separation of 0 to 1,000 feet. Values less than API = 0.4 round to zero. This includes a/c separated by as little 1.6 nmi horizontally and 850 feet vertically.

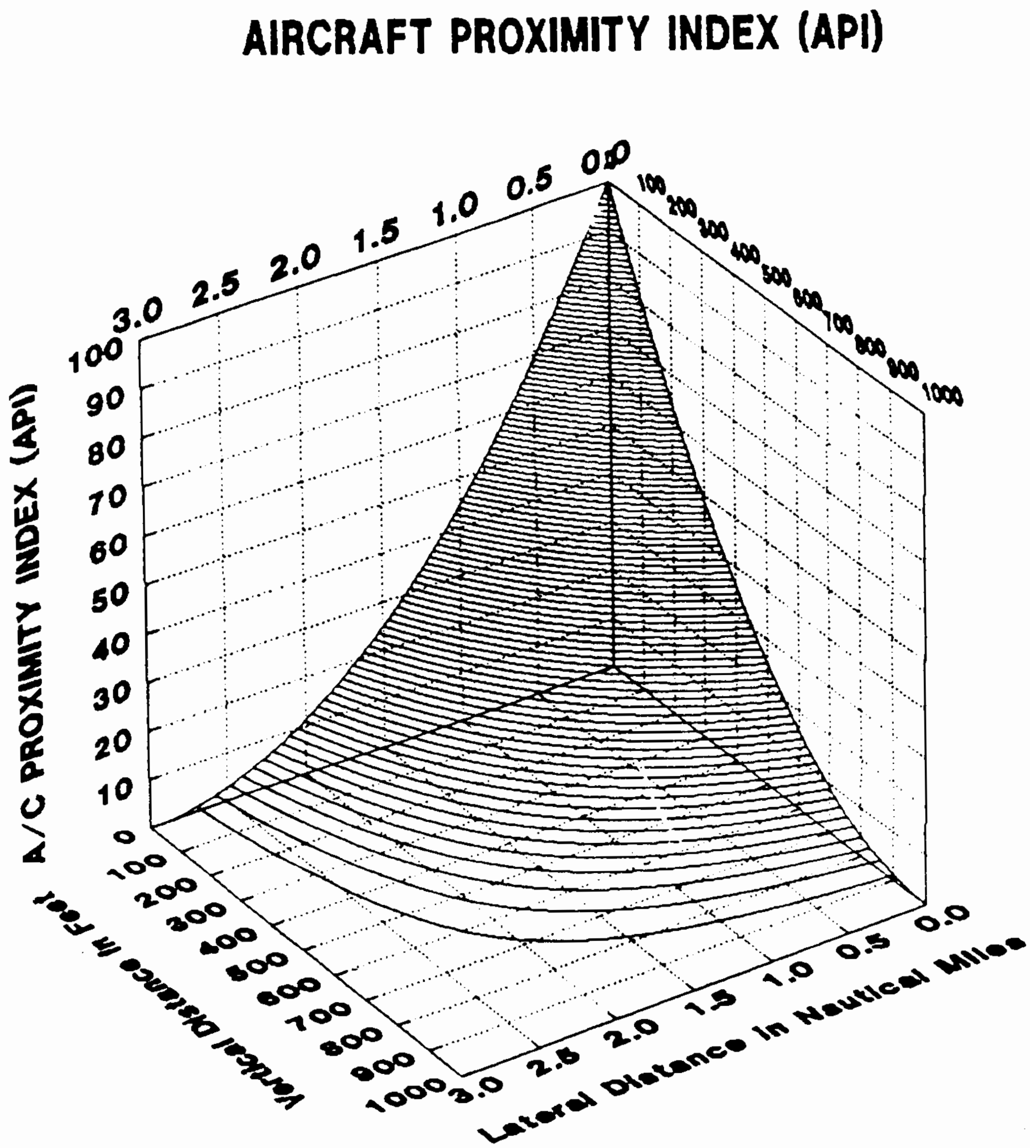

FIGURE A-2. THREE-DIMENSIONAL CONTOUR PLOT

Three-dimensional contour plot of API, for horizontal separation of 0 to 3 nmi, and vertical separations of 0 to 1,000 feet.

AIRCRAFT PROXIMITY INDEX (API)

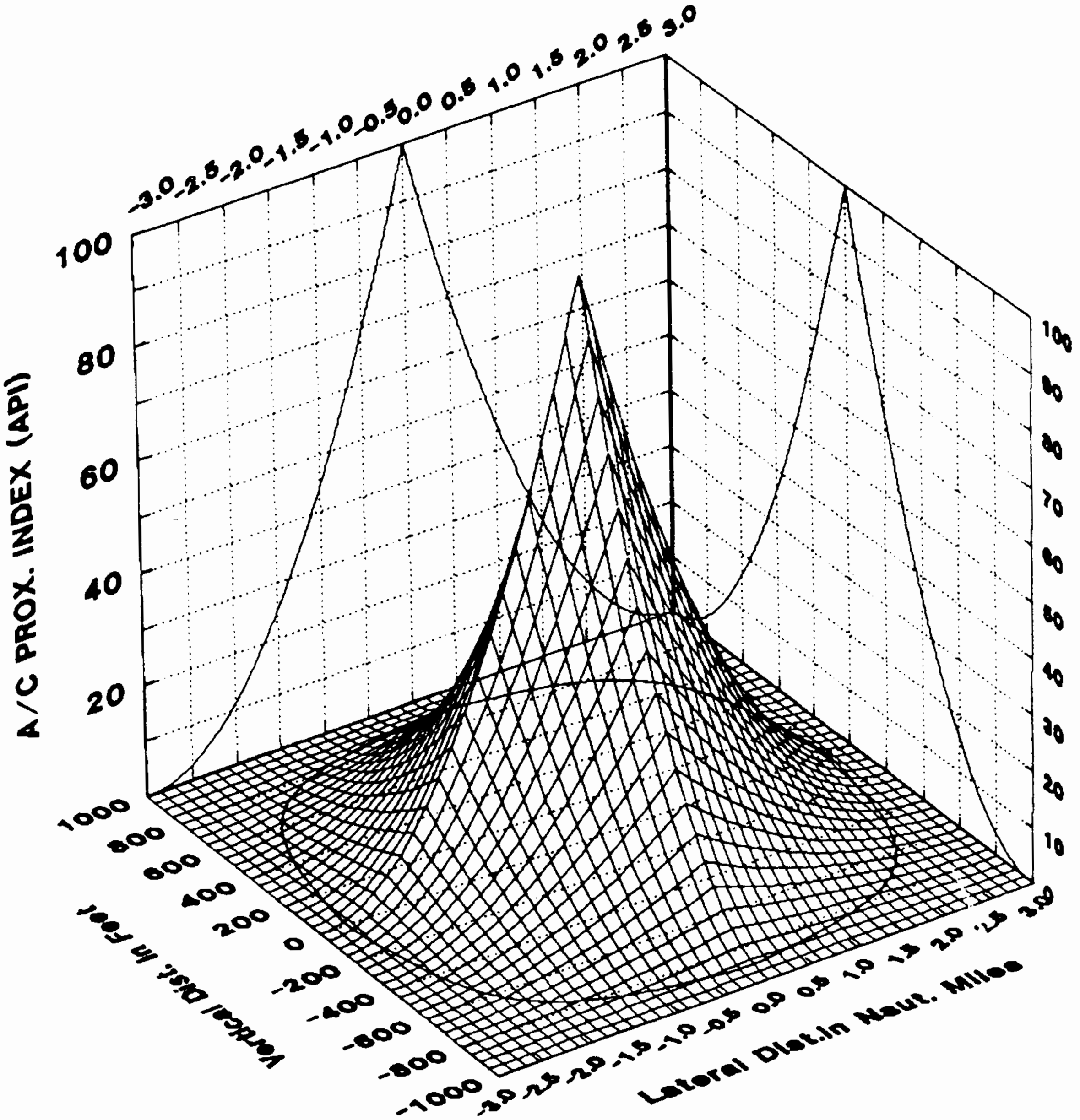

FIGURE A-3. THREE-DIMENSIONAL CONTOUR PLOT

Left vertical plane show API vs horizontal distance with vertical distance = 0. Right vertical plane shows API vs vertical separation with horizontal distance = 0. Right vertical plan shows API vs vertical separation with horizontal distance = 0.

Plot may be interpreted by considering one a/c at the center of the base plane, while the height of the figure shows the API for another a/c anywhere else on the base plane.

The contour on the base plane shows the boundary between API = 0 and API = 1.

A/C PROXIMITY INDEX (API)

API VALUES FOR SLANT RANGES OF 300 AND 500 FEET

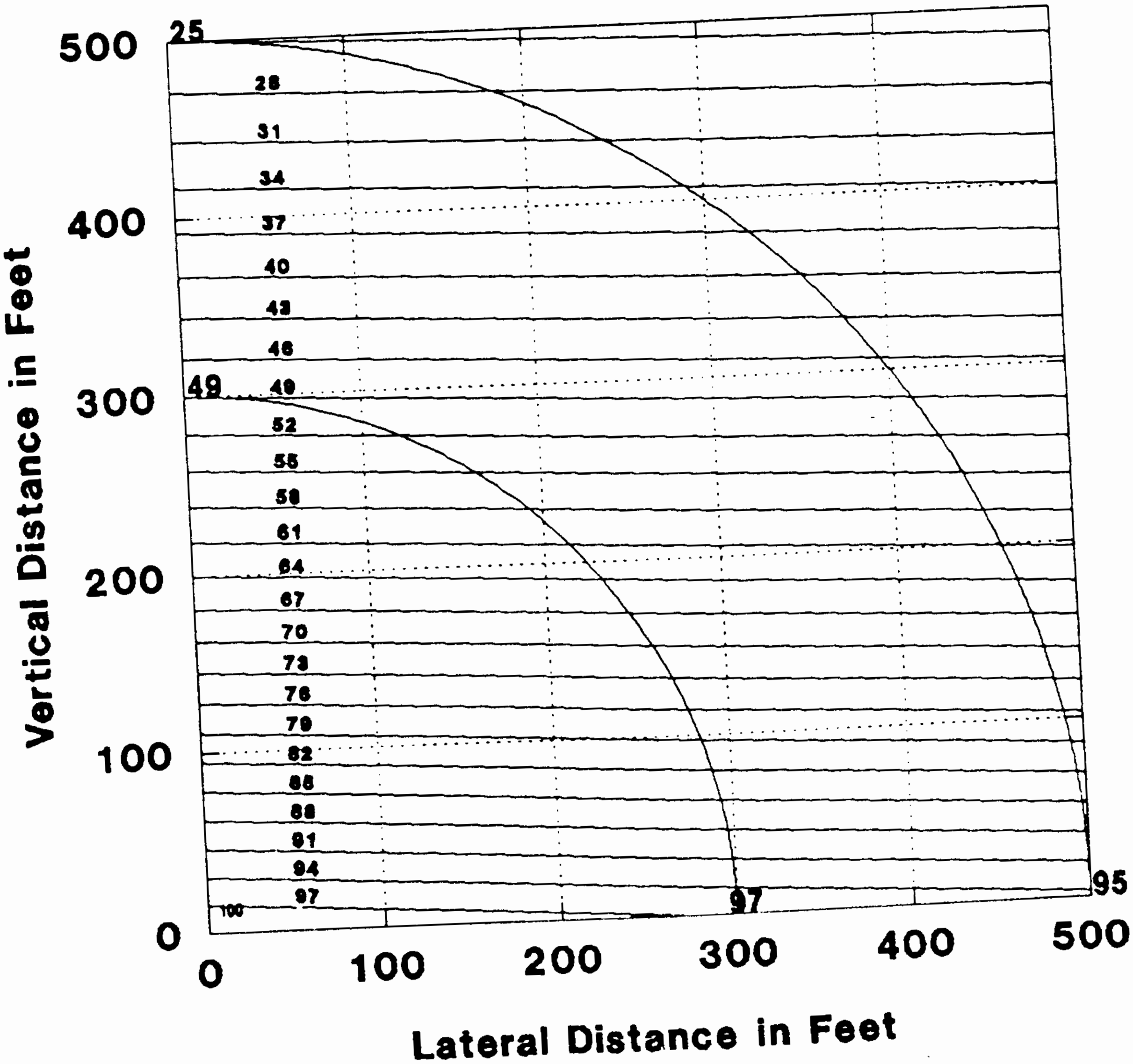

FIGURE A-4. CONTOUR PLOT OF API FOR HORIZONTAL AND VERTICAL DISTANCES OF 0 TO 500 FEET, SHOWING SLANT RANGE CONTOURS OF 300 AND 500 FEET

This plot shows the API values (the small numbers, inside the square running from 25 at the top to 100 at the bottom) for equal API contours (the slightly sloping horizontal lines) for horizontal and vertical distances of 0 to 500 feet. API values range form 25 (500 feet vertical, 0 horizontal separation) to 100 (0/0).

The 500-foot slant range contour has API values ranging from 25 to 95, depending on amount of vertical component. The 300-foot slant range contour runs form API - 49 to 97. Using API as a criterion, 500-foot slant range can be more dangerous than 300-foot.

APPENDIX B

CONTROLLER QUESTIONAIRE

POST RUN CONTROLLER QUESTIONNAIRE

PARTICIPANT CODE ______ DATE _____

PARTNER'S CODE(S) ____ ____ ____ TIME _____

RUN NUMBER ______ RUNWAY _____

---

1. CIRCLE THE NUMBER WHICH BEST DESCRIBES THE EASE OF TRAFFIC HANDLING DURING THE PAST SESSION.

1 2 3 4 5 6 7 8 9 10

DIFFICULT AVERAGE EFFORTLESS

---

2. RATE THE LEVEL OF ACTIVITY REQUIRED DURING THE PAST SESSION.

1 2 3 4 5 6 7 8 9 10

MINIMAL MODERATE INTENSE

---

3. RATE THE LEVEL OF STRESS EXPERIENCED DURING THE PAST SESSION.

1 2 3 4 5 6 7 8 9 10

SLIGHT MODERATE EXTREME

---

4. ARE THE CONDITIONS OF THIS PAST SESSION (traffic volume, procedures, geography, separation requirements...) WORKABLE AT YOUR PRESENT FACILITY? CIRCLE YOUR RESPONSE.

1 2 3 4 5 6 7 8 9 10

STRONG YES YES POSSIBLY NO STRONG NO

5. PLEASE DESCRIBE ANY UNUSUAL OCCURRENCES FROM THE LAST HOUR. PLEASE NOTE ANY UNUSUALLY LONG DELAYS OR INCORRECT PILOT RESPONSES. ANY ADDITIONAL COMMENTS CONCERNING THE SESSION OR SIMULATION WOULD BE WELCOME HERE.

---

6. **BRIEFLY DESCRIBE THE STRATEGY USED BY YOU AND YOUR PARTNER(S) TO REDUCE THE RISK CAUSED BY THE BLUNDERING AIRCRAFT FOR THE PAST SESSION. INCLUDE PROCEDURES FOR PULLING AIRCRAFT OFF THE LOCALIZER AS WELL AS OBSERVATIONAL STRATEGIES.**

7. PLEASE RATE THE SESSION YOU HAVE JUST COMPLETED. CHOOSE THE ONE RESPONSE THAT BEST DESCRIBES THE WORKLOAD LEVEL BASED UPON MENTAL EFFORT AND THE EASE OF TRAFFIC HANDLING.

---

1. MINIMAL MENTAL EFFORT IS REQUIRED AND TRAFFIC HANDLING TASKS ARE EASILY PERFORMED.

2. LOW MENTAL EFFORT IS REQUIRED AND SATISFACTORY TRAFFIC HANDLING IS ATTAINABLE.

3. ACCEPTABLE MENTAL EFFORT IS REQUIRED TO MAINTAIN SATISFACTORY TRAFFIC HANDLING.

4. MODERATELY HIGH MENTAL EFFORT IS REQUIRED TO MAINTAIN SATISFACTORY TRAFFIC HANDLING.

5. HIGH MENTAL EFFORT IS REQUIRED TO MAINTAIN SATISFACTORY TRAFFIC HANDLING.

6. MAXIMUM MENTAL EFFORT IS REQUIRED TO MAINTAIN SATISFACTORY TRAFFIC HANDLING.

7. MAXIMUM MENTAL EFFORT IS REQUIRED TO LESSEN THE THREAT OF BLUNDERING AIRCRAFT.

8. MAXIMUM MENTAL EFFORT IS REQUIRED TO MODERATE THE THREAT OF BLUNDERING AIRCRAFT.

9. INTENSE MENTAL EFFORT IS REQUIRED TO LIMIT THE THREAT OF BLUNDERING AIRCRAFT.

10. THE THREAT OF BLUNDERING AIRCRAFT CANNOT BE CONTROLLED.

APPENDIX C

Blunder Scenarios

DFW QUADS 16 START: 00:02:00
RUN #6

TIME	RW	A/C#	LR	AMT	COMM	ALTITUDE	INTERVAL
00:05:30	18R	1ST	R	20deg	YES	MAINTAIN	00:03:30
00:09:45	17L	C	L	20deg	YES	DESCEND	00:04:15
00:14:44	16L	1ST	R	30deg	NO	DESCEND	00:04:59
00:18:39	16R	3RD	L	30deg	YES	DESCEND	00:03:55
00:21:29	17L	3RD	R	20deg	YES	DESCEND	00:02:50
00:22:45	18R	3RD	R	30deg	NO	DESCEND	00:01:16
00:25:11	16L	3RD	R	20deg	YES	MAINTAIN	00:02:26
00:26:17	17L	2ND	R	30deg	YES	MAINTAIN	00:01:06
00:29:59	16L	3RD	R	30deg	NO	DESCEND	00:03:42
00:33:10	16R	1ST	L	20deg	YES	DESCEND	00:03:11
00:38:44	18R	3RD	L	30deg	YES	MAINTAIN	00:05:34
00:43:30	16L	1ST	R	10deg	NO	DESCEND	00:04:46
00:46:31	17L	1ST	L	20deg	YES	MAINTAIN	00:03:01
00:49:29	18R	2ND	R	30deg	NO	MAINTAIN	00:02:58
00:54:20	17L	2ND	L	30deg	YES	DESCEND	00:04:51
00:58:16							00:03:56
01:02:34							00:04:18
01:04:39							00:02:05
01:06:59							00:02:20
01:08:06							00:01:07

RUNWAY	#	SEQ	#	DEG	#
16L	4	1ST	5	10	1
17L	5	2ND	3	20	6
18R	4	3RD	6	30	8
16R	2	C	1		

ALTITUDE	#	DIR	#	COMM	#
DESCEND	9	LEFT	6	NO	5
MAINTAIN	6	RITE	9	YES	10

DFW DUALS WEST AIRPORT START 00:02:00
RUN #5

TIME	RW	A/C#	LR	AMT	COMM	ALTITUDE	INTERVAL
00:03:10	16R	3RD	L	20deg	NO	DESCEND	00:01:10
00:04:28	18R	2ND	R	30deg	YES	DESCEND	00:01:18
00:08:11	16R	1ST	L	20deg	YES	MAINTAIN	00:03:43
00:12:01	16R	C	L	20deg	YES	DESCEND	00:03:50
00:14:58	18R	3RD	R	20deg	NO	MAINTAIN	00:02:57
00:20:29	16R	C	L	30deg	NO	MAINTAIN	00:05:31
00:24:19	16R	3RD	L	20deg	NO	DESCEND	00:03:50
00:27:25	18R	2ND	R	10deg	YES	DESCEND	00:03:06
00:30:05	18R	3RD	R	20deg	NO	MAINTAIN	00:02:40
00:32:57	18R	2ND	R	30deg	YES	DESCEND	00:02:52
00:36:48	16R	3RD	L	20deg	NO	DESCEND	00:03:51
00:40:12	16R	2ND	L	30deg	YES	MAINTAIN	00:03:24
00:43:39	18R	2ND	R	30deg	NO	MAINTAIN	00:03:27
00:48:24	18R	3RD	R	10deg	YES	MAINTAIN	00:04:45
00:51:25	18R	3RD	R	30deg	YES	MAINTAIN	00:03:01
00:52:36	16R	1ST	L	30deg	NO	MAINTAIN	00:01:11
00:57:03	16R	2ND	L	30deg	NO	DESCEND	00:04:27
00:58:32							00:01:29
01:02:50							00:04:18
01:06:42							00:03:52

RUNWAY	#	SEQ	#	DEG	#
16L	0	1ST	2	10	2
17L	0	2ND	6	20	7
18R	8	3RD	7	30	8
16R	9	C	2		

ALTITUDE	#	DIR	#	COMM	#
DESCEND	8	LEFT	9	NO	9
MAINTAIN	9	RITE	8	YES	8

APPENDIX D

INDUSTRY OBSERVER QUESTIONNAIRE

Industry Observers Comments

Representatives from various airlines and the Air Transport Association were invited to observe the simulation. Following the Phase III simulation, industry observers were asked to respond to two questions and to provide any comments or observations. The questions were based on a scale of 1 to 10.

The first question asked, How realistic was the simulation? Observers responded with an average rating of 7, this indicates an above average degree of realism was attained.

The second question asked, Whether quadruple simultaneous parallel ILS operations are workable? Industry observer ratings resulted in an average of 8, a definite yes.

A suggestion provided by the observers concerned consideration of the performance characteristics of each type of aircraft under the same classification (e.g., turboprops). The performance characteristics from a representative group of turboprop aircraft were averaged together, and resulted in a generalized model for the performance of turboprops in the simulation. (PLEASE NOTE: the model did not accurately reflect the performance characteristics of all aircraft under the specified (turbojet) aircraft classification). It was felt that a model may need to be developed for each type of turbojet used in the simulation.

Overall, Industry Observers were very enthusiastic to view research being conducted on triple and quadruple simultaneous parallel approach runways. They encourage the industry to conduct further simulations, to continue to investigate issues relative to multiple parallel approach operations.

INDUSTRY OBSERVER QUESTIONNAIRE

NAME ____________________ DATE __________

ORGANIZATION __________

---

1. On which days did you observe the simulation?

DATES:
TIME:

---

2. How realistic was the simulation?

1	2	3	4	5	6	7	8	9	10

NOT REALISTIC AT ALL — AVERAGE — VERY REALISTIC

---

3. Based on your observations of this simulation, is the triple parallel runway operation workable?

1	2	3	4	5	6	7	8	9	10

STRONG NO — NO — POSSIBLY — YES — STRONG YES

---

4. Please provide any comments or observations.

APPENDIX E

CONTROLLER INFORMATION QUESTIONNAIRE AND CONSENT FORM

CONTROLLER BIOGRAPHICAL AND INFORMED
CONSENT QUESTIONNAIRE
SIMULATION OF TRIPLE PARALLEL RUNWAY APPROACHES

Part 1: Biographical Information

This questionnaire will help us to obtain relevant information with respect to your background as a controller, which may help us to better understand your performance in the simulation experiment. We would appreciate your taking the time to complete the few questions listed below. All information provided on this form will remain confidential, and the form itself will be destroyed following the completion of this project.

Date: ________________

1. How many years of experience do you have as an air traffic controller? ____________

2. How many years of experience have you had at your current facility? ____________

3. How many years have you worked parallel approaches? ____________

Part 2: Informed Consent

It is important to us that participating controllers in the simulation experiment 1) are fully informed with respect to the goals and procedures to be used in the experiment, and 2) have freely consented to participate in the simulation.

Please sign your name to indicate your agreement with the following statement:

"I have been fully briefed with respect to the goals of the simulation experiment and my role as a controller in the experiment. I further submit that I have freely chosen to participate in this study, and understand that I may withdraw from participation at any time, should I find it necessary to do so."

____

APPENDIX F

TECHNICAL OBSERVERS REPORT

D/FW METROPLEX
AIR TRAFFIC SYSTEM PLAN

Operational Assessment of Quadruple
Simultaneous Parallel Instrument
Landing System Approaches
to
Dallas/Fort Worth International Airport

Jan 29 - Feb 8, 1990

Prepared by
D/FW METROPLEX
AIR TRAFFIC SYSTEM PLAN
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U.S. DEPARTMENT OF TRANSPORTATION

FEDERAL AVIATION ADMINISTRATION

SOUTHWEST REGION

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EXECUTIVE SUMMARY

The quadruple, independent instrument landing system (ILS) simulation was conducted at the Federal Aviation Administration (FAA) Technical Center in Atlantic City, New Jersey, from January 29 through February 9, 1990. The goals were to demonstrate the safety and feasibility of multiple parallel ILS approaches and missed approaches/departures to independent runways with a mix of aircraft (props, turboprops, and turbojets).

The Dallas/Fort Worth (D/FW) Metroplex Air Traffic System Plan Program Office provided the staff support and served as observers documenting the actions of the controllers throughout the simulation. The records of the observers indicate two types of situations. The first type of situation was blunders--this includes turns of 30 degrees or less, with and without radio communications, which required aircraft on adjacent ILS courses be vectored to avoid the blundering aircraft. The second type of situation recorded the "turn left/right and rejoin the ILS" instructions issued to resolve the simulated navigational error.

The simulation of four simultaneous parallel ILS approaches required detailed evaluation of those situations which resulted in less than 500 feet slant range distance. However, the simulation did not produce any situations requiring detailed evaluation. The D/FW Metroplex Air Traffic System Plan Program Office decided to analyze all situations in which less than 3,000 feet slant range distance was computed. These situations are described in Annex 1 (Dual), Annex 2 (Quadruple), and Annex 3 (Missed Approach/Departure).

The simulation included 14 dual ILS runs in which 7 percent of the blunders resulted in less than 3,000 feet slant range distance. The closest point of approach was computed to be 1,482 feet slant range. There were 19 quadruple ILS runs in which 3.5 percent of the blunders resulted in less than 3,000 feet slant range distance. The closest point of approach was computed to be 914 feet vertical distance. None of the blunders in the 5 missed approach/departure runs resulted in less than 3,000 feet slant range distance. The closest point of approach was computed to be 3,765 feet slant range distance.

The quadruple simulation had one run in which the blunders were not scripted. Representatives of Aviation Standards National Field Office (AVN) and Flight Standards Service (AFS) induced, on a random basis, blunders that would result in a "worse case" condition. This was accomplished by manipulating aircraft to a point where they were either parallel or slightly behind on an adjacent ILS and approximately the same altitude before beginning the blunder. During this run, the closest point of approach was computed to be 1,368 feet slant range.

The simulation proved most emphatically that the implementation of the quadruple, parallel ILS approach at Dallas/Fort Worth International Airport will be a safe, efficient, and effective procedure.

INTRODUCTION

Implementation of the D/FW Metroplex Air Traffic System Plan will require new and innovative procedures to accommodate the increased volume of traffic projected for Dallas/Fort Worth International Airport.

Dallas/Fort Worth International Airport will construct two new parallel north/south runways on the east and west side of the airport. The east runway (16L/34R) will be approximately 8,500 feet long and 5,000 feet east of the center of Runway 17L. The west runway (16R/34L) will be approximately 8,500 feet long and 5,800 feet west of the centerline of Runway 18R. In order to gain full capacity of the new runways, procedures must be developed which will allow multiple (more than two), simultaneous parallel ILS approaches to be conducted during weather minimums of 200-foot ceiling and visibility of 1/2 nautical mile (NM).

The multiple, simultaneous parallel ILS approach simulations are being conducted in phases. Phase I was completed in June 1988. Phase II was completed in October 1989. Phase III was conducted at the FAA Technical Center in Atlantic City, New Jersey, from January 29 through February 9, 1990. Phases I, II, and III are site specific to Dallas/Fort Worth International Airport.

Phase IV, National Standards for Multiple (more than 2) Parallel ILS Approach Simulation, will be conducted at the FAA Technical Center April 23 through May 4, 1990.

The Dallas/Fort Worth TRACON/Tower provided seven individuals--one supervisor, one planning & procedures specialist, and five controllers--to participate in the simulation. The D/FW Metroplex Air Traffic System Plan Program Office provided the staff support and served as observers documenting the actions of the controllers throughout the simulation.

ANALYSIS

The simulation consisted of three separate scenarios with the runway layout unique to Dallas/Fort Worth International Airport. The first scenario studied dual parallel ILS approaches consisting of three separate runway layouts. The runway layouts were: 16L and 17L, 17L and 18R, and 18R and 16R. The second scenario studied the quadruple parallel ILS approaches using Runways 16L, 17L, 18R, and 16R. The third scenario studied quadruple missed approaches/departures. The simulation compared the data from the dual runway with the quadruple runway. Throughout the simulation, the controllers encountered unexpected situations and conditions to which they responded with excellent success.

The test plan for the Simulation of Quadruple Simultaneous Parallel ILS Approaches at D/FW included a minimum acceptable slant range distance of 500 feet between aircraft. The D/FW Metroplex Air Traffic System Plan Program Office arbitrarily decided to analyze all situations in which less than 3,000 feet slant range was computed. The following paragraphs outline some of the general problems and situations.

BLUNDERS: The simulation included several types of scripted blunders, which were introduced at various times during a 1-hour run, without the prior knowledge of the controllers or observers. These blunders included 10-, 20-, and 30-degree turns with and without radio communication. Due to the navigational parameters set in the computer, the controllers and observers were unable to differentiate between 10- or 20-degree blunders in which the controller had radio communications with the aircraft and other navigational errors. Further explanation of this is in the Navigation paragraph. All blunders were detected immediately. During blunders involving nonradio conditions, the controllers issued instructions to the aircraft on the adjacent ILS to turn/climb.

NAVIGATION: The navigation error model for this simulation created a situation which eliminated most of the 10- and 20-degree blunders with radio communications. The navigation parameters allowed the aircraft to deviate either side of the centerline of the ILS along the entire final approach course. The controllers would detect these deviations and instruct the aircraft to turn left/right and rejoin the ILS. Pseudoroutes were established where aircraft were initially offset either side of the localizer and are asymptotic to the threshold.

PILOTS: Simulation pilots were a major concern because simulation results could be greatly affected by the ability of the pilots. During the course of the simulation, pilot error fell into two categories:

a. Human Error - Slow response to aircraft calls and the entry of control instructions.

b. Computer Problems - Entry problems which were beyond the control of the pilots.

The controllers and observers were unable to determine the difference, and all the problems are combined under the general category of "pilot error."

Initially, the pilots were unfamiliar with the simulation scenarios which was reflected by their slow response times. The runs conducted on the morning of January 30 were not recorded and were used for pilot and controller familiarization. This allowed the pilots and controllers to become comfortable with the simulation process, which generated realistic results. Overall, the pilots performed in an outstanding manner and are to be commended.

EQUIPMENT: During the simulation, we encountered some minor computer problems and scope failures which were an inconvenience to the simulation. However, the controllers were able to handle the indicator failures without any difficulty. The indicator failures were unplanned but added realism to the evaluation.

These failures validate the one runway, one monitor concept and the associated equipment layout plan for the final monitor position.

RUNS: The information contained in Annex 1 (Dual), Annex 2 (Quadruple), and Annex 3 (Missed Approach/Departure) provides a brief explanation of the occasions in which a blundering aircraft came within 3,000 feet or less slant range of an aircraft on the adjacent ILS courses. The following is a brief explanation of the format used in this report. The first sections contain run number, date, start time, runways used, and controller assignment. The second section outlines the blunder. The aircraft call sign that follows the time is the blundering aircraft. The aircraft call signs which follow are those aircraft which were affected by this blunder. Under each of these aircraft is the minimum estimated vertical and lateral distance as viewed by the observers. The last section is a brief overview of what control actions were initiated and the results.

The Aircraft Proximity Index (API), developed by the Technical Center, is a single value that reflects the relative seriousness or danger of the situation. The API assigns a weight or value to each conflict, depending on vertical and lateral distance. API facilitates the identification of the more serious conflicts in a data base where many conflicts are present. A figure of 100 is the maximum value of the API. Therefore, the higher the API, the closer the aircraft. It should be noted that, in the dual runs, Run 1-3 produced the highest API of 73, but pilot error heavily influenced this figure. In the quadruple runway runs, Run 8 produced the highest API of 62. In the missed approach/ departure, Run 32 produced the highest API of 4. If further explanation of the API is desired, it can be obtained from the FAA Technical Center.

CONCLUSION

The D/FW Metroplex Air Traffic System Plan Program Office is thoroughly convinced that the quadruple, simultaneous parallel ILS simulation was a complete success. The failure of the radar indicators during the simulation only serves to emphasize the controllers' ability to resolve the problems when they occur and supports the feasibility of quadruple, simultaneous parallel ILS approaches. The simulation proved without a doubt that the implementation of the quadruple, simultaneous parallel ILS approaches at D/FW International Airport will be a safe, efficient, and effective procedure.

RECOMMENDATIONS

During the simulation, events occurred which created problems and delayed some of the runs. These events included both hardware and software problems with the computer, inexperience of the pilots, and the unfamiliarity of the participating controllers. These problems were minor and did not delay the simulation. The D/FW Metroplex Air Traffic System Plan Program Office recommends the following:

a. Makeup time should be scheduled during any simulation to resolve computer problems.

b. The maximum number of 1-hour runs should be five each day with no exceptions.

c. Enough controllers should be available to ensure that each controller works no more than three runs per day and a maximum of two runs in a row.

d. Training time should be devoted for indoctrination and familiarization for both the controllers and pilots.

ANNEX 1

(DUAL)

ANNEX 1 (DUAL)

RUN SUMMARY

RUN	BLUNDERS	TURN/JOIN
1 - 3	15	54
1 - 2	17	7
2 - 1	13	27
2 - 3	15	34
5 - 3	11	28
5 - 1	15	19
9 - 1	9	12
9 - 2	10	28
27 - 2	14	11
27 - 3	14	3
30 - 1	12	16
30 - 3	15	15
31 - 1	13	14
31 - 2	10	4
TOTALS 14	173	272

Blunders: less than 3,000 feet slant range distance - 13
less than 500 feet slant range distance - 0

NOTE: - 1 refers to Runway 16R and 18R
- 2 refers to Runway 17L and 18R
- 3 refers to runway 17L and 16L

DUAL RUN ANALYSIS

RUN 1 - 3 1/30/90 14:30 LCL

	RUNWAY	CONTROLLER
	16L	C
	17L	F

0017:52 AAL828 Rwy 16L Turned right - No radio

DAL1546 Rwy 17L Turned right and climbed to 6,000 (600 ft - 1/3 NM)

The closest point of approach was computed to be 2,302 feet slant range with an API of 3.

0020:30 MTR801 Rwy 16L Turned right - With radio

AAL326 Rwy 17L Turned right and climbed (200 ft - 1/3 NM)

Approximately 20 seconds lapsed before a turn was observed.

The closest point of approach was computed to be 2,761 feet slant range with an API of 52.

0049:06 DAL1107 Rwy 16L Turned right - No radio

AAL898 Rwy 17L Turned right and climbed (200 ft - 1/4 NM)

The pilot turned AAL898 left to the assigned heading which resulted in a 270 degree turn.

The closest point of approach was computed to be 2,120 feet slant range with an API of 73.

0057:25	AAL1944	Rwy 17L Turned left - No radio
	AAL900	Rwy 16L Turned left and descended (700 ft - 1/2 NM)

The closest point of approach was computed to be 2,679 feet slant range with an API of 1.

RUN 2 - 1	1/30/90	15:35 LCL

RUNWAY	CONTROLLER
18R	F
16R	B

0037:00	ASE800	Rwy 16R	Turned left - No radio
	AAL488	Rwy 18R	Turned left heading 090 (500 ft - 1/2 NM)

The aircraft was slow in making the turn.

The closest point of approach was computed to be 2,527 feet slant range with an API of 39.

0038:00	ASE966	Rwy 16R	Turned left - No radio
	AAL1185	Rwy 18R	Turned left heading 090 and climbed (300 ft - 1/4 NM)

The aircraft was very slow in turning.

The closest point of approach was computed to be 2,745 feet slant range with an API of 30.

RUN 2 - 3	1/30/90	15:15 LCL

RUNWAY	CONTROLLER
16L	E
17L	A

0033:10	AAL68	Rwy 17L	Turned left - With radio
	AAL1374	Rwy 16L	Turned left (200 ft - 1/4 NM)

The pilot was slow to acknowledge the turn instruction and after the turn was acknowledged the aircraft did not turn.

The closest point of approach was computed to be 2,152 feet slant range with an API of 38.

RUN 5 - 3 1/31/90 11:00 LCL

RUNWAY	CONTROLLER
16L	B
17L	D

0029:12 AAL1443 Rwy 17L Turned left - No radio

USA1465 Rwy 16L Turned left and climbed (0 ft - 1/8 NM)

USA1465 was 300 feet below AAL1443 when the turn by AAL1443 began. USA1465 began a climb in a timely manner; however, 16 to 20 seconds lapsed before the turn could be observed.

The closest point of approach was computed to be 1,538 feet slant range with an API of 70.

0045:00 AAL287 Rwy 17L Turned left - No radio

N2487A Rwy 16L Turned left and descended (200 ft - 1/4 NM)

After the turn was given, the pilot responded with, "Say again." The aircraft descended in a timely manner, but the turn required 20 seconds or more to be observed.

The closest point of approach was computed to be 1,482 feet slant range with an API of 11.

RUN 5 - 1 | 1/31/90 | 13:00 LCL

RUNWAY	CONTROLLER
18R	G
16R	C

0053:00 ASE966 and AAL1185 have a computed slant range distance of 2,940 feet with an API of 19.

0057:00 AAL363 and AAL715 have a computed slant range distance of 2,301 feet with an API of 1.

All observer data was lost for these two runs.

RUN 30 - 3 2/7/90 10:55 LCL

RUNWAY	CONTROLLER
16L	D
17L	G

0033:00	AAL1374	Rwy 16L	Turned right - No radio
	AAL68	Rwy 17L	Turned right and climbed (200 ft - 1/4 NM)

The closest point of approach was computed to be 2,700 feet slant range with an API of 72.

RUN 31 - 1	2/7/90	12:00 LCL

RUNWAY	CONTROLLER
16L	G
17L	B

0058:51	AAL1067	Rwy 16L	Turned right - No radio
	AAL759	Rwy 17L	Turned right and climbed (200 ft - 1/2 NM)

The closest point of approach was computed to be 2,689 feet slant range with an API of 22.

ANNEX 2
(QUADRUPLE)

ANNEX 2 (QUADRUPLE)

RUN SUMMARY

RUN	BLUNDERS	TURN/JOIN
3	16	41
4	5	31
6	15	53
7	18	28
8	14	33
10	9	35
11	18	29
12	11	34
13	13	11
16	16	17
17	14	39
18	14	41
19	13	25
21	10	40
22	17	14
23	14	14
24	16	14
26	15	27
28	14	16
TOTALS 19	262	542

Blunders: less than 3,000 feet slant range distance - 10
less than 500 feet slant range distance - 0

QUADRUPLE RUN ANALYSIS

RUN 4 1/31/90 09:50 LCL

RUNWAY	CONTROLLER
16L	A
17L	F
18R	C
16R	E

0006:58	AAL347	Rwy 17L	Turned left - With radio
	AAL349	Rwy 16L	Turned left and climbed (500 ft - 1/2 NM)

The controller made three calls to which the pilot responded; however, the aircraft was very slow to respond.

The closest point of approach was computed to be 2,964 feet slant range with an API of 11.

RUN 7 1/31/90 09:50 LCL

RUNWAY	CONTROLLER
16L	C
17L	E
18R	A
16R	D

0048:51	DAL623	Rwy 16L	Turned right - No radio
	TWA623	Rwy 17L	Climbed (100 ft - 1/2 NM)

The closest point of approach was computed to be 2,835 feet slant range with an API of 47.

0058:00	DAL1896	Rwy 18R	Turned right - No radio
	ASE448	Rwy 16R	Turned right (400 ft - 1/2 NM)

The closest point of approach was computed to be 1,996 feet slant range with an API of 1.

RUN 8 2/1/90 08:10 LCL

RUNWAY	CONTROLLER
16L	A
17L	C
18R	D
16R	G

0024:30	AAL497	Rwy 18R	Turned right - No radio
	EME139	Rwy 16R	Turned right and descend (100 ft - 1/5 NM)

The controller issued instructions for EME139 to immediately descend to 2,000 feet and turn right. When the instructions were issued, the aircraft were estimated to be 200/300 feet apart. EME139 began the descent in a timely manner; however, 20-25 seconds elapsed, and the turn instructions were issued again before an indication of a turn could be observed.

The closest point of approach was computed to be 1,080 feet slant range with an API of 62.

RUN 11 2/2/90 13:20 LCL

RUNWAY	CONTROLLER
16L	C
17L	G
18R	A
16R	D

0027:55	DAL516	Rwy 16R	Turned left - No radio
	AAL1305	Rwy 18R	Turned left and descended (0 ft - 1/4 NM)

The controller issued the turn left instruction twice before the turn could be observed.

The closest point of approach was computed to be 2,359 feet slant range with an API of 53.

RUN 13 2/2/90 08:10 LCL

RUNWAY	CONTROLLER
16L	D
17L	A
18R	C
16R	F

0010:16	ASE455	Rwy 16R	Turned left - No radio
	AAL384	Rwy 18R	Turned left and climbed (800 ft - 0 NM)

The closest point of approach was computed to be 914 feet vertical distance with an API of 3.

RUN 18 2/5/90 13:20 LCL

RUNWAY	CONTROLLER
16L	F
17L	B
18R	E
16R	A

0007:22	FDX185	Rwy 16R	Turned left - With radio
	DAL798	Rwy 18R	Climbed (200 ft - 1/4 NM)

The controller was experiencing communication problems and was in the process of changing his headset when the blunder occurred.

The closest point of approach was computed to be 2,315 feet slant range with an API of 56.

RUN 22 2/6/90 12:45 LCL

RUNWAY	CONTROLLER
16L	D
17L	B
18R	D
16R	G

0028:55	DAL981	Rwy 16L	Turned right - No radio
	DAL517	Rwy 17L	Turned and climbed (200 ft - 1/4/NM)

The closest point of approach was computed to be 2,903 feet slant range with an API 50.

RUN 28 2/7/90 08:00 LCL

RUNWAY	CONTROLLER
16L	F
17L	C
18R	A
16R	E

0045:35	AAL347	Rwy 17L	Turned left - No radio
	MTR823	Rwy 16L	Turned left and climbed (300 ft - 1/5 NM)

The pilot response of MTR823 was very slow and hesitant, resulting in less than necessary separation. This pilot was involved in two different situations in less than 7 minutes which contributed to very close situations.

The closest point of approach was computed to be 1,445 feet slant range with an API of 42.

RUN 29 2/7/90 09:45 LCL

UNSCRIPTED BLUNDERS

RUNWAY	CONTROLLER
16L	G
17L	B
18R	F
16R	D

0005:10	ASE315	Rwy 16R	Turned left - No radio
	AAL303	Rwy 18R	Climbed (900 ft - 1/3 NM)

The closest point of approach was computed to be 2,633 feet slant range with an API of 5.

0013:00	N2431A	Rwy 16L	Turned left - No radio
	DAL789	Rwy 17L	Climbed (0 ft - 1/4 NM)

The closest point of approach was computed to be 2,059 feet slant range with an API of 64.

0024:33	AAL497	Rwy 18R	Turned right - No radio
	EME139	Rwy 16L	Turned right and climbed (200 ft - 1/4 NM)

The pilot of EME139 was slow to respond and react.

The closest point of approach was computed to be 1,368 feet slant range with an API of 33.

0026:06	DAL612	Rwy 18R	Turned right - No radio
	MTR923	Rwy 16R	Turned right and climbed (400 ft - 1/4 NM)

The closest point of approach was computed to be 2,480 feet slant range with an API of 10.

0032:10	AAL1460	Rwy 18R	Turned right - No radio
	EME244	Rwy 16R	Turned right and climbed (100 ft - 1/3 NM)

The closest point of approach was computed to be 2,443 feet slant range with an API of 15.

0034:00	AAL1306	Rwy 18R	Turned right - No radio
	AAL796	Rwy 16R	Turned right and climbed (100 ft - 1/3 NM)

The closest point of approach was computed to be 2,466 feet slant range with an API of 49.

0038:15	MTR854	Rwy 16L	Turned right - No radio
	AAL800	Rwy 17L	Climbed (100 ft - 1/4 NM)

Initially both aircraft were "NORDO"; therefore, the controllers had no possible chance of separating the aircraft. The pilot of AAL800 finally responded after the fourth or fifth call but, by this time, the aircraft were in such proximity that separating the aircraft was almost impossible.

The closest point of approach was computed to be 1,719 feet slant range with an API of 10.

0048:10	ASE314	Rwy 16R	Turned left - No radio
	AAL170	Rwy 18R	Climbed (200 ft - 1/4 NM)

The closest point of approach was computed to be 1,858 feet slant range with an API of 39.

0052:30	AAL1801	Rwy 18R	Turned right - No radio
	ASE634	Rwy 16R	Turned right and climbed (200 ft - 1/4 NM)

The closest point of approach was computed to be 1,844 feet slant range with an API of 56.

0055:00	AAL715	Rwy 16L	Turned right - No radio
	DAL1766	Rwy 17L	Climbed (200 ft - 1/3 NM)

The closest point of approach was computed to be 1,568 feet slant range with an API of 45.

ANNEX 3
(MISSED APPROACH/DEPARTURE)

ANNEX 3 (MISSED APPROACH/DEPARTURE)

RUN SUMMARY

	RUN	MISSED APPROACHES
	14	10
	15	10
	20	9
	24	4
	32	5
TOTAL	5	38

Blunders: less than 3,000 feet slant range distance - 0
less than 500 feet slant range distance - 0

RUN 14 | 2/2/90 | 09:30 LCL

RUNWAY	CONTROLLER
16L	E
17L/R	D
18L/R	G
16R	B

0026:30 AAL264 Rwy 18R Missed approach - No radio

AAL142 Rwy 17R Departure
(800 ft - 2 1/2 NM)

The closest point of approach was computed to be 7,324 feet slant range with an API of 1.

The closest point of approach in the blunder between AAL142 and DAL105 was computed to be 4,582 feet. DAL105 was not a blundering aircraft, and position reference to AAL142 is unknown.

The closest point of approach between AAL264 and DAL105 was computed to be 10,341 feet slant range.

APPENDIX G

QUADRUPLE PARALLEL RUNWAY SIMULATION

CONTROLLER REPORT

D/FW METROPLEX
AIR TRAFFIC SYSTEM PLAN

SIMULATION OF QUADRUPLE INDEPENDENT SIMULTANEOUS INSTRUMENT LANDING SYSTEM APPROACHES

JANUARY 29 - FEBRUARY 9, 1990

Prepared by the following
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U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
SOUTHWEST REGION

QUADRUPLE PARALLEL RUNWAY SIMULATION

CONTROLLER REPORT

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ACKNOWLEDGEMENTS

We would like to thank the Southwest Region for the opportunity to represent the Region during this simulation. The region's initiative in developing the project and its unwavering support are commendable. Also, the Technical Center and contract personnel should be commended for their efforts. Both their detailed preparation and cooperation were obvious throughout the simulation. We would also like to thank the National Airspace Capacity Staff, ATO-20 for their administration of both resources and arrangement at the national level. Finally, we would like to express our appreciation to the DFW Metroplex Plan Task Force for their efforts. Their careful attention to details pertaining to both the laboratory and outside accommodations allowed us to complete the assigned tasks.

INTRODUCTION

On January 29, 1990 a team of controllers from DFW Terminal Radar Approach Control (TRACON) consisting of six air traffic controllers and one supervisor, met at the Federal Aviation Administrations (FAA) Technical Center at Atlantic City, International Airport, New Jersey. The purpose was to conduct the simulation of monitoring quadruple simultaneous approaches for the proposed runways 16L and 16R and the present runways 17L and 18R and to monitor radar departures from the same runways.

ANALYSIS

The objective of the simulation was to determine the feasibility of quadruple simultaneous ILS arrivals and departures at Dallas Fort Worth International Airport. We unanimously agree that quadruple simultaneous arrivals and departures can be conducted in a safe and efficient manner. The primary controller skills used to achieve the objective were continuous scanning of all traffic and timely coordination between adjacent controllers. Both skills were critical to the recognition and resolution of potential traffic conflictions. The objective was accomplished despite three noteworthy limitations. First, there were no primary or secondary radar targets, which made it difficult to recognize deviations from the localizer. Second, the simulation was designed with aircraft constantly weaving on both sides of the localizer (wandering), which is absurd. In our collective years of air traffic control experience, we have never observed this phenomenon. Third, pilots that operate in todays complex air traffic environment, are able to respond more readily to commands for expeditious compliance clearances, than the simulator pilots are able to.

RECOMMENDATIONS

FEDERAL AVIATION ADMINISTRATION TECHNICAL CENTER

1. Provide lighted keyboards at the radar positions. Use of overhead rather than direct lighting for keyboard illumination was a distraction because of glare on the screen.

2. The present simulator pilot and aircraft configurations make their reaction times slower than normal. We believe the Technical Center should consider a modification to the present procedures to more closely resemble real-life performance characteristics.

DALLAS FT. WORTH TERMINAL RADAR APPROACH CONTROL

1. An Employee Participation Group (EPG) should be formed to analyze traffic integration and airspace constraints in order to formulate procedures for the quadruple simultaneous ILS program at Dallas Ft. Worth International airport, (D/FW).

2. There should be one radar scope for each monitor position. All monitor positions should be located together and near their respective arrival and departure positions.

3. The DFW ARTS keyboard should be adapted to enable the leader line to be independently placed in any cardinal position to avoid overlaps of the data tags.

CONCLUSION

Based on the criteria established, we were able to meet our objectives despite the limitations cited in the analysis.

The arrival and departure monitor positions proved to be functional for DFW airport in a simulated environment.

We believe that quadruple ILS approaches as simulated, without regard to the interaction of adjacent airspace and traffic, is a safe, efficient and workable procedure.

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APPENDIX H

PROJECTED CLOSEST POINT OF APPROACH (PCPA) COMPUTATIONS

CALCULATION OF PCPA AND TIME-TO-PCPA

Consider two aircraft (A and B) having X, Y, and Z spatial positions (coordinates) at Time i; that is:

Position of A/C_A at $Time_i$ = $X_{A_i}, Y_{A_i}, Z_{A_i}$, and (1.1)

Position of A/C_B at $Time_i$ = $X_{B_i}, Y_{B_i}, Z_{B_i}$, and (1.2)

The same A/C also have X, Y, and Z locations at Time i + 1:

Position of $A/C_A = X_{A_{i+1}}, Y_{A_{i+1}}, Z_{A_{i+1}}$ at Time = i + 1. (2.1)

Position of $A/C_B = X_{B_{i+1}}, Y_{B_{i+1}}, Z_{B_{i+1}}$ at Time = i + 1. (2.2)

The change in locations of the two aircraft between $Time_i$ and i + 1 will be (subtracting eqs. 1.1 from 2.1 and 1.2 from 2.2):

$$\Delta X_A = X_{A_{i+1}} - X_{A_i};\ \Delta Y_A = Y_{A_{i+1}} - Y_{A_i};\ \Delta Z_A = Z_{A_{i+1}} - Z_{A_i} \quad (3.1)$$

$$\Delta X_B = X_{B_{i+1}} - X_{B_i};\ \Delta Y_B = Y_{B_{i+1}} - Y_{B_i};\ \Delta Z_B = Z_{B_{i+1}} - Z_{B_i} \quad (3.2)$$

The slant range (SR) between A/C_A and A/C_B at $Time_i$ =

$$SR_{AB_i} = \left[\left(X_{A_i} - X_{B_i}\right)^2 + \left(Y_{A_i} - Y_{B_i}\right)^2 + \left(Z_{A_i} - Z_{B_i}\right)^2 \right]^{.5} \quad (4.0)$$

Assuming that both A/C continue along the vectors defined by their locations at $Time_i$ and $Time_{i+1}$, then SR at Time "s" later will be found by

$$SR_{AB_{i+s}} = \Big[\left(\left(X_{A_i} + s \cdot \Delta X_A\right) - \left(X_{B_i} + s \cdot \Delta X_B\right)\right)^2$$

$$+ \left(\left(Y_{A_i} + s \cdot \Delta Y_A\right) - \left(Y_{B_i} + s \cdot \Delta B_i\right)\right)^2 \quad (5.0)$$

$$+ \left(\left(Z_{A_i} + s \cdot \Delta Z_A\right) - \left(Z_{B_i} + s \cdot \Delta Z_B\right)\right)^2 \Big]^{.5}$$

$$= \left[\left((X_{A_i} - X_{B_i}) + s\,(\Delta X_A - \Delta X_B) \right)^2 \right.$$

$$+ \left((Y_{A_i} - Y_{B_i}) + s\,(\Delta Y_A - \Delta Y_B) \right)^2 \qquad (5.1)$$

$$\left. + \left((Z_{A_i} - Z_{B_i}) + s\,(\Delta Z_A - \Delta Z_B) \right)^2 \right]^{.5}$$

$$= \left[(X_{A_i} - X_{B_i})^2 + s^2\,(\Delta X_A - \Delta X_B)^2 + 2s\,(X_{A_i} - X_{B_i})(\Delta X_A - \Delta X_B) \right.$$

$$+ (Y_{A_i} - Y_{B_i})^2 + s^2\,(\Delta Y_A - \Delta Y_B)^2 + 2s\,(Y_{A_i} - Y_{B_i})(\Delta Y_A - \Delta Y_B)$$

$$\left. + (Z_{A_i} - Z_{B_i})^2 + s^2\,(\Delta Z_A - \Delta Z_B)^2 + 2s\,(Z_{A_i} - Z_{B_i})(\Delta Z_A - \Delta Z_B) \right]^{.5}$$

$$= \left[SR_{AB_i}{}^2 + s^2 \left((\Delta X_A - \Delta X_B)^2 + (\Delta Y_A - \Delta Y_B)^2 + (\Delta Z_A - \Delta Z_B)^2 \right) \right.$$

$$+ 2s \left((X_{A_i} - X_{B_i})(\Delta X_A - \Delta X_B) + (Y_{A_i} - Y_{B_i})(\Delta Y_A - \Delta Y_B) \right.$$

$$\left. + (Z_{A_i} - Z_{B_i})(\Delta Z_A - \Delta Z_B) \right]^{.5}$$

Since the X, Y, Z and Δ_X , Δ_Y , Δ_Z values are known for each aircraft, we can let:

$$C_1 = \left[(\Delta X_A - \Delta X_B)^2 + (\Delta Y_A - \Delta Y_B)^2 + (\Delta Z_A - \Delta Z_B)^2 \right] \qquad (6.1)$$

and

$$C_2 = \left[(X_{A_i} - X_{B_i})(\Delta X_A - \Delta X_B) + (Y_{A_i} - Y_{B_i})(\Delta Y_A - \Delta Y_B) + (Z_{A_i} - Z_{B_i})(\Delta Z_A - \Delta Z_A) \right] \qquad (6.2)$$

Substituting these values into the previous equation

$$SR^2_{AB_{i+s}} = SR^2_{AB_i} + s^2C_1 + 2s\,C_2 \tag{7.0}$$

Differentiating $SR_{AB_{i+s}}$ with respect to s, we obtain

$$\frac{SR^2_{AB_{i+s}}}{d_s} = 2C_1 s + 2C_2 \tag{7.1}$$

To find the minima, we set the left side of Eq. (7.1) to zero and solve for "s".

$$o = 2C_1 s + 2C_2$$

$$s = \frac{-C_2}{C_1} \tag{8.0}$$

Solving for "s", we can now solve for $SR^2_{AB_{i+s}}$ using Eq. (7.0) and, taking the square root we obtain the projected slant range at $\text{Time}_{i+s} = (SR^2_{AB_{i+s}})$.

Thus, for any two consecutive (and simultaneous) views of any two aircraft, their positional data (X, Y, and Z) can be used to predict both the slant range at PCPA and the time to reach the current projection of PCPA. It should be noted that if "s" is negative, the aircraft are diverging and projecting of PCPA becomes the current slant range. If "s" is zero, (which occurs when $C_2 = 0$), the A/C are on parallel courses at identical speeds and the predicted CPA will also equal the current slant range.

Finally, with regard to the prediction of PCPA, the X, Y, and Z coordinates for each aircraft can be predicted for Time_{i+s};

$$\dot{X}_{A_{i+s}} = X_{A_i} + s\Delta X_A \; ; \; \dot{Y}_{A_{i+s}} = Y_{A_i} + s\Delta Y_A \; ; \; \dot{Z}_{A_{i+s}} = Z_{A_i} + s\Delta Z_A$$

$$\dot{X}_{B_{i+s}} = X_{B_i} + s\Delta X_B \; ; \; \dot{Y}_{B_{i+s}} = Y_{B_i} + s\Delta Y_B \; ; \; \dot{Z}_{B_{i+s}} = Z_{B_i} + s\Delta Z_B$$

These values can be used to compute the PAPI value for the PCPA projected for Time_{i+s}.

APPENDIX I

MULTIPLE PARALLEL APPROACH TECHNICAL WORK GROUP ADMINISTRATIVE ASSESSMENT

MULTIPLE PARALLEL APPROACH TECHNICAL WORK GROUP
ADMINISTRATIVE ASSESSMENT

The quadruple, simultaneous arrival/departure simulation was conducted at the Federal Aviation Administration (FAA) Technical Center, Atlantic City International Airport, New Jersey, from January 29 through February 9, 1990. The goals were to demonstrate the safety and feasibility of conducting simultaneous arrivals and departures to/from quadruple parallel runways with a mix of aircraft (props, turboprops, and turbojets) at Dallas/Fort Worth (D/FW).

The D/FW Metroplex Program Office provided the staff support and served as observers documenting the actions of the controllers throughout the simulation. The records of the observers indicate two types of situations. The first of which was blunders--this includes turns of 30 degrees or less, with and without radio communications, which required aircraft on adjacent ILS courses be vectored to avoid the blundering aircraft. The second situation, recorded the "turn left/right and rejoin the ILS" instructions issued to resolve the simulated navigational error.

The simulation of four simultaneous parallel ILS approaches required detailed evaluation of those situations which resulted in 500 feet (ft) or less slant range distance. However, the simulation did not produce any situations requiring detailed evaluation through the decision tree analysis.

The simulation included 14 dual ILS runs in which 7 percent of the blunders resulted in less a 3000 ft slant range distance. The closest point of approach was computed to have a 1482 ft slant range distance. There were 19 quadruple ILS runs in which 3.5 percent of the blunders resulted in less than a 3000 ft slant range distance. The closest point of approach was computed to be 914 ft vertical distance. None of the blunders in the 5 missed approach/ departure runs resulted in less than 3000 ft slant range distance. The closest point of approach was computed to be 3765 ft slant range distance.

The quadruple simulation had one run in which the blunders were not scripted. Representatives of Aviation Standards National Field Office (AVN) and Flight Standards Service (AFS) induced, on a random basis, blunders that would result in a "worse case" condition. This was accomplished by manipulating aircraft to a point where they were either parallel or slightly behind other aircraft on an adjacent ILS and approximately the same altitude before beginning the blunder. During this run, the closest point of approach was computed to have a 1368 ft slant range distance.

INTRODUCTION

The multiple, simultaneous parallel Instrument Landing System (ILS) approach simulations are being conducted in phases. Phase I was completed in June 1988. Phase II was completed in October 1989. Phase III was conducted at the Federal Aviation Administration (FAA) Technical Center, Atlantic City, New Jersey, from January 29 through February 9, 1990. Phases I, II, and III are site specific to the Dallas/Fort Worth (D/FW) International Airport.

Phase IV, National Standards for Multiple (more than 2) Parallel ILS Approach Simulation, was conducted at the FAA Technical Center April 23 through May 4, 1990.

The D/FW Terminal Radar approach Control Facility (TRACON)/Tower provided seven individuals--one supervisor, one planning and procedures specialist, and five controllers--to participate in the simulation. The D/FW Metroplex Program Office provided the staff support and served as observers documenting the actions of the controllers throughout the simulation.

The simulation consisted of three separate scenarios with the runway layout unique to the D/FW International Airport. The first scenario studied dual parallel ILS approaches consisting of three separate runway layouts. The runway layouts were: 16L and 17L, 17L and 18R, and 18R and 16R. The second scenario studied the quadruple parallel ILS approaches using Runways 16L, 17L, 18R, and 16R. The third scenario studied quadruple missed approaches/departures. The simulation compared the data from the dual runway with the quadruple runway. Throughout the simulation, the controllers encountered unexpected situations and conditions to which they responded with excellent success.

The test plan for the Simulation of Quadruple Simultaneous Parallel ILS Approaches at D/FW included a minimum acceptable slant range distance of greater than 500 ft between aircraft. The D/FW Metroplex Program Office analyzed all situations in which less than 3000 ft slant range was computed.

The Aircraft Proximity Index (API), developed by the Technical Center, is a single value that reflects the relative seriousness or danger of the situation. The API assigns a weight or value to each conflict, depending on vertical and lateral distance. API facilitates the identification of the more serious conflicts in a data base where many conflicts are present. A figure of 100 is the maximum value of the API. Therefore, the higher the API, the closer the aircraft. It should be noted that, in the dual runs, run 1-3 produced the highest API of 73, but pilot error heavily influenced this figure. In the quadruple runway runs, run 8 produced the highest API of 62. In the missed approach/departure, run 32 produced the highest API of 4. If further explanation of the API is desired, it can be obtained from the FAA Technical

Center, through Mr Lee Paul, ACD-340.

OPERATIONAL ANALYSIS

The objective of the simulation was to determine the feasibility of conducting quadruple simultaneous ILS arrivals and quadruple simultaneous departures at the D/FW International Airport. The TWG agrees unanimously that quadruple simultaneous arrivals and departures can be conducted in a safe and efficient manner.

The test subjects were experienced controllers from D/FW. No special training was provided. Current procedures as defined in FAA Handbook 7110.65, paragraph 5-126, 7210.3, paragraph 1235, and 8260.3, were applied, except that monitoring was provided through the missed approach. Simultaneous departures on the four parallel runways were also monitored through the use of a 2000 ft No Transgression Zone (NTZ) extended to a point 7 nautical miles from the departure end of the runways. This was necessary because current procedures (TERPS/Air Traffic) governing simultaneous operations are not adaptable for simultaneous departures on four parallel runways.

Based on the established test criteria, the controllers in this simulation met all objectives. The arrival and departure monitor positions in the simulation proved to be operationally effective and feasible for the D/FW airport.

The test controllers participated in the simulation as though they were controlling live traffic. Their attention and dedication was critical to the success of the simulation.

The TWG believes that quadruple ILS approaches and departures as simulated for D/FW is acceptable, achievable, and safe. Therefore, the TWG recommends the implementation of quadruple parallel runway operations at D/FW.

RECOMMENDATIONS

The Multiple Parallel Technical Work Group (TWG) recommends:

1. There shall be one monitor controller for each runway. Personnel and equipment shall be provided to support the procedure.

2. All monitor positions should be located together and near their respective arrival and departure positions.

3. Radar coverage must be provided through the missed approach point 7 nautical miles (nmi) beyond the departure end of the runway, as low as 50 feet (ft) above the runway surface or approved by flight standards. Approach minimums will be dependent upon the

lowest point at which radar coverage can be provided, e.g., CAT II minimums if radar coverage can be accomplished as low as 50 ft above the runway surface, etc.

4. The No Transgression Zone (NTZ) needs to be extended through the missed approach to a point 7 nmi beyond the departure end of the runways.

5. Implementation strategy prior to conducting quadruple approaches to the lowest authorized minimum for D/FW a phase in period of 60 days or 1000 approaches with weather minimum of 1500 ft/3 nmi be conducted.

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