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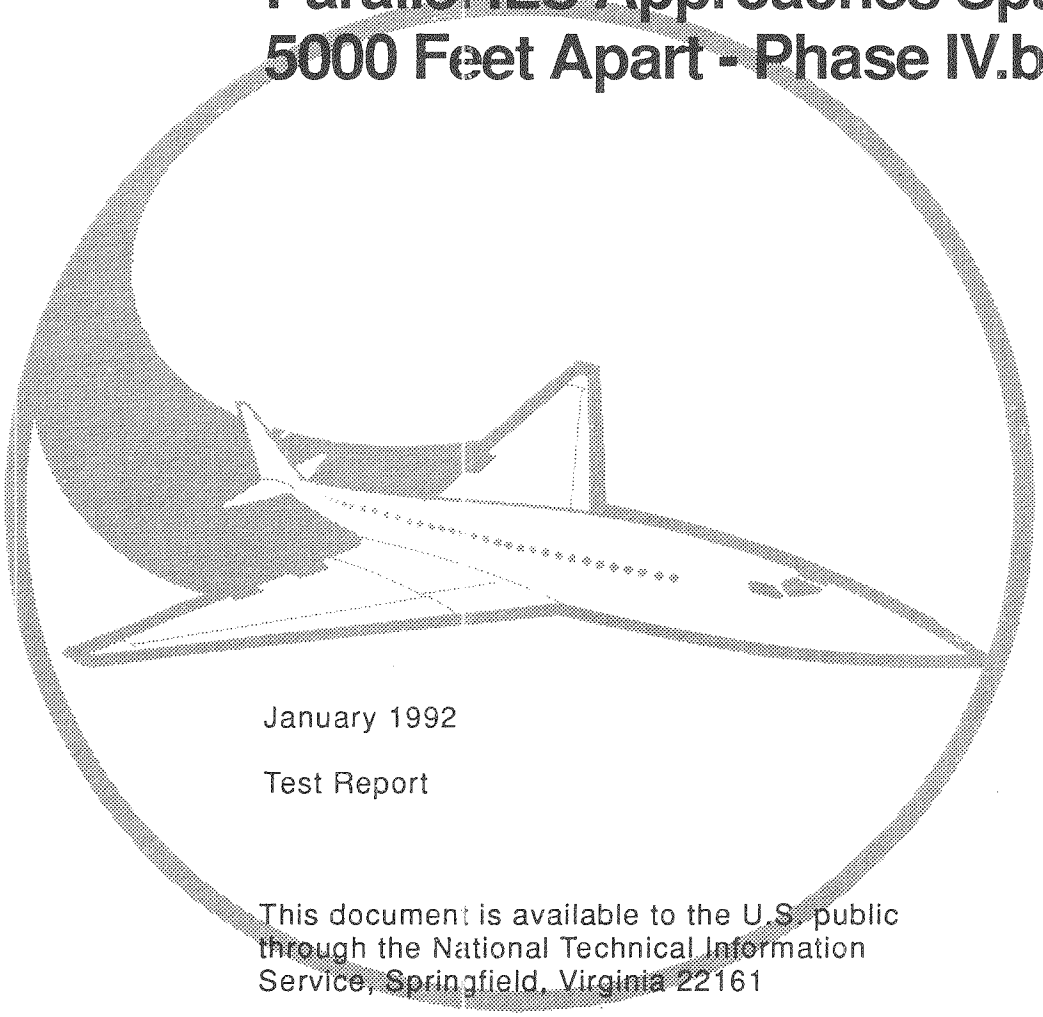
Evaluation of Triple Simultaneous Parallel ILS Approaches Spaced 5000 Feet Apart - Phase IV.b



January 1992

Test Report

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16. Abstract

This study was part of an on-going effort to evaluate plans for increasing air traffic capacity and to evaluate the feasibility of using multiple simultaneous, parallel, Instrument Landing System (ILS) approaches. The objective of this study was to evaluate the ability of experienced controllers to handle approach traffic during Instrument Meteorological Conditions (IMC) to a proposed parallel runway airport configuration, using a real-time, interactive, air traffic control (ATC) simulation. This simulation utilized a current radar system, Airport Surveillance Radar (ASR-9), and a current display system, Automated Radar Terminal System (ARTS) IIIA. The proposed configuration consisted of parallel runways (i.e., 18R, 18C, and 18L), 10,000 feet (ft) long, spaced 5000 ft apart with even thresholds.

Triple simultaneous parallel ILS approaches were simulated with controllers monitoring traffic on the approach localizers. To challenge the system, blunders were introduced, according to predetermined scenarios, by having some of the simulated aircraft deviate from the localizer by either 10, 20, or 30 degrees. Furthermore, half of the blundering aircraft also simulated a total loss of radio communication (NORDO) with the controllers.

The results indicated that controllers were able to resolve 99 percent of the blunders initiated in the simulation. Of the 484 blunders simulated, only 3 blunders resulted in aircraft violating the criterion miss distance of 500 ft. The Multiple Parallel Technical Work Group (TWG), based on their observations during the simulation and their understanding of the contingencies that must be accounted for in such an operation, determined that triple simultaneous parallel ILS approach operations spaced at 5000 ft are acceptable using the ASR-9 radar and the ARTS IIIA displays.

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The Multiple Parallel Technical Work Group (TWG) is comprised of individuals from the Office of System Capacity and Requirements, Air Traffic (including Regional and Field Facility personnel), Flight Standards, Aviation Standards, and Research and Development. These individuals have been appointed by their Division Managers, Service Directors, and/or Associate Administrators to participate in the TWG. The TWG brings together the various areas of expertise to establish acceptance criteria for evaluating the feasibility of multiple (greater than two) parallel runway approaches in an effort to increase airport capacity in a safe and acceptable manner. These individuals include: Ralph W. Dority, ASC-201, Office of System Capacity and Requirements, and TWG Chairman; Frank Soloninka, ATP-126, Terminal Procedures Branch; D. Spyder Thomas, AFS-400, Flight Standards Technical Programs Division; David N. Lankford, AVN-540, Aviation Standards Development Branch (Oklahoma City); Rich Nehl, ASC-202, Office of System Capacity and Requirements; Ronnie Uhlenhaker, ASW-1C, DFW Metroplex Program Office; Wally Watson, ASO-531, Southern Region System Management Branch; Gene Wong, ARD-240, Airport System Technology Branch, and Research and Development Program Manager; and Archie Dillard, AAC-950C, Aviation Standards Branch - FAA Academy.

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CTA, Incorporated is contracted with the FAA Technical Center to plan, design, and develop ATC simulations and to conduct statistical analysis on simulation data. In addition, CTA prepares documentation as well as provides support during the simulation. These individuals are: Terence Fischer, Task Manager; Gloria Yastrop, L.W. Bensel, Rickie Jones, Renee Luongo, and Kimberly Reardon.

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EXECUTIVE SUMMARY

This study is part of an on-going effort to evaluate plans for increasing air traffic capacity and to evaluate multiple parallel approaches. The objective of this study was to evaluate the ability of controllers to handle traffic during Instrument Meteorological Conditions (IMC) for the proposed triple parallel airport configuration, using a real-time air traffic control (ATC) simulation. The proposed runway configuration consisted of three parallel runways 10,000 feet (ft) long and spaced 5000 ft apart with even thresholds. All aircraft were assigned speeds of approximately 170 knots.

Triple 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 a loss of radio communication with the controllers.

The central issue in the study was the ability of the controllers to maintain distance between the blundering aircraft and aircraft on adjacent approaches. With this in mind, two questions were to be answered:

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

2. Do flight standards, aviation standards, and air traffic representatives agree that the operation of the proposed triple simultaneous parallel ILS approaches is acceptable, achievable, and safe?

Analysis of the data from the simulation indicated that controllers were able to maintain aircraft miss distances of 500 ft or greater in approximately 99 percent of the blunders. The controllers concluded that triple simultaneous ILS approaches with runway centerlines spaced 5000 ft apart would be a "safe and viable operation" using current technology radar systems and procedures. The Multiple Parallel Technical Work Group (TWG), composed of individuals from the Office of System Capacity and Requirements, Air Traffic Control, Flight Standards, Aviation Standards and Operations personnel, participated in the simulation and evaluated the simulation findings. *Based upon their understanding of daily operations, the knowledge and skills of controllers, and the contingencies which must be accounted for in such an operation, the TWG determined that the triple simultaneous parallel ILS approach operation spaced at 5000 ft is acceptable using the Airport Surveillance Radar (ASR)-9 and the Automated Radar Terminal System*

(ARTS) IIIA displays. In addition, the TWG made the following recommendations:

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

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

3. The Implementation Strategy used prior to any airport conducting triple approaches with runways spaced 5000 ft apart shall consist of a graduated, sliding scale weather minimums criteria. This strategy will facilitate a smooth transition period to permit adequate training and to develop requisite competency. The recommended required meteorological conditions to be satisfied are categorized as follows:

a. Basic VFR - Ceiling greater than 3000 ft and visibility greater than 5 miles.

b. MVFR (Marginal VFR) - Ceiling 1000 to 3000 ft and visibility 3 to 5 miles inclusive.

c. IFR - Ceiling 500 to less than 1000 ft and visibility 1 to less than 3 miles.

d. LIFR (Low IFR) - Ceiling less than 500 ft and visibility less than 1 mile down to the lowest minimums authorized for the approach.

In addition, facilities must develop experience levels of 1000 approaches or 60 days, whichever occurs first, in conducting operations in each weather category. Once the required experience level has been acquired, they will be authorized to conduct approaches during conditions in the next, more restrictive weather minimums.

1. OBJECTIVE.

The Federal Aviation Administration (FAA) and the Multiple Parallel Technical Work Group (TWG) are evaluating the capability of multiple parallel runways to increase airport capacity in a safe and acceptable manner. The goal is to develop national standards for using multiple simultaneous parallel Instrument Landing System (ILS) approaches with existing and/or new technology equipment. The objective of this study was to evaluate the ability of controllers to handle traffic on triple simultaneous parallel ILS approaches with runways spaced 5000 feet (ft) apart, during Instrument Meteorological Conditions (IMC). Current technology radar systems were examined through a real-time air traffic control (ATC) simulation. The results of this study will enable the establishment of national standards for triple simultaneous parallel ILS approaches.

2. BACKGROUND.

The ability of the National Airspace System (NAS) to meet future air traffic demands is a serious concern at the national level. Programs to improve NAS capacity have been underway since the early 1980's, both to reduce air traffic delays and to accommodate the increased demand. Included in these programs are efforts to redesign the existing airways structure, to modernize air traffic flow management, and to incorporate state-of-the-art automation technology throughout the system.

Contributing to the capacity problem are the limitations imposed by current airport runway configurations and the associated air traffic separation criteria, particularly as related to aircraft executing ILS approaches under IMC. To alleviate these constraints, the FAA is investigating the use of triple, quadruple, and closely spaced dual parallel runway configurations as a means to increase airport capacity while maintaining the high level of safety evident today.

2.1 AIRPORT LIMITATIONS.

The number of aircraft that can land at an airport during IMC is a major factor influencing system capacity. The use of independent simultaneous ILS approaches during IMC would significantly increase airport capacity and potentially improve traffic flow throughout the NAS.

At present, during Visual Meteorological Conditions (VMC) simultaneous approaches to parallel runways may be operated with runways spaced 2500 ft apart and greater. However, due to limitations in current radar and displays, independent approaches are restricted to runways spaced greater than 4300 ft apart during IMC. Under these circumstances, ATC must use dependently sequenced approaches. (McLaughlin, 1960)

The procedures required for dual simultaneous ILS approaches at the time of this simulation are described by Federal Aviation Administration, Air Traffic Control (September 1989), FAA HDBK 7110.65F, Paragraph 5.126, as follows:

a. Parallel runways that are at least 4300 ft apart.

b. Straight-in landings will be made.

c. Provide a minimum of 1000 ft vertical or a minimum distance of 3 nautical miles (nmi) between aircraft during turn-on to parallel final approaches.

d. Provide the minimum applicable radar separation between aircraft on the same final approach course.

e. Aircraft established on final approach course are considered separated from aircraft established on an adjacent parallel final approach course provided neither aircraft penetrates the depicted No Transgression Zone (NTZ).

f. Separate monitor controllers, each with transmit/receive and override capability on the local control frequency, shall ensure aircraft do not penetrate the depicted NTZ.

As of November 14, 1991 FAA HDBK 7110.65 was modified to incorporate runways spaced 3400 to 4300 ft apart with the caveat that Precision Runway Monitors (PRMs) and a radar update rate of 2.4 seconds (s) or less be used. The modification to the requirement was the result of research conducted at Raleigh/Durham and Memphis (Resalab Inc., 1975; Haines, A.L. and Swedish, W.J., 1981; Buckanin, D., et al., 1984; Precision Runway Monitor Program Office, 1991) which indicated that through improvements in radar sensors and displays, the minimum runway spacing requirement could be reduced while maintaining the current level of safety. Reducing the minimum runway spacing requirement permits current airports to be modified rather than new airports being built.

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. (McLaughlin, F., 1960; Resalab Inc., 1975; ICAO, 1980; Haines, A.L. and Swedish, W.J., 1981; Shimi, T.N., et al., 1981; Romei, J., 1981; and Steinberg, H.) Analyses have considered controller and pilot response times, navigational accuracy on the localizers, radar accuracy, and update rates, et cetera. (Altschuler, S., and Elsayed, E., 1989)

2.2 PREVIOUS MULTIPLE PARALLEL RUNWAY STUDIES.

Early studies of multiple runways concentrated on reducing the separation between aircraft during simultaneous parallel

approaches. (McLaughlin, F., 1960; Haines, A.L., 1973; Resalab Inc., 1975; ICAO, 1980; Haines, A.L. and Swedish, W.J., 1981; Shimi, T.N., et al., 1981; Romei, J., 1981) The amount of separation reduction that can be safely achieved is highly dependent upon aircraft navigational accuracy.

A simulation conducted in 1984 considered runways spaced 3000, 3400, and 4300 ft apart, employing both standard and modified radar displays, using three levels of radar accuracy and radar update rates. (Altschuler, S. and Elsayed, E., 1989) The study established the importance of navigational accuracy in determining system capacity, and it showed the relationships between a number of system parameters and the controllers' abilities to cope with blunders.

Since the 1984 simulation was completed, additional data have been collected at the Memphis International Airport, and a major navigation survey has been completed at the Chicago O'Hare facility. (Buckanin, D., et al., 1984; Buckanin D. and Biedrzycki, R., 1987) The data from these surveys, which directly considered simultaneous parallel approaches under IMC, were used in the development of the navigational error model for the present simulation.

Additional real-time ATC simulations have been conducted at the FAA Technical Center to investigate parallel runway proposals. (Timoteo, B. and Thomas, J., 1989; Hitchcock, L., et al., 1989, Art 1) These studies are an important complement to the models cited above since they generated estimates of the model parameters; more importantly, they allowed direct observation and recording of criterion measures related to safety and capacity.

The 1988 and 1989 Dallas/Fort Worth (DFW) simulations and the 1988 Atlanta Tower simulation are of direct interest to the ongoing effort since they addressed most of the issues unique to multiple runway operations.

2.3 ATC STANDARDS MODIFICATION REQUIREMENTS.

The absolute requirement for modifying ATC standard procedures is the demonstration of undiminished 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 new or improved standards can be developed.

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, introducing errors and failures, to assess system performance.

These approaches are neither independent nor mutually exclusive. Ultimately, it falls to experienced system users (e.g., controllers, pilots, and operations personnel) to weigh the evidence and to decide upon the proposed change based upon their understanding of daily operations, the knowledge and skills of the controllers, and the contingencies to which the system must respond.

2.4 MULTIPLE SIMULTANEOUS ILS APPROACH PROGRAM.

The Multiple Simultaneous ILS Approach Program was initiated to develop procedures for the safe execution of simultaneous ILS approaches to triple and quadruple runway configurations. This program consists of six phases described in sections 2.4.1 through 2.4.6. and is shown as figure 1.

2.4.1 Phase I.

The DFW 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, and En Route and Terminal Radar Approach Control (TRACON) facilities traffic flows in the implementation of quadruple approaches.

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

The analyses indicated that blunders which threatened two or three approaches were no more dangerous than blunders which threatened only one approach. Additionally, the controllers agreed that the new configuration maximized the en route airspace. (Hitchcock, L., et al., 1989, Art 2) Based upon this simulation, triple simultaneous parallel ILS approaches were approved for DFW, with only turboprop aircraft landing on 16L.

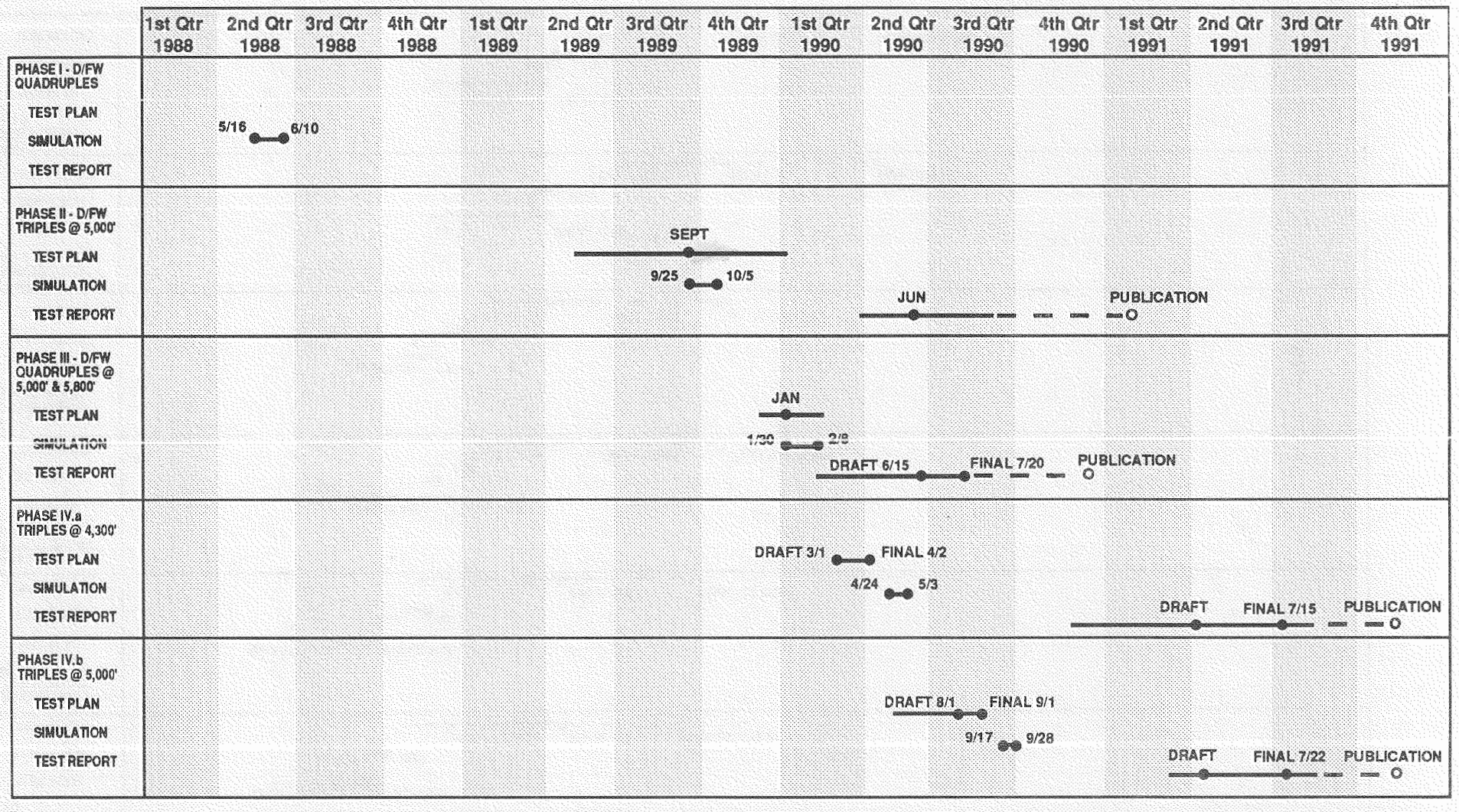


FIGURE 1. MULTIPLE SIMULTANEOUS PARALLEL ILS APPROACH SIMULATION SCHEDULE (SHEET 1 OF 2)

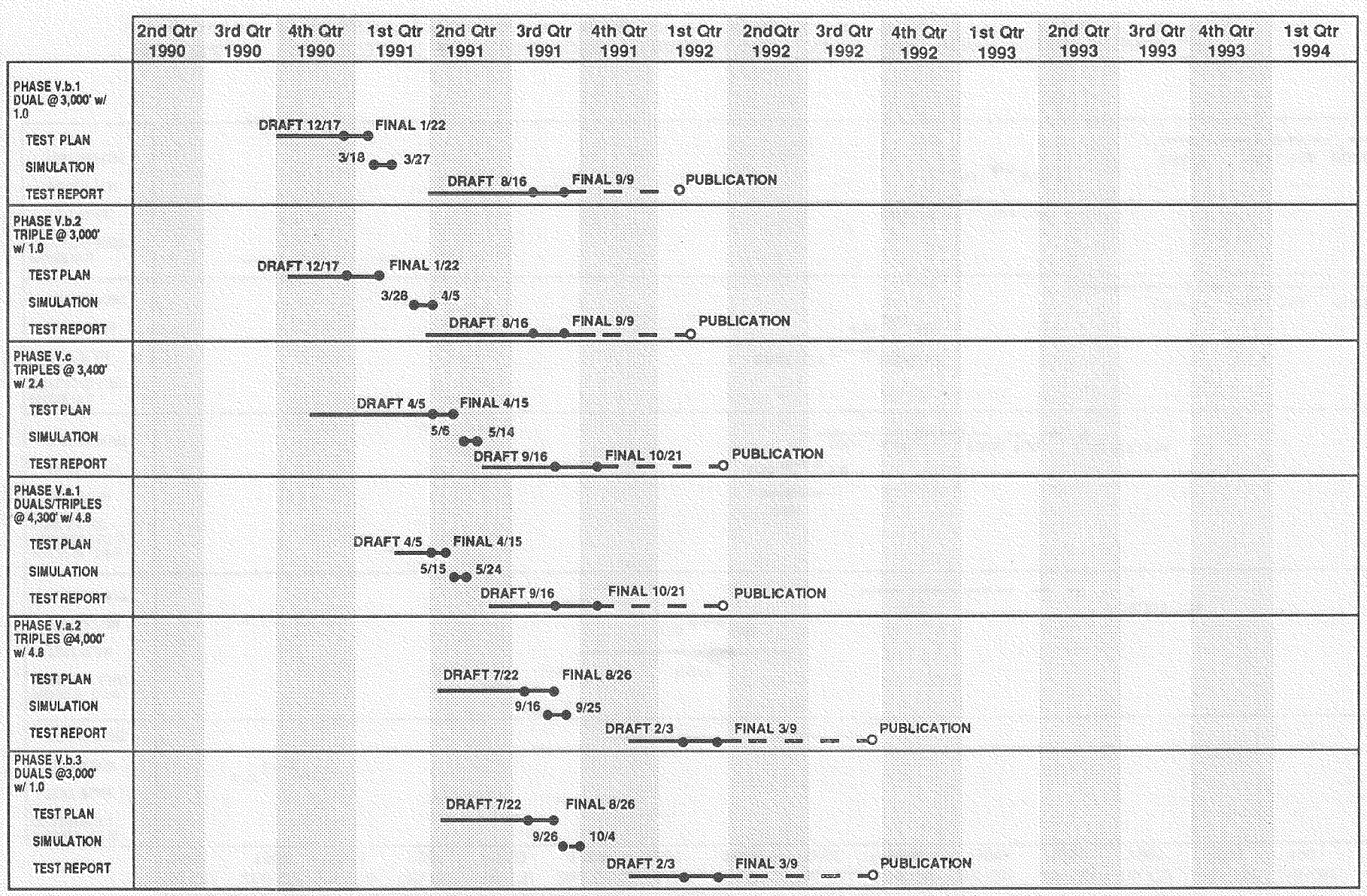


FIGURE 1. MULTIPLE SIMULTANEOUS PARALLEL ILS APPROACH SIMULATION SCHEDULE (SHEET 2 OF 2)

2.4.2 Phase II.

This simulation was conducted at the FAA Technical Center from September 25 to October 5, 1989. The simulation assessed triple simultaneous ILS approaches at DFW. 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 successfully intervene in the event of a blunder. They provided distances between conflicting aircraft in the triple approach condition that were comparable to the distances achieved in the dual approach condition. No blunders, in either the dual or triple approach condition, resulted in a slant range miss distance of 1100 ft or less. Additionally, the controllers, controller observers (e.g., ATC supervisors), and ATC management observers concluded that the proposed triple approach operation at DFW was acceptable, achieveable, and safe. (CTA Inc., 1990) Results from this simulation supported the approval of turbojets operating on three parallel runways at DFW.

2.4.3 Phase III.

The Phase III simulation reconsidered the DFW quadruple simultaneous ILS approach and departure operations assessed in Phase I, with changes in runway lengths and traffic samples. In this simulation, 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 only turbojets on the inside runways.

The simulation found that air traffic controllers were able to maintain miss distances between aircraft in excess of the 500-ft criterion. There were no operational differences between the dual and quadruple approach conditions. Controllers, controller observers, and ATC management concluded that the quadruple approach operation was a "safe, acceptable, and achievable procedure." (CTA Inc., 1990)

2.4.4 Phase IV.

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

a. Phase IV.a assessed triple simultaneous ILS approaches to runways spaced 4300 ft apart with even thresholds. This simulation included the integration of a Phase II B-727 flight simulator and a General Aviation Trainer (GAT) flight simulator. This simulation was conducted at the FAA Technical Center from April 24 to May 3,

1990. The results of this simulation indicated that triple simultaneous ILS approaches with runways spaced 4300 ft apart, in conjunction with ARTS IIIA displays and ASR-9 radar with 4.8 s update rate, are not satisfactory for a safe airport operation.

b. Phase IV.b assessed triple simultaneous ILS approaches to runways spaced 5000 ft apart with even thresholds. This simulation included the integration of two Phase II CAT-121 B-727 flight simulators and one GAT flight simulator. This simulation was conducted at the FAA Technical Center from September 17 to 28, 1990. The results of this simulation are addressed in this report.

2.4.5 Phase V.

The Phase V simulations incorporated the use of high resolution, 20 X 20 inch color displays with enhanced graphics capabilities and audio conflict alert algorithms. Phase V was assessed in five subphases as described below:

a. Subphase V.b.1. Assessed dual simultaneous parallel ILS approach operations to runways spaced 3000 ft apart using radar with an update rate of 1.0 s. This subphase was conducted March 18 to 27, 1991, and the report is in the final stages of development.

b. Subphase V.b.2. Assessed triple simultaneous parallel ILS approach operations to runways spaced 3000 ft apart using radar with an update rate of 1.0 s. This subphase was conducted March 28 to April 5, 1991. The report for this simulation is also in the final stages of development.

c. Subphase V.c. Assessed triple simultaneous parallel ILS approach operations to runways spaced 3400 ft apart using radar with an update rate of 2.4 s. This subphase was conducted May 6 to 14, 1991. The report for this simulation is currently being composed.

d. Subphase V.a.1. Assessed dual and triple simultaneous parallel ILS approach operations to runways spaced 4300 ft apart using radar with an update of 4.8 s. This simulation was conducted from May 15 to 24, 1991. The report for this simulation has been composed and is currently being revised.

e. Subphase V.b.3. Assessed the effects of flight technical error (FTE) on dual simultaneous independent offset ILS approach operations to runways spaced 3000 ft apart with a localizer offset of 1 degree and radar with an update rate of 1.0 s. This subphase was conducted September 16 to 23, 1991. The results of this simulation are currently being analyzed.

f. Subphase V.a.2. Assessed triple simultaneous parallel ILS approach operations to runways spaced 4000 ft apart using radar with an update rate of 4.8 s. This subphase was conducted

September 24 to October 4, 1991, and the results are also currently being analyzed.

2.4.6 Phase VI.

Phase VI will address quadruple simultaneous parallel ILS approaches using technology varying from present day systems to advanced technology. Final criteria will be determined at a future date based largely on the results of Phases IV and V.

3. PHASE IV.b EVALUATION OF TRIPLE SIMULTANEOUS PARALLEL ILS APPROACHES SPACED 5000 FT APART.

This section describes the simulation performed September 17-28, 1990. An overview of the simulation, a description of the controllers, simulation facilities, data collection, simulation procedures, and various approaches used in the analysis are presented in sections 3.1 through 3.6.

3.1 SIMULATION OVERVIEW.

The Phase IV.b simulation evaluated triple simultaneous parallel ILS approaches to runways spaced 5000 ft apart with even thresholds. The simulation was designed to examine operational issues relative to developing national standards to implement triple simultaneous parallel ILS approaches.

The participating controllers manned the approach positions to monitor traffic movement in accordance with established procedures. Approach aircraft were scripted to execute blunders of 10, 20, or 30 degrees toward aircraft on adjacent approaches. The controllers issued instructions, via voice communications, to the pilots in order to maintain adequate distances between aircraft at all times. The simulation addressed two questions:

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

b. Do flight standards, aviation standards, and air traffic representatives agree that the operation of the proposed triple simultaneous parallel ILS approaches is acceptable, achievable, and safe?

3.1.1 Controller Activities.

Monitor controllers, each with transmit/receive capability on the local control frequency, monitored the final approach courses to ensure that aircraft did not penetrate the NTZ. When aircraft penetrated the NTZ, controllers issued the necessary instructions to achieve longitudinal, lateral, and/or vertical separation between aircraft. A facility directive delineated responsibility

for providing the minimum applicable longitudinal separation between aircraft on the same final approach course. Coordination among the controllers also ensured effective responses to the potential conflict situation.

3.1.2 Blunders.

Blunders occurred when an aircraft established on the localizer deviated from its intended course. These deviations usually resulted in aircraft coming into conflict with each other. Depending on the degree of blunder from the localizer, controllers either instructed the blundering aircraft to rejoin the localizer, or they instructed the blundering aircraft and the 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. Aircraft that blundered or were vectored off their ILS as a result of a blunder were removed from the traffic flow.

3.1.3 Airport Configuration.

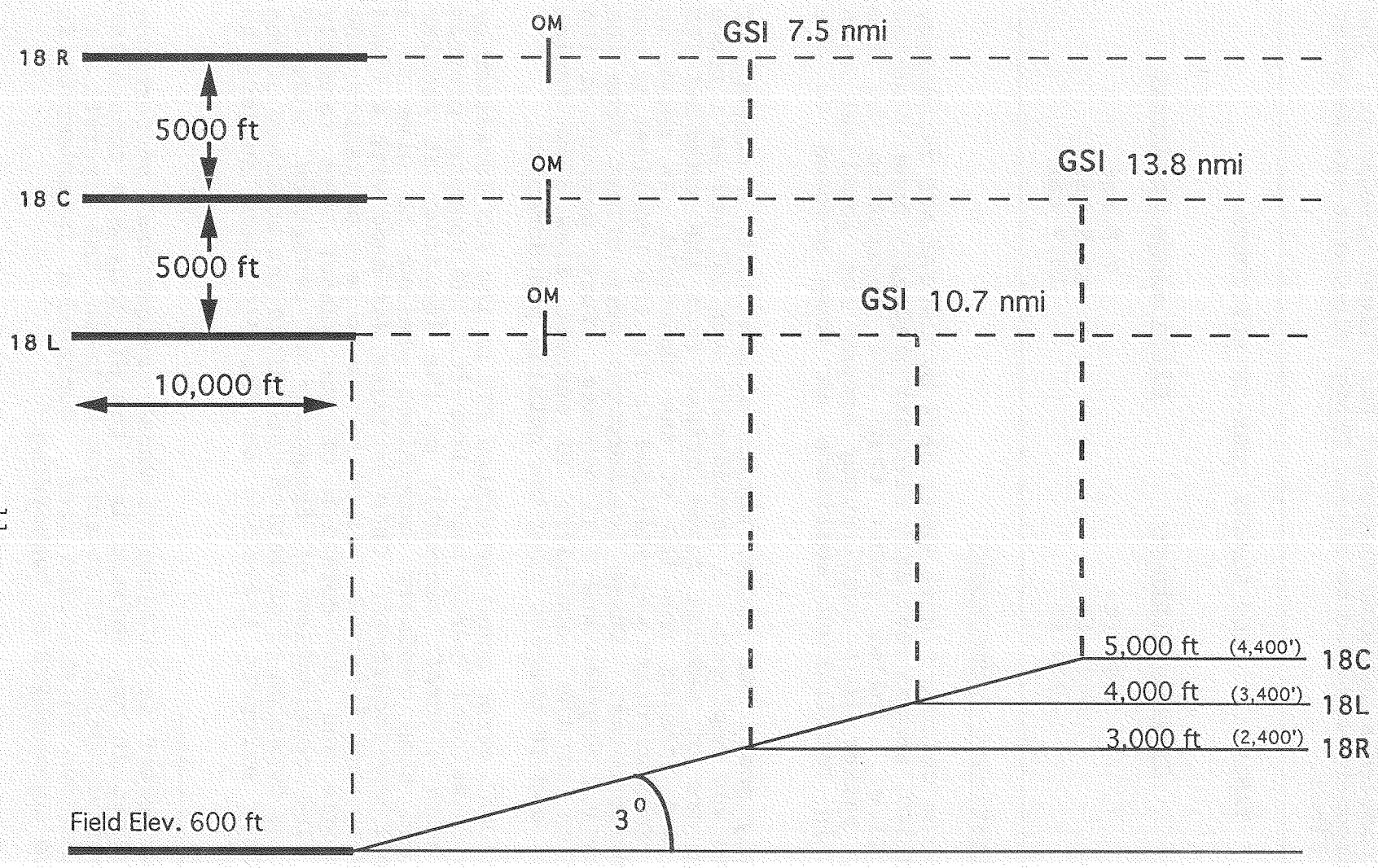
The airport layout, runways, and arrival frequencies emulated a generic airport with even thresholds and glide slopes of 3 degrees. The runway lengths were 10,000 ft to accommodate all aircraft types. The airport configuration had three parallel runways with an arrival heading of 180 (18R, 18C, and 18L) as shown in figure 2. The distance between the runway centerlines was 5000 ft. Only the monitor controller positions were manned during the simulation.

Aircraft started on the localizers and maintained the altitude at which they were cleared until glide slope intercept. The starting altitude and glide slope intercept for each runway is shown in table 1. After glide slope intercept, the aircraft commenced at a normal descent rate appropriate to its aircraft type.

3.1.4 Traffic Samples.

Traffic samples, for the simulation, were based on actual traffic from a combination of several large hub airports around the country (e.g., Atlanta, Chicago, Dallas/Fort Worth, Denver, Los Angeles, and other TRACONs). These samples consisted of a representative population of propeller-driven, turboprop, and turbojet aircraft including carrier type such as DC-9/MD-80, B-727, B-737, B-747, and B-767. From this data, seven traffic samples were developed for the simulation.

The traffic samples developed resulted in all aircraft flying wing tip-to-wing tip at the initiation of the run. This was done to produce frequent worse case situations. Additionally, the Phase IV.b simulation included two to three speed overtakes during each



OM = outermarker at 5 nmi
GSI = glide slope intercept

FIGURE 2. AIRPORT CONFIGURATION

run and introduced a headwind component for flight simulators. The headwind component was used to adjust flight simulator speeds after turn-on to final.

TABLE 1. ILS RUNWAY TURN-ON ALTITUDES

Runway	Turn-On Altitude	Glide Slope Intercept
18R	3000 ft	7.5 nmi
18C	5000 ft	13.8 nmi
18L	4000 ft	10.7 nmi

3.1.5 Navigational Error Model.

A review of the Chicago O'Hare Radar data 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 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 then randomly determined whether to give it a deviation off the localizer. This decision was made with a fixed probability at each interval. If there was to be a deviation, the deviation angle and the duration of the wander were randomly assigned. The combination of frequency of deviation, size of deviation, and duration of deviation determined the accuracy of the sample. Only aircraft traveling on the ILS were subject to "wandering."

[1] A "wanderer" is an aircraft whose navigational 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 on its own to the localizer. Controller intervention is permitted to correct FTE or "wandering."

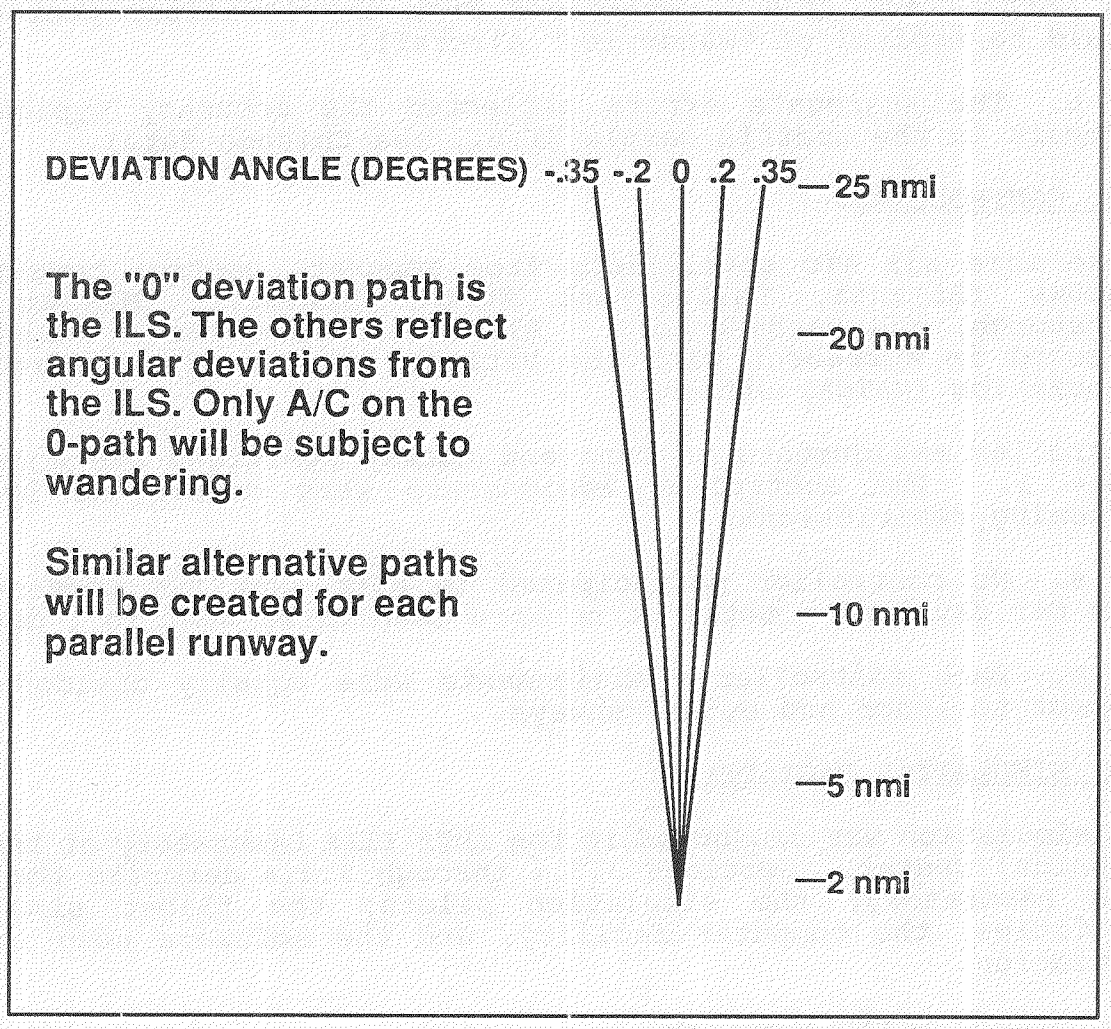


FIGURE 3. GRAPHICAL DEPICTION OF PSEUDOROUTES

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

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

b. The aggregate errors reflected the accuracy typical of aircraft in the traffic sample (i.e., the Chicago data).

3.2 CONTROLLERS.

There were six ATC specialists from separate control towers, or TRACONs (Atlanta, Dallas/Fort Worth, Denver, Minneapolis, Pittsburgh, and Sacramento). All controllers were volunteers selected in agreement with the National Air Traffic Controllers Association (NATCA) offices.

Controller assignments to runs and runway positions are shown in table 2. The controller assignments were determined by the following restrictions:

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

b. Each controller's assignments were equally divided with respect to inner and outer runways.

3.3 SIMULATION FACILITIES.

The simulation was conducted in the ARTS IIIA Laboratory at the FAA Technical Center. Sections 3.3.1 through 3.3.4 describe the ARTS IIIA Laboratory, the simulation pilots, the flight simulator facilities, the computer facility, and the software used in the simulation.

3.3.1 ARTS IIIA Laboratory.

The ARTS IIIA Laboratory is located at the FAA Technical Center, Atlantic City International Airport, NJ. A schematic diagram of the simulation hardware is shown in figure 4. The ARTS IIIA Laboratory houses 10 Data Entry and Display Subsystems (DEDS). The DEDS have digital random write displays to present primary targets and aircraft identification tags, and associated key board entry and communication equipment. The DEDS provided a background detail of the airport through phosphor persistence of the radar sweep. The laboratory was realistically configured permitting controllers to function with little or no acclimation. A communication system provided controller-to-pilot and pilot-to-controller communication. The proximity of the controller stations to each other during the simulation accommodated intercontroller communication.

TABLE 2. CONTROLLER ASSIGNMENTS

Date	Run	18R	18C	18L	Traffic Samples
9/17	1	A	B	C	601
	2	D	E	F	602
9/18	5	F	A	B	605
	6	C	D	E	606
	7	E	F	A	607
9/19	Day used to correct computer malfunctions				
9/20	15	D	E	F	602
	16	A	B	C	601
	17	C	D	E	604
	18	E	A	B	603
	19	F	C	D	607
9/21	20	C	D	E	606
	21	F	A	B	605
	22	B	C	D	604
	23	D	F	A	603
	24	E	B	C	602
	10	E	F	A	601
9/24	25	B	C	D	601
	26	E	F	A	607
	27	A	B	C	605
	28	C	E	F	606
	29	D	A	B	604
	12	D	E	F	605
9/25	30	A	B	C	603
	31	D	E	F	602
	32	F	A	B	601
	33	B	D	E	607
	34	C	F	A	605
	4	E	C	D	604
9/26 MITRE Engineering Runs	35	F	A	B	604
	36	C	D	E	606
	37	E	F	A	607
	38	A	C	D	602
	39	B	E	F	601
	11	B	D	C	603
9/27	40	E	F	A	605
	41	B	C	D	604
	42	D	E	F	603
	43	F	B	C	607

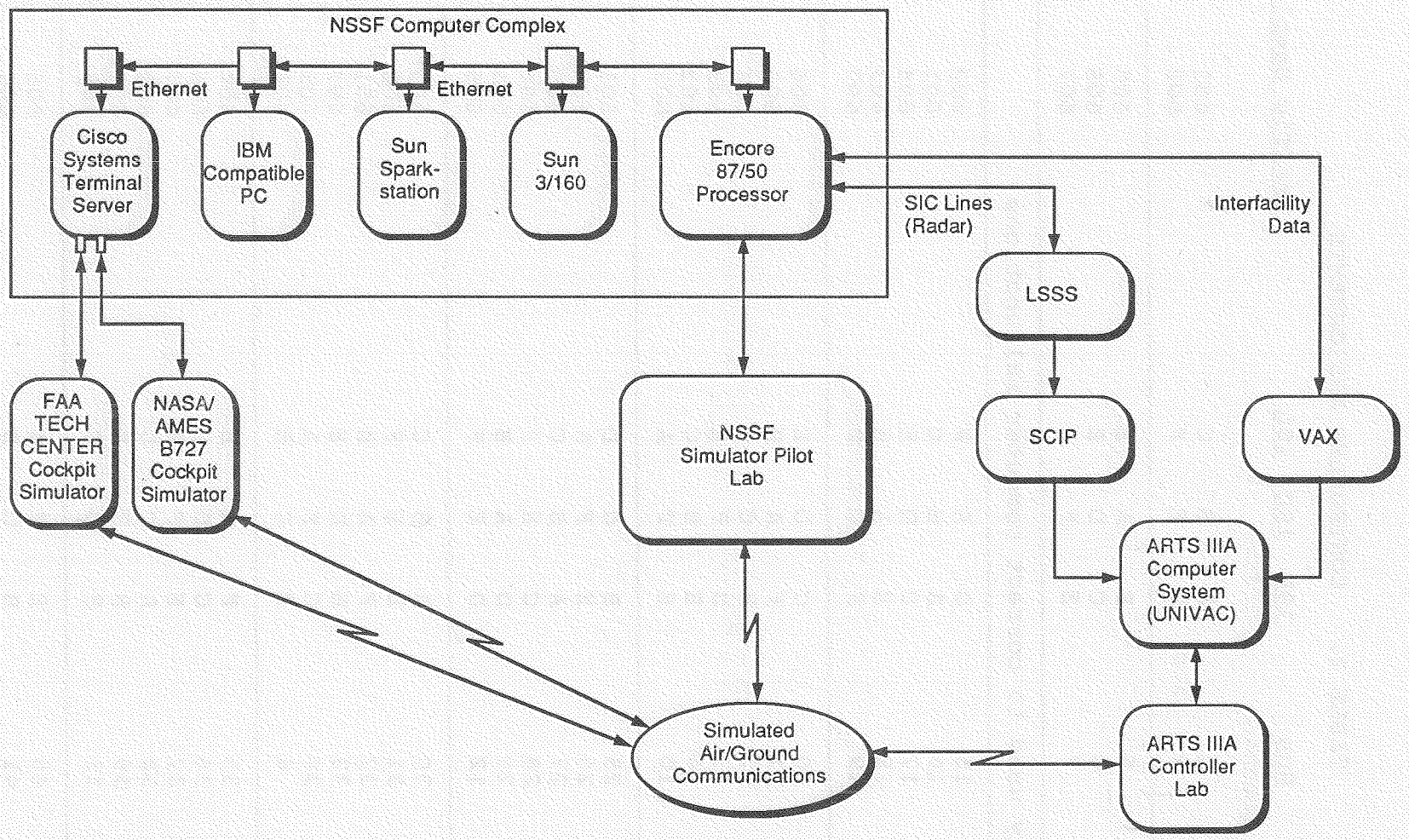


FIGURE 4. SCHEMATIC DIAGRAM OF SIMULATION HARDWARE

3.3.2 Simulation Pilots.

The National Airspace System Simulation Support Facility (NSSF) Pilot Complex housed the personnel who "operated" the simulated aircraft and the equipment used to accomplish this task. NSSF simulator pilots were in voice contact with the controllers, and they responded to controller instructions by entering aircraft heading and altitude changes using a specialized keyboard. These actions resulted in the simulated aircraft changing course, altitude, or speed. NSSF simulated aircraft responses were programmed to be consistent with the aircraft being simulated. Each NSSF simulator pilot had the ability to control as many as 10 aircraft, but normally controlled only 3 or less in this simulation.

3.3.3.3 Flight Simulator Facilities.

Flight simulators located at NASA-Ames, Moffett Field, CA, Mike Monroney Aeronautical Center, Oklahoma City, OK, and the FAA Technical Center, Atlantic City International Airport, NJ, were integrated into the Phase IV.b simulation to provide an assessment of the airport configuration. The flight simulators were flown by airline management and airline and instructor pilots. The flight simulators assumed the configuration of aircraft flying the localizer on approach.

The flight simulator pilots were in voice communication with the controllers. Additionally, the flight simulator site coordinator assisted the pilots prior to and following each flight. Each flight simulator performed approximately five to six flights per simulation run.

3.3.4 Computer Facility.

The FAA Technical Center Computer Facility simulated the aircraft and the functions of the ATC ground facility. The simulation programs dynamically updated each aircraft's position based upon its last position and its current status, i.e., turning, climbing, or accelerating. An aircraft's status was constantly monitored to reflect changes caused by predetermined flight plans, maneuvers, and/or simulator pilot inputs. In providing the functions of an ATC ground facility, the central computer simulated the radar-beacon, target detection system, and maintained and updated information on the controller displays.

3.3.5 Software.

The NSSF 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.

3.4 DATA COLLECTION.

The system performance data were collected via several methods. These methods included computer generated data bases, audio and video tape recordings, and questionnaire data as described in sections 3.4.1 through 3.4.4.

3.4.1 Computer Generated Databases.

Data reduction and analysis routines provided a means of extracting data and analyzing the data related to the concept under study. The routines provided data such 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 aircraft's closest point of approach (CPA); and a categorization of the instructions (e.g., speed commands and vectors) issued to each aircraft.

3.4.2 Voice Communications.

Controller, NSSF, and flight simulator pilot voice communications were recorded using a 20-channel audio recorder at the FAA Technical Center. Controller and flight 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 the simulator run time, onto the video and audio recordings.

3.4.3 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 three monitor positions, was dedicated to video recording using a S-VHS format video recorder. Two microphones were used to record controllers' voices during each run. This permitted the analysis of interaction between controllers.

3.4.4 Controller and Pilot Questionnaires.

Following each run, a questionnaire and a workload rating scale were administered to the controllers. The controller questionnaire assessed controller opinions concerning run realism, difficulty, controllability, and their recommendations for operational use. The workload rating scale was derived from the Modified Cooper-Harper Scale. Also following each run, a questionnaire was administered to the flight simulator pilots. The pilot questionnaire assessed pilot opinions concerning pilot performance,

activity level, stress level, and passenger comfort. Pilot comments concerning the simulation were elicited from the questionnaires.

3.5 SIMULATION PROCEDURES.

During the simulation, 36 runs were conducted for the proposed three-runway operation. All runs were approximately 60 minutes in length.

The first morning of the simulation was used to familiarize controllers with the ARTS IIIA Laboratory and the equipment. Practice runs were conducted to familiarize the controllers with the strategies involved in the control of aircraft for the triple runway configuration. The practice runs were abbreviated in length, and the data from these runs were not subjected to formal analysis.

3.5.1 Blunder Scripts.

The test director and his assistant used scripts to create blunders. Turns were 10, 20, or 30 degrees, always toward at least one other localizer. Fifty percent of the blundering aircraft executed 30 degree turns, 35 and 15 percent executed 20 and 10 degree turns, respectively.

For the approach runs, 50 percent of the blunders on the center approach (18C) turned to the left and 50 percent turned to the right. Blundering aircraft on the outside approaches (18R and 18L) turned toward the inboard localizer.

Blunder scripting 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.

Blunders commenced 10 nmi or less from the threshold. They were scripted so that aircraft randomly maintained altitude or they randomly continued descent following the blunder. Each scenario included one or two blunders which occurred within 2 nmi of the threshold. Fifty percent of the blunders occurred before the blundering aircraft crossed the outer marker.

During the simulation, 50 percent of the blundering aircraft experienced a loss of communication (NORDO). This was done by instructing the NSSF simulator pilot not to respond to the controller's issuance of vector changes.

3.6 ASSESSMENT METHODOLOGY.

The ability of controllers to resolve blunders was assessed by statistically analyzing factors that may have affected controller performance. Analyses were conducted to determine the influence of blunder degree, loss of communication, and the number of runways threatened by a blunder on conflict severity.

Blunders that resulted in a slant-range miss distance CPA of less than 500 ft were assessed individually to determine the factors that contributed to the conflict. A comprehensive review of the blunders, which included plots of aircraft position, controller-pilot communications, and computer data was conducted. A review of the factors contributing to conflict severity was then conducted to determine their operational impact.

The TWG evaluated the results from the simulation to make recommendations concerning approval of the proposed operation. To make their recommendations, the TWG drew upon their understanding of the nature of daily air traffic operations, the knowledge and skills of controllers, and the full range of traffic contingencies which must be taken into account.

4. PHASE IV.b SIMULATION RESULTS.

This section describes the findings of the Phase IV.b Simulation. Section 4.1 gives an overview of the analyses that were conducted. Section 4.2 describes the results of the controller performance analyses (CPA data). Questionnaire analyses, response time analyses, and pilot/flight simulator performance analyses are described in sections 4.3 through 4.5.

4.1 OVERVIEW OF ANALYSES.

Generally, a blunder in the triple parallel approach condition will result in two or more conflicts. Usually only the conflicts involving the blundering aircraft and the aircraft on the adjacent approach are 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 triple approach condition data would contain a disproportionate number of nonserious conflicts.

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

With regard to the ANOVA technique, two types of effects are considered: main effects and interactions. A main effect is the influence of a single variable on the system performance measures when considered in isolation. For example, the main effect of the

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 CPA. Other variables which might influence the results (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).

Main effects and interactions in an ANOVA are denoted by F statistic values. The presentation of these values is exemplified by $F(1,21) = 19.05$, $p. < 0.01$, where the numbers in parentheses following the F signify the numerator and denominator degrees of freedom. The probability of falsely detecting differences between levels of the variable being tested are indicated by a "p." 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.

4.2 CONTROLLER PERFORMANCE ANALYSES.

The following analyses examined the influence of blunder degree, controller-to-pilot communication, and the number of runways threatened, on the controller's ability to maintain distance between aircraft as indicated by CPA.

4.2.1 CPA Analysis.

Of the 484 scripted blunders in Phase IV.b, 95 percent resulted in a conflict. The average CPA was 3542 ft (s.d. = 2055 ft) and the smallest CPA was 267 ft. The distribution of CPA values is shown in figure 5.

An ANOVA was performed to assess the effects of the number of runways threatened, the degree of blunder, and the radio/no radio communication condition on controller performance as indicated by the CPA. None of these factors had a significant effect on the controllers' abilities to maintain distance between conflicting aircraft.

4.2.2 Longitudinal Separation Analyses.

Longitudinal separation between aircraft was the distance between two aircraft along two adjacent ILS's. As shown in figure 6, the less longitudinal separation between aircraft, the lower the CPA. However, the effect diminished when the longitudinal separation was within 500 ft.

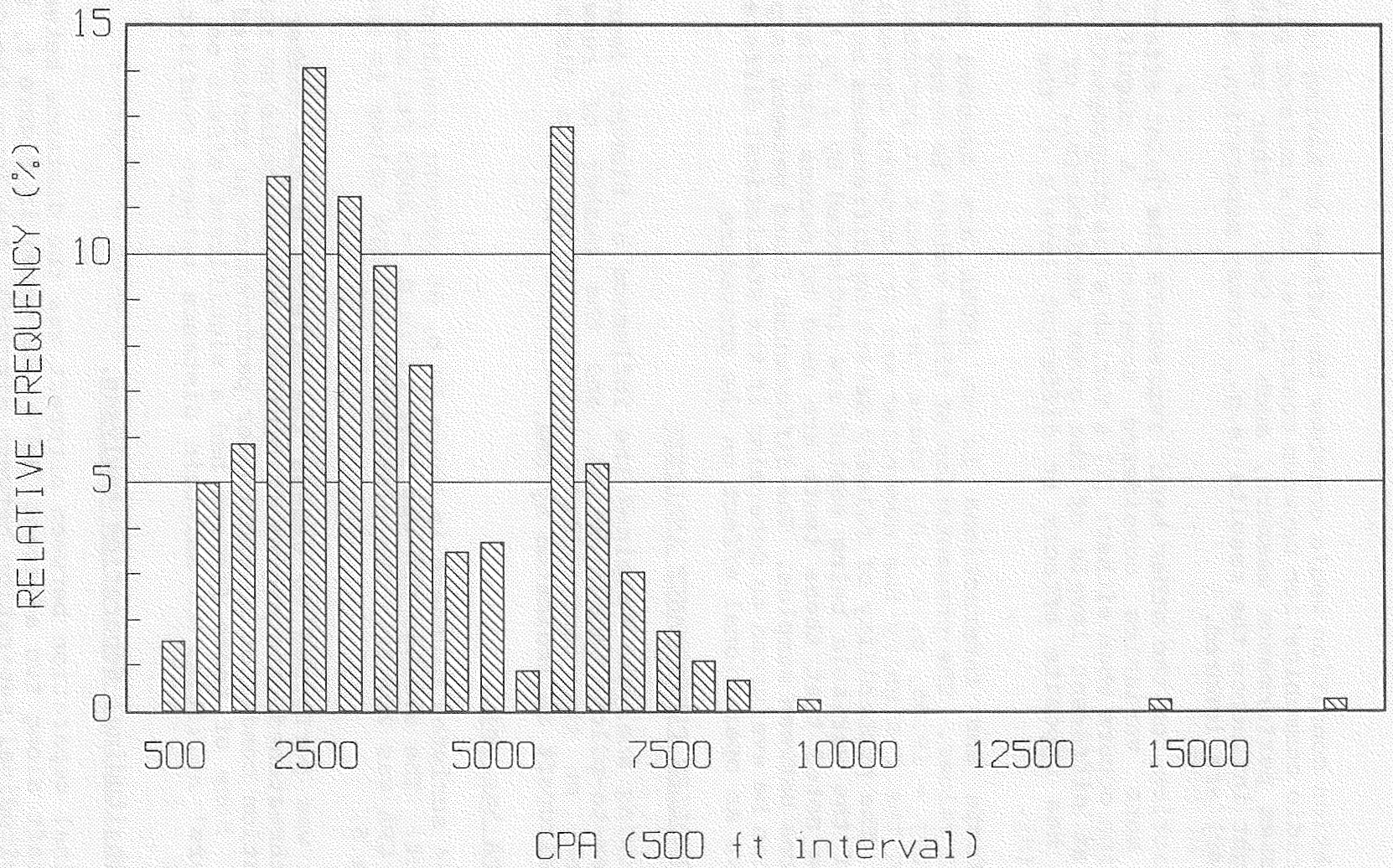


FIGURE 5. DISTRIBUTION OF CPA VALUES

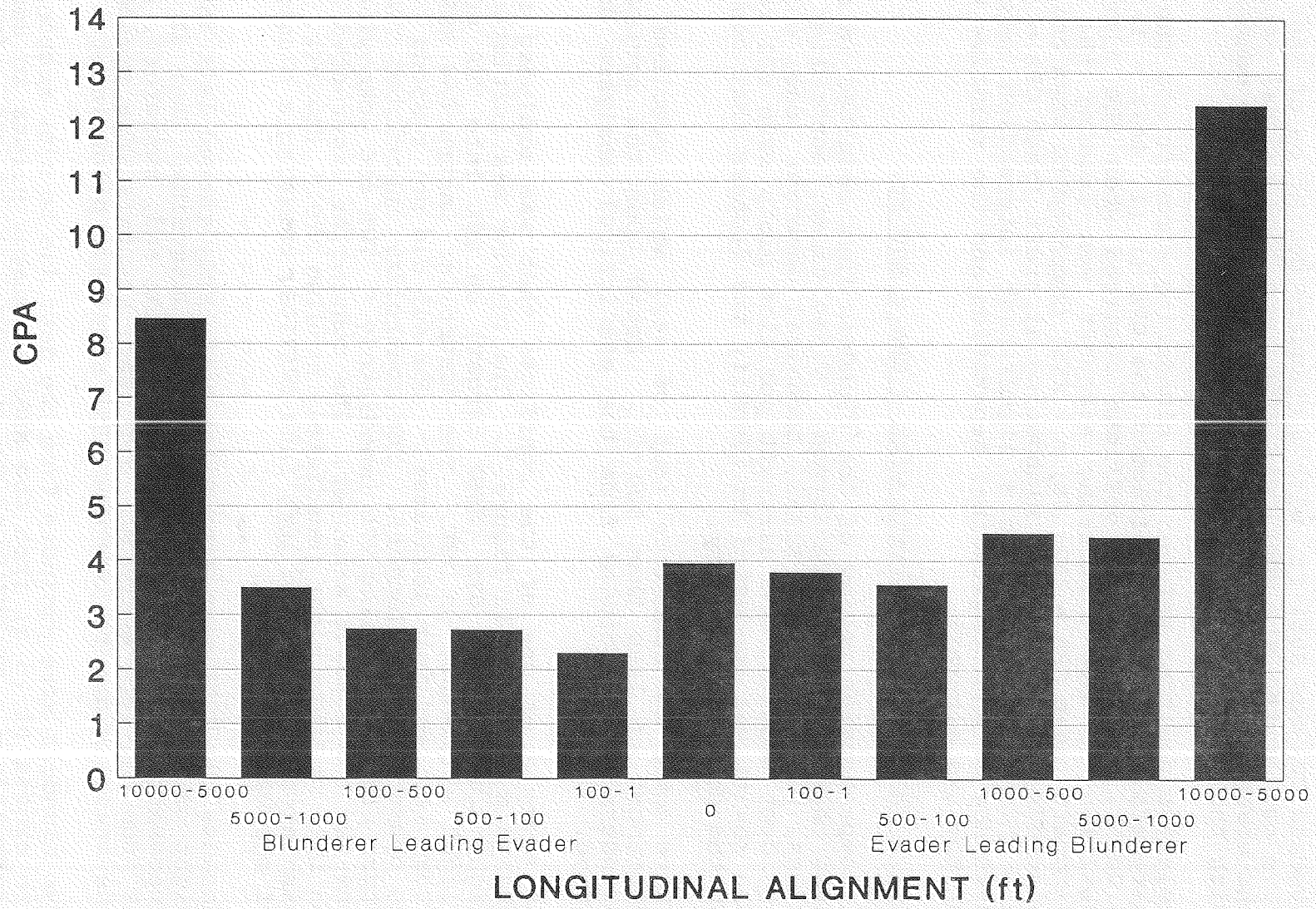


FIGURE 6. EFFECT OF LONGITUDINAL SEPARATION ON CPA

There were six occasions when aircraft were "wing tip-to-wing tip," or zero longitudinal separation. During these conditions, the average CPA was 3951 ft, with a standard deviation of 2808 ft. In five out of the six conflicts with zero longitudinal separation, the blundering aircraft turned 30 degrees and had no communication with the controller.

Relative position between the blundering aircraft and the evading aircraft significantly affected the CPA ($F(1, 443) = 13.53$, $p < 0.0005$). More serious conflicts occurred when the along track position of the blundering aircraft was leading the evading aircraft (mean CPA = 2923 ft; n = 255) compared to when the evading aircraft was leading the blundering aircraft (mean CPA = 4314 ft; n = 201). There was not a significant interaction between the distance of the longitudinal separation and the relative position of the two aircraft.

4.2.3 Review of Conflicts with a CPA < 500 Ft.

A comprehensive review of the blunders that resulted in a CPA of less than 500 ft was performed. Video tapes, controller message times, pilot response times, technical observer logs, controller incident reports, and aircraft position plots were all reviewed. The review was conducted to identify the factors that contributed to the conflict severity.

There were 10 conflicts (out of 462) which resulted in miss distances of less than 500 ft. Based upon the review, seven blunders were excluded from the statistical analyses described above.

An example of one of the conflicts that was excluded from the analysis is shown in figure 7. The blunder was initiated with a right turn by MSE 615 (NSSF target) on 18L into TWA 406 (NASA flight simulator) on 18C. The controller instructed MSE 615 to "turn left and join localizer." MSE 615 did not respond (scripted no communication blunder). The controller instructed TWA 406 to "turn right to heading 270 immediately." TWA 406 acknowledged and started the evasive maneuver. The controller instructed AAL 238, on 18R, to "turn <u>right</u> immediately heading 270." However, the NSSF simulator pilot turned <u>left</u> into TWA 406, creating a closest point of approach of 224 ft.

Because the NSSF simulator pilot mistakenly turned left instead of right as he was instructed, the TWG determined that it was not representative of an actual pilot action and, therefore, excluded it from the data analysis. Two other blunders were excluded from the analysis due to improper NSSF simulator pilot input.

Two blunders were excluded from the data due to slow response times (in excess of 25 s) from the NSSF simulator pilots to controller instructions. In addition, two blunders with a CPA < 500 ft were

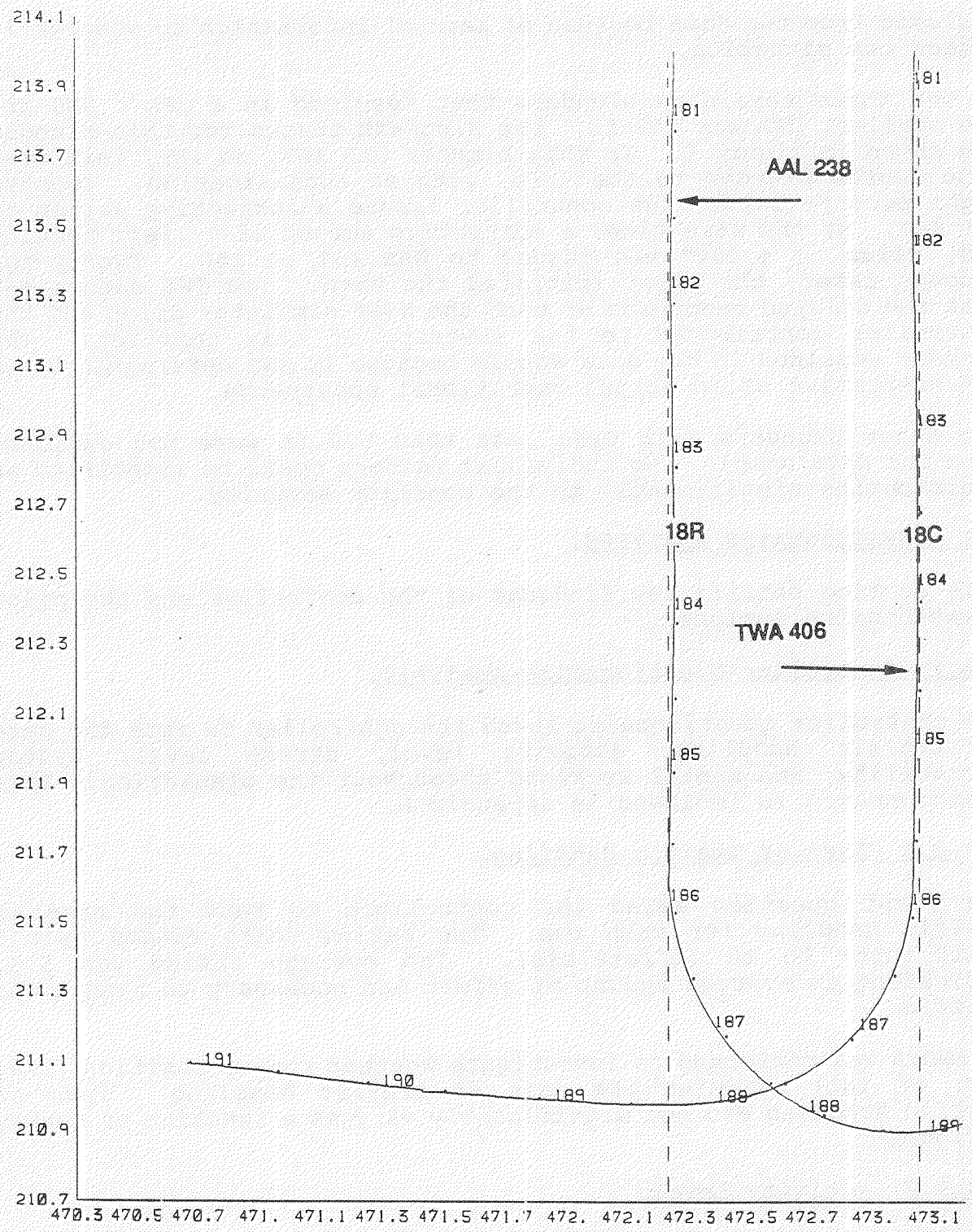


FIGURE 7. EXAMPLE OF CONFLICT EXCLUDED FROM ANALYSIS

excluded from the data because of lack of information to completely assess the situation.

Of the three remaining blunders that resulted in a CPA < 500 ft, the smallest CPA was 267 ft. The aircraft tracks for this blunder are shown in figure 8. In this blunder UAL 457, on 18R, initiated a 30-degree blunder to the left, with no communication. Twenty-eight seconds later, the controller issued a corrective action to UAL 457. At the same time, a corrective action of "..left heading 080, climb to 4,000" was issued to USA 451 on 18C. Twenty-two seconds later, the pilot initiated the turn. The TWG determined that the delayed responses of both the NSSF simulator pilot and the controller contributed to the severity of this conflict. The blunder remained in the data sample because it was determined to be representative of an actual operational occurrence.

Two other blunders with CPAs less than 500 ft were not excluded from the data sample. No individual factors could be identified as contributing significantly to the conflict severity.

4.3 QUESTIONNAIRE ANALYSES.

This section details the findings of the controller and the pilot questionnaire analyses.

4.3.1 Controller Questionnaire Analysis.

The controller questionnaire asked the controller to rate the ease of traffic handling, activity level, stress level, system workability, and mental workload throughout the simulation. This questionnaire is included as appendix A.

4.3.1.1 Ease of Traffic Handling.

The first question asked the controllers to rate the ease of traffic handling for each run. The rating scale ranged from 1 (difficult) to 10 (effortless). The average rating was 5.5, indicating an average amount of effort was necessary to handle the traffic.

An ANOVA was performed to investigate whether runway position (18R, 18C, or 18L) affected the ease of traffic handling. Ease of traffic handling did not significantly vary as a function of runway assignment.

4.3.1.2 Activity Level.

Controllers were asked to rate the level of activity required for each run. The scale for this question ranged from 1 (minimal) to 10 (intense). Controllers rated their activity level as moderate

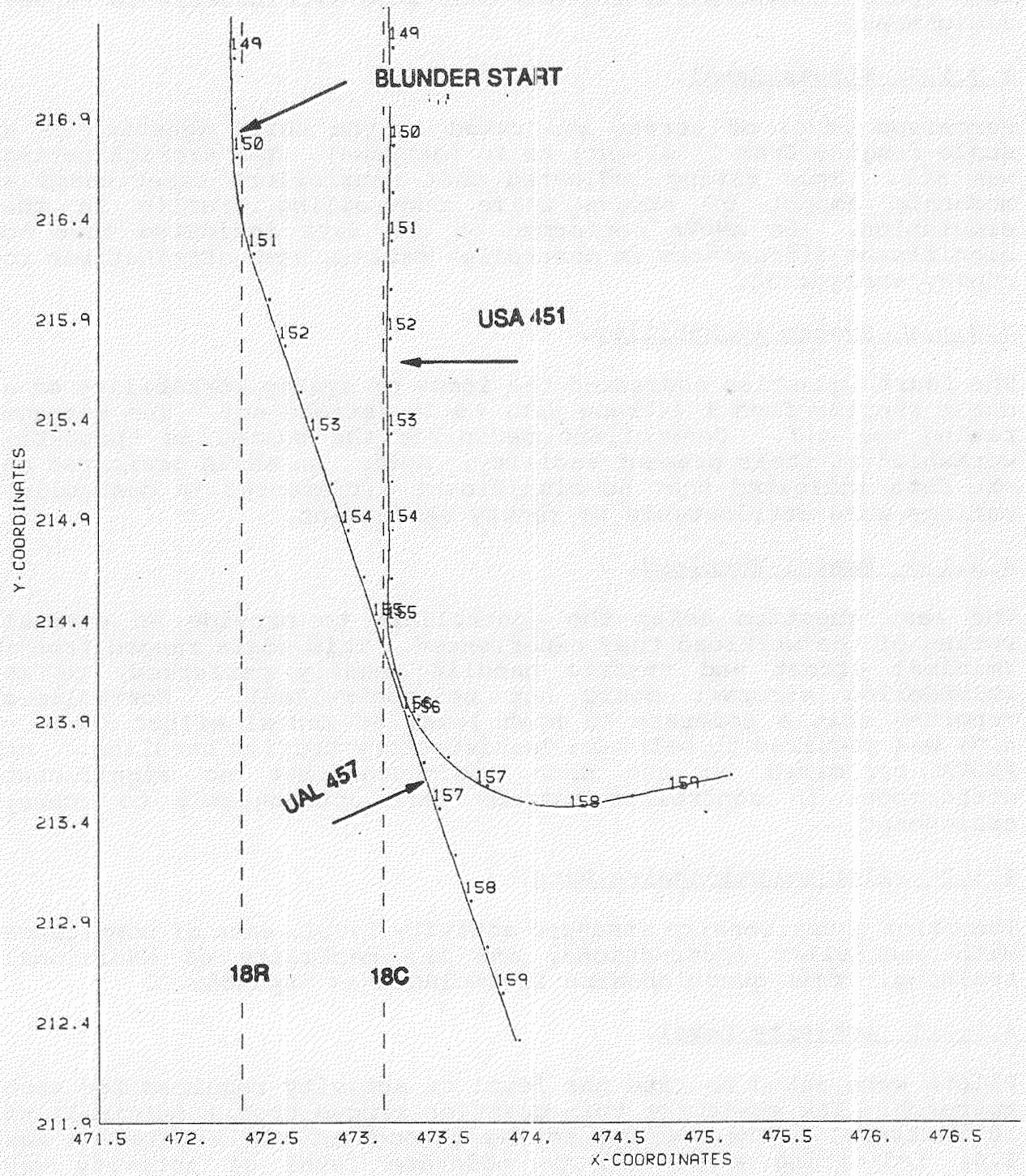


FIGURE 8. BLUNDER PLOT OF THE SMALLEST CPA

(5.8). As in the previous question, no significant differences were found in controller ratings that were attributable to runway assignment.

4.3.1.3 Stress Level.

Perceived level of stress was rated in the third question on a scale ranging from 1 (slight) to 10 (extreme). The average rating was 5.7. This rating indicated that controllers experienced a moderate amount of stress while controlling traffic in the simulation. An ANOVA performed on the data indicated that no significant differences in controller ratings were attributable to runway assignment.

4.3.1.4 System Workability.

The fourth question addressed the issue of system workability on a scale ranging from 1 (strong yes) to 10 (strong no). The average rating was 4.1. Controllers perceived the system as "probably workable" at their present facility. Again, an ANOVA performed on the data indicated that no significant differences in controller ratings were attributable to runway assignment.

4.3.1.5 Mental Workload.

The last question asked the controllers to provide an overall rating of the workload they experienced. This scale ranged from 1 (minimal effort and traffic handling easily performed) to 10 (blundering aircraft could not be controlled). Controllers reported that a moderate to high level of mental effort (mean = 4.9) was required to maintain "satisfactory traffic handling." An ANOVA performed on the data indicated that no significant differences in controller ratings were attributable to runway assignment.

4.3.2 Pilot Questionnaire Data.

The pilot questionnaire assessed activity level, ease of compliance with controller instructions, and the necessity of additional training. This questionnaire is included as appendix C.

4.3.2.1 Activity Level.

Pilots were asked to rate the level of activity required for each approach. The scale for this question ranged from 1 (minimal) to 10 (intense). The average rating throughout the simulation was 3.0, indicating a minimal to moderate level of activity was required throughout the simulation.

4.3.2.2 Controller Instruction.

The second question asked pilots if they were able to follow controller instructions, and if not, to provide an explanation. Pilots reported that they were able to follow controller requests; however, they expressed concerns with the types of maneuvers that they were asked to perform. The pilots reported that their ability to hear ATC instructions was "poor to unacceptable," and the amount of communication pilots had with controllers was not representative of that occurring in an operational setting. Pilots also reported that nonstandard phraseology was used by the controllers when vectoring an aircraft. The pilots were not receptive to receiving changes in heading without receiving instructions concerning altitude. The pilots also indicated that controller commands to descend to an altitude below the glide slope were contrary to standard procedures. Generally, pilots were concerned about the differences between commands given by controllers during the simulation versus those given in the operational environment.

4.3.2.3 Additional Training.

The final question asked pilots if they felt any additional flight training would be necessary in order to operate aircraft in the proposed aircraft configuration. The majority of pilot responses indicated that no additional training would be necessary.

4.4 RESPONSE TIME ANALYSES.

An analysis was performed to examine the effects of blunder degree on the controllers' ability to detect blunders as indicated by blunder response times. Blunder response times were measured from blunder initiation until the controller keyed the microphone to issue a command to the blundering aircraft. The ANOVA indicated that blunder degree ($F(2,454) = 1840.13$, $p. < .014$) had a significant effect on the controllers' ability to detect blunders. Controllers detected 30-degree blunders (mean = 17.7 s) quicker than 20-degree (mean = 24.5 s) and 10-degree (mean = 21.8 s) blunders.

Response times were measured to assess the effect of message complexity on NSSF simulator pilot performance. Message complexity was measured by the number of keystrokes required to enter a command. The range of keystrokes executed was 7-13. A message with 7-10 keystrokes indicated moderate complexity while 11-13 keystrokes indicated a message of high complexity. An ANOVA indicated that there were significant differences in NSSF simulator pilot performance as a function of message complexity ($F(1,305) = 17.69$, $p. < 0.00014$). The message that had 7-10 (mean = 27.10 s) keystrokes, on average, took the shortest length of time to enter. This could have been a change in heading. The message that had 11-13 (mean = 32.38 s) keystrokes, on average, took the longest length of time to enter. This could have been a change in heading

accompanied by a change in altitude. The most frequent message consisted of 9 keystrokes. An example of this would be "turn left heading 270."

4.5 PILOT/FLIGHT SIMULATOR ANALYSES.

An analysis was conducted to examine differences in performance between flight simulators and NSSF computer generated aircraft as indicated by controller response time. The analysis indicated that controllers responded significantly quicker to deviations by flight simulators than to the NSSF aircraft ($F(1,455) = 5.0$, $p. < .02$). The means for the flight simulators and NSSF aircraft are 16.21 and 20.94, respectively.

5. DISCUSSION.

The simulation was designed to test the procedures for triple simultaneous parallel ILS approaches spaced 5000 ft apart under extreme conditions. Controllers were asked to resolve conflicts that rarely occur in the operational environment. The conflicts were the result of aircraft randomly blundering (10, 20, or 30 degrees) toward an adjacent approach. Often the blundering aircraft simulated a loss of communication.

Analysis of the data indicated that controllers were able to maintain aircraft miss distances of 500 ft or greater in approximately 99 percent of the blunders. The controllers were able to detect 30-degree blunders significantly quicker than 20 and 10-degree blunders. Additionally, they resolved 99 percent of all 30-degree no communication blunders.

A review of the blunders that resulted in miss distances of less than 500 ft revealed several factors which appeared to contribute to the conflict. Slow pilot and controller responses and NSSF simulator pilot error were the factors which contributed to conflict severity.

In a triple approach condition, a blunder can threaten one or two other approaches. Analyses were conducted to determine whether the number of approaches threatened was related to the conflict severity. The analyses indicated that controllers were able to resolve blunders that threatened two approaches as well as blunders that threatened only one approach.

The average response time for NSSF simulator pilots was determined. NSSF simulator pilot response times consisted of the following sequence of actions: from the time a blunder was initiated, the controller identified the deviating aircraft and instructed the NSSF simulator pilot to take corrective action. The NSSF simulator pilot acknowledged the instruction, input the instruction, and pressed the enter key. The responses were analyzed according to the message complexity. The average response

time by NSSF simulator pilots was from 27.10 s for moderate length messages and 32.38 s for complex messages.

Overall, the controllers indicated that the operations in this simulation may be workable. The controllers rated ease of traffic handling, stress, and activity levels as being moderate. Controllers also reported that a moderate to high level of mental effort was necessary to maintain "satisfactory traffic handling."

The Controller Report, appendix B, documented the findings of the controllers that participated in the simulation. The controllers indicated that they were effective in resolving blunders in the proposed triple approach configuration. Secondly, the controllers concluded, based upon their knowledge of blunder occurrence, that triple simultaneous parallel ILS approaches were "achievable, acceptable, and safe."

The pilots rated their activity level as minimal to moderate throughout the approaches. The pilots involved in the simulation at NASA-Ames and Oklahoma City commented on the simulation and on simultaneous triple approach procedures. They concluded that with some procedure changes and additional controller training, a triple simultaneous parallel ILS runway configuration would be possible.

6. CONCLUSIONS.

This study was part of an on-going effort to evaluate plans for increasing air traffic capacity and to evaluate the feasibility of using multiple simultaneous parallel Instrument Landing System (ILS) approaches. The objective of this study was to evaluate the ability of experienced controllers to handle approach traffic during Instrument Meteorological Conditions (IMC) to a proposed parallel runway airport configuration, using a real-time, interactive, air traffic control (ATC) simulation. This simulation utilized a current radar system, Airport Surveillance Radar (ASR-9, and a current display system, Automated Radar Terminal System (ARTS) IIIA. The proposed configuration consisted of parallel runways (i.e., 18R, 18C, and 18L), 10,000 feet (ft) long, spaced 5000 ft apart with even thresholds. All aircraft were assigned speeds of approximately 170 knots.

Triple simultaneous parallel ILS approaches were simulated with controllers monitoring traffic on the approach localizers. To challenge the system, blunders were introduced, according to predetermined scenarios, by having some of the simulated aircraft deviate from the localizer by either 10, 20, or 30 degrees. Furthermore, half of the blundering aircraft also simulated a total loss of radio communication (NORDO) with the controllers.

The test director and his assistant used scripts to create blunders. Turns were 10, 20, or 30 degrees, always toward at least one other localizer. Fifty percent of the blundering aircraft

executed 30 degree turns, 35 and 15 percent executed 20 and 10 degree blunders, respectively.

For the approach runs, 50 percent of the blunders on the center approach (18C) turned to the left and 50 percent turned to the right. Blundering aircraft on the outside approaches (18R and 18L) turned toward the inboard localizer.

The central issue in the study was the ability of the controllers to maintain distance between a blundering aircraft and aircraft on adjacent parallel approaches. Two questions were to be answered:

a. Would the controllers be able to maintain the test criterion miss distance, established at 500 ft between aircraft, in response to blunders occurring in the proposed triple approach configuration?

b. Do the controllers, technical observers, the Multiple Parallel Technical Work Group (TWG), and other Federal Aviation Administration (FAA) management observers agree that the operation of the proposed triple simultaneous parallel ILS approaches is acceptable, achievable, and safe?

The results indicated that controllers were able to resolve 99 percent of the blunders initiated in the simulation. Of the 484 blunders simulated, only three blunders resulted in aircraft violating the criterion miss distance of 500 ft.

The controllers that participated in the simulation stated that in a terminal environment, it is unlikely that there would be a continuous flow of three aircraft traveling on the final as simulated in this study. Even under these extreme circumstances, controllers were able to maintain the test criterion miss distance of 500 ft or greater between aircraft the majority of the time. The controllers concluded that the triple simultaneous parallel ILS approaches with runway centerlines spaced 5000 ft apart would be a "safe and viable operation," using current technology radar systems and procedures.

The TWG, composed of individuals from the Office of System Capacity and Requirements, Air Traffic Control, Flight Standards, Aviation Standards and Operations personnel, participated in the simulation and evaluated the simulation findings. *Based upon their understanding of daily air traffic operations, the knowledge and skills of controllers, and the contingencies which must be accounted for in such an operation, the TWG determined that the triple simultaneous parallel ILS approach operation spaced at 5000 ft is acceptable using the ASR-9 radar and the ARTS IIIA displays*.

BIBLIOGRAPHY

Altschuler, S. and Elsayed, E., Simultaneous ILS Approaches to Closely Spaced Parallel Runways: Literature Survey and Parameter Identification, *Rutgers IE Working Paper Series*, No. 89-102, Piscataway, New Jersey, February 1989.

Buckanin, D. and Biedrzycki, R., Navigation Performance of Aircraft Making Dependent Instrument Landing System (ILS) Approaches at Memphis International Airport, DOT/FAA/CT-TN86/59, February 1987.

Buckanin, D., Guishard, R., and Paul, L., Closely Spaced Independent Parallel Runway Simulation, DOT/FAA/CT-84/45, October 1984.

CTA INCORPORATED, Dallas/Fort Worth Simulation Phase II - Triple Simultaneous Parallel ILS Approaches, DOT/FAA/CT-90/2, FAA Technical Center, Atlantic City, New Jersey, March 1990.

CTA INCORPORATED, Simulation of Quadruple Simultaneous Parallel ILS Approaches at DFW - Phase III, DOT/FAA/CT-90/15, FAA Technical Center, Atlantic City, New Jersey, August 1990.

Federal Aviation Administration, Air Traffic Control, DOT/FAA/HDBK 7110.65F, September 1989.

Haines, A. L., Reduction of Parallel Runway Requirements, The MITRE Corp., MTR-6282, January 1973.

Haines, A. L. and Swedish, W. J., Requirements for Independent and Dependent Parallel Instrument Approaches at Reduced Runway Spacing, The MITRE Corp., MTR-81W15, May 1981.

Hitchcock, L., Paul, L., Shochet, E. and Algeo, R., Atlanta Tower Simulation, DOT/FAA/CT-TN89/27, March 1989, Art 1.

Hitchcock, L., Paul, L., Shochet, E. and Algeo, R., Dallas/Forth Worth Simulation, DOT/FAA/CT-TN89/28, March 1989, Art 2.

ICAO, Manual on the Use of the Collision Risk Model for ILS Operations, Document No. 9274-AN/904, 1980.

McLaughlin, Francis X., An Analysis of the Separation Between Dual Instrument Approaches, Franklin Institute Labs, FAA/BRD-14/12, April 1960.

Resalab Inc., Lateral Separation, Report FAA-RD-72-58, Volumes I and II, July 1975.

Romei, Joseph, An Exploratory Study of Simultaneous Approaches, FAA Technical Center, Atlantic City, New Jersey, December 1981.

Shimi, T. N., Swedish, W. J., and Newman, L. C., Requirements for Instrument Approaches to Triple Parallel Runways, The MITRE Corp., MTR-81W145, July 1981.

Steinberg, Herbert A., Collision and Missed Approach Risks in High-Capacity Airport Operations, *Proceedings of the IEEE*, Vol. 38, No. 3, pg. 314.

Timoteo, B. and Thomas J., Chicago O'Hare Simultaneous ILS Approach Data Collection and Analysis, FAA Technical Center, Concepts and Analysis Division, October 1989.

GLOSSARY

Airport Surveillance Radar (ASR) - Approach control radar used to detect and display an aircraft's position in the terminal area. ASR provides range and azimuth information but does not provide elevation data. Coverage of the ASR can extend up to 60 miles.

Analysis of Variance (ANOVA) - A statistical analysis involving the comparison of deviations between groups and within groups reflecting different sources of variability.

Automated Radar Terminal System (ARTS) - The Radar Tracking and Beacon Tracking Level (RT&BTL) of the modular, programmable automated radar terminal system. ARTS IIIA detects, tracks, and predicts primary as well as secondary radar-derived aircraft targets. This more sophisticated computer driven system upgrades the existing ARTS III system by providing improved tracking, continuous data recording, and failsoft capabilities.

Blunder - An unexpected turn by an aircraft already established on the localizer into another aircraft.

Closest Point of Approach (CPA) - The smallest slant range distance between two aircraft in conflict.

Dependently Sequenced Approaches - When used in conjunction with parallel runways, ILS approaches conducted at many facilities in the United States where at least 2 nmi separation must be maintained between aircraft on the parallel approaches in addition to the standard radar separation required between aircraft on the same approach.

Flight Technical Error (FTE) - The accuracy with which the pilot controls the aircraft as measured by the indicated aircraft position with respect to the indicated command or desired position. It does not include procedural blunders.

Glide Slope Intercept - The minimum altitude to intercept the glide slope during a precision approach. The intersection of the published intercept altitude with the glideslope, designated on Government charts by the lightning bolt symbol, is the precision Final Approach Fix (FAF); however, when ATC directs a lower altitude, the resultant lower intercept position is then the FAF.

Instrument Flight Rules (IFR) - An aircraft conducting flight in accordance with instrument flight rules.

Instrument Landing System (ILS) - A precision instrument approach system which normally consists of the following electronic components and visual aids; localizer, glide slope, outer marker, middle marker, and approach lights.

Instrument Meteorological Conditions (IMC) - Any weather condition which causes a pilot to navigate an aircraft solely via cockpit instrumentation. Meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling less than minima specified for visual meteorological conditions. Conditions which require a pilot to fly primarily with reference to the aircraft's instruments.

Missed Approach - A maneuver conducted by a pilot when an instrument approach cannot be completed to a landing. The route of flight and altitude are shown on instrument approach procedure charts. A pilot executing a missed approach prior to the Missed Approach Point (MAP) must continue along the final approach to the MAP. The pilot may climb immediately to the altitude specified in the missed approach procedure.

National Airspace System (NAS) - The National Airspace System is the United States' air traffic environment. The system is comprised of procedures, equipment, and the airway structure within the boundaries of the geographical United States.

National Airspace System Simulation Support Facility (NSSF) - The facility located at the FAA Technical Center, which houses the individuals who operate the simulation aircraft and the equipment used to accomplish this task.

NORDO - An aircraft simulating a loss of radio communication.

No Transgression Zone (NTZ) - The NTZ is an area in space 2000 ft wide in which aircraft are prohibited to enter. It is established equidistant between runway centerlines.

Outer Marker (OM) - A marker beacon at or near the glide slope intercept altitude of an ILS approach. It is keyed to transmit two dashes per second on a 400 Hz tone, which is received aurally and visually by compatible airborne equipment. The OM is normally located 4 to 7 miles from the runway threshold on the extended centerline of the runway.

Parallel ILS Approaches - Approaches to parallel runways by aircraft flying under Instrument Flight Rules (IFR) which, when established inbound toward the airport on the adjacent final approach courses, are radar-separated by at least 2 miles.

RDO - An aircraft with radio communication.

Simultaneous ILS Approaches - An approach system permitting simultaneous ILS approaches to airports having parallel runways separated by at least 4300 ft between centerlines.

S-VHS - High resolution video tape format used to record controller displays during the simulation.

t-test - A statistical test used to compare two small sample data sets.

Technical Observer - An individual who monitors each control position visually and aurally during each simulation run. Their duties include: documenting discrepancies between issued control instructions and actual aircraft responses; assist in alerting responsible parties to correct any problems which may occur during the test (e.g., computer failure, stuck microphone); assist controllers in preparation of reports, and assist in final evaluation of data in order to prepare a Technical Observer report at the end of the simulation.

Test Criterion Violation (TCV) - A conflict resulting in a slant range miss distance (CPA) of less than 500 ft. The test criterion for simultaneous independent ILS approaches is 500 ft.

Visual Meteorological Conditions (VMC) - When weather conditions are above the minimums prescribed for IMC, pilots may fly with visual reference to the ground without referring to radio navigational aids.

Wanderer - 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 on its own to the localizer.

Worst Case Blunders (WCB) - A worst case blunder is defined as to be a 30 degree blunder, without communication.

APPENDIX A

CONTROLLERS QUESTIONNAIRE

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 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 LIMIT THE THREAT OF BLUNDERING AIRCRAFT.

10. THE THREAT OF BLUNDERING AIRCRAFT CANNOT BE CONTROLLED.

APPENDIX B

CONTROLLER REPORT

INTRODUCTION

On September 17,1990 a team of six controllers from facilities around the nation, met at the Federal Aviation Administration's Technical Center (FAATC), at Atlantic City International Airport, New Jersey.

The team was briefed by Ralph Dority of ASC-200 on their purpose to evaluate 5,000 foot runway centerline separation for independent simultaneous Instrument Landing System (ILS) approaches for three runways.

OBJECTIVE

The objective for this simulation was to evaluate the traffic handling capabilities of triple simultaneous parallel ILS approaches with evenly spaced runway thresholds and five thousand foot runway centerline spacing. The controller team had to use current technology equipment and procedures.

ANALYSIS

The controller team using present day Airport Surveillance Radar (ASR) and the Automated Terminal System (ARTS), with a 4.8 second update rate, had to implement control instructions that would provide miss distances between blundering and non-blundering aircraft. These aircraft were making triple independent simultaneous approaches to an airport.aligned north to south with evenly spaced thresholds with 5,000 feet between runway centerlines The control instruction had to result in a five hundred foot or more miss distance between aircraft in a blundering event.

Blunders consisted of targets that turned ten, twenty, or thirty degrees off the localizer. Some of the blunders were no radio (NORDO). We believe the probability of a thirty degree blunder with or without radio is highly unlikely.

In a terminal environment, we believe it is unlikely that there would be a continuous flow of three aircraft abreast on the final, as conducted during the test.

The simulation used the FAATC 's (GAT) general aviation simulator, pseudo- pilot lab and two flight simulators. For the most part all the pilot simulators performed well. The radio communication with the flight simulators was poor.

Several times during the first week of the simulation the ASR sweep visibly slowed on the radar screen. This caused the targets to coast for three sweeps. After the tags repositioned, altitude information was not available for two more sweeps. This sweep slowdown caused an adverse effect on the control action initiated by a controller when it happened during a blunder. The controller had to rely on intuitive skill when the radar update was not consistent , and evaluate whether a blunder was occurring and if his control instruction had a positive effect on the outcome.

CONCLUSION

Based on current technology radar systems and procedures, we believe that

triple simultaneous ILS approaches with runway centerlines spaced 5,000 feet

apart is a safe and viable operation.

RECOMMENDATIONS

We believe parallel runway monitor equipment now being evaluated by the FAATC would increase safety, airport capacity and controller effectiveness. Since controller response time is a factor in the detection of a blunder, we believe the same team of controllers should be assembled to provide a more accurate comparison of the effectiveness of each system.

SIGNATORY

Harold R. Anderson ATCS
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Denver Tower

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Charles T. Maxwell ATCS
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APPENDIX C

PILOT QUESTIONNAIRE

Date _____ Time _____

Simulation of Triple Simultaneous Approaches

Pilot Questionnaire

Pilot Letter _____ Total B-727 Flight Time _____ hrs.

Total Flight Time _____ Total Instrument Time _____

Company you fly for _____ Captain _____ F/O _____

Type rated and/or current in B-727 _____

---

1. RATE THE LEVEL OF ACTIVITY REQUIRED DURING THE PAST RUN.

1 2 3 4 5 6 7 8 9 10

MINIMAL MODERATE INTENSE

---

2. When the controller issued a vector change, were you able to follow the instructions immediately? Yes ___ No ___.

If No, Please explain. _____

3. Please describe any unusual occurrences during the past blunder. Pleas include aircraft ID's and approximate time if possible. __

4. Given the current simulation, do you feel additional flight training would be beneficial? Yes ___ No ___.

If yes, Please explain. _____

APPENDIX D

PILOT SURVEY RESULTS

PILOT SURVEY

Following the completion of their participation in the simulation, pilots completed an aircrew opinion survey. This survey assessed pilots' opinions regarding the conduct of closely spaced parallel simultaneous approaches. Questions 1-4 required pilots to rate their opinions on a scale from 1 (strongly disagree) to 5 (strongly agree). The averages of the pilots' ratings are given below. Also responses to questions 5 and 6 are summarized below.

1.1 In the event an aircraft overshoots the localizer, pilots overall agreed (4.1) that current parallel runway procedures requiring 1000 feet (ft) of vertical separation at the localizer turn-on provides an acceptable safety margin provided aircraft maintain their assigned altitude until established on the localizer course.

1.2 Pilots' responses were not conclusive (3.3) whether all closely spaced parallel approaches should be conducted with a coupled autopilot.

1.3 Pilots are adamant (4.4) that if an aircraft penetrates the NTZ while another aircraft is conducting a simultaneous parallel approach, the monitor controller will immediately direct the threatened aircraft off it's approach course to a heading/altitude that will prevent a collision. In addition, special phraseology should be used for the break out maneuver.

1.4 It was not indicated (3.2) that additional pilot training/currency requirements (e.g. Category 2 and 3 ILS requirements) is mandatory to qualify pilots for simultaneous independent approaches to parallel runways separated by 5000 ft.

The following summarizes the pilots' suggestions for the safe and effective operation of multiple simultaneous parallel ILS approaches:

Approaches should only be made with an autopilot and/or the flight director. CAT II standards for ground and airborne equipment would be necessary for the safe operation of parallel approaches. Additionally, a traffic display with audio warnings (e.g., TCAS II) would enhance situational awareness and put the pilot into the collision avoidance loop.

If more than two approaches are being conducted, the additional approach should be staggered to facilitate break out maneuvers. "In the event an aircraft strays from his altitude/course, only one aircraft should be in immediate conflict."

Special training (conflict resolution) is needed for approach controllers during the conduct of multiple parallel approaches.

For example, when a climbing or descending turn instruction is given for the breakout maneuver, when possible the climb instruction should be given first, then the turn instruction, or the turn instruction should be given first, then the descent instruction. The pilots reported that this is more effective in handling the inertia of the aircraft.

Descending an aircraft below the glide slope is contrary to pilot flight training. Therefore, the pilot will be slower to respond to these type of controller instructions.

"A descent close to the ground combined with the distraction of departing aircraft and readjusting NAV-AIDS (e.g., flight director) provides ample opportunity to drive on into the ground. Adding expedite just speeds up the process."

The pilots had three major over-riding concerns with the simulation. First, more frequent ATC communication is needed to accurately simulate the real world. Also, the volume of radio communications was extremely low, "marginal to unacceptable." Pilots found the headset apparatus that was used to be very cumbersome; they felt that it made the barely audible controller transmissions even more difficult to understand. They would have preferred to use the headset that is used in normal day-to-day operations.

Secondly, the pilots reported that controllers did not use standard phraseology. Controller avoidance instructions were not complete; e.g., "immediate left turn to 090." An altitude assignment or an instruction to maintain present altitude should be given and the transmission should be in one command. A heading change given without an altitude, or vice versa, leaves the pilot uncertain as to how to reconfigure the airplane.

Finally, recurrent ATC commands to "turn and join the localizer," when the pilots' instruments indicated that the aircraft was on the localizer, was very disconcerting. Pilots wondered if the controllers knew where the aircraft was located.

APPENDIX E

TECHNICAL OBSERVERS REPORT

Phase IV B of the National Standards for Triple/Quadruple Parallel ILS Approach Simulation using 5,000 feet centerline separation was conducted at the FAA Technical Center in Atlantic City, New Jersey September 17 - 28, 1990.

During the simulation the Technical Observers recorded the control instructions of the controllers involved in each run. The simulation scheduled a total of 43 runs, however, due to software and hardware problems encountered during the simulation Runs 3, 8, 9, 13, and 14 were not conducted.

During the 38 runs accomplished the Technical Observers recorded 486 blunders including 790 turn and join instructions and 111 speed adjustments. The 486 blunders resulted in 9 situations in which the minimum acceptable miss distance of less than 500 feet, slant range, was lost. The following is a brief outline of those situations listing the run number, time, and possible cause when obvious:

Run 10	0023:26 -	Requires review.
	0028:07 -	Pilot error - turned wrong direction.
Run 15	0032:52 -	Pilot error - turned wrong direction.
	0059:40 -	Pilot/Controller contributed

Run 19	0044:30 -	Requires review.
Run 22	-	Run ended due to video mapper failure prior to the blunder.
Run 25	0031:03 -	Pilot error - turned wrong direction.
Run 34	0025:00 -	Requires review.
Run 43	0056:12 -	Requires review.

TRIPLE ILS SIMULATION

5,000 FEET CENTERLINE SEPARATION

RUN	BLUNDERS	SPEED	TURN/JOIN
1	13	12	10
2	11	-	9
3	-	-	-
4	11	7	26
5	16	12	49
6	11	4	18
7	8	-	8
8	-	-	-
9	-	-	-
10	11	3	10
11	13	1	17
12	13	5	9
13	-	-	-
14	-	-	-
15	14	7	18
16	14	4	33
17	15	5	19
18	15	1	12
19	12	-	36
20	13	3	13
21	10	2	35
22 (00:17) (Video Mapper failed)	3	-	7
23	13	-	32

RUN	BLUNDER	SPEED	TURN/JOIN
24	15	2	16
25	13	4	27
26	11	2	12
27	14	-	27
28	12	3	7
29	15	2	26
30	14	5	20
31	14	-	9
32	16	5	33
33	12	2	19
34	14	-	22
35	14	1	39
36	13	6	25
37	16	-	36
38	11	-	24
39	14	3	18
40	15	6	18
41	11	3	12
42	13	-	14
43	13	1	25

RUN 10 9/21/90 11:05 PM LCL

RUNWAY	CONTROLLER
18L	A
18C	F
18R	E

0023:36	MID613	Rwy 18C	Turned right - NORDO
	NWA684	Rwy 18R	Turned right and descended to 2,000 feet. (200 FT - 1/10 NM)

The controller on Runway 18R turned NWA684 right and descended the aircraft to 2,000 feet. The pilot of NWA684 required two calls to respond. It took 16 seconds for the pilot to descend 300 feet and halfway through the turn the pilot asked what heading he should turn to.

The closest point of approach was estimated to be 200 feet and 1/10 NM and was computed to be 415 feet slant range (386 feet vertical - 153 feet lateral) with an API of 69.

The slow pilot response is believed to have been a contributing factor in this situation.

0028:07	COM3329	Rwy 18L	Turned right - NORDO
	NWA201	Rwy 18C	Turned right and climbed (100 feet - 1/2 NM)
	MTR959	Rwy 18R	Turned right and climbed

The controller on Runway 18R turned MTR959 right and climbed the aircraft. The pilot of MTR959 made a left turn passing within 778 feet slant range of NWA201 with an API of 12 and 278 feet slant range of COM3329 with an API of 75.

Pilot error was the contributing factor in this situation.

RUN 15 9/20/90 04:15 PM LCL

RUNWAY	CONTROLLER
18L	F
18C	E
18R	D

0032:52	UAL174	Rwy 18C	Turned left - NORDO
	UAL830	Rwy 18L	Turned left (0 FT - 0 NM)

The controller on Runway 18L turned UAL830 left. The pilot of UAL830 made a right turn passing within 280 feet slant range (165 feet vertical - 226 feet lateral) with an API of 59.

Pilot error was the contributing factor in this situation.

0059:40	UAL518	Rwy 18R	Turned left - NORDO
	AAL677	Rwy 18C	Turned left and climbed (0 FT - 0 NM)
	UAL3320	Rwy 18L	Turned left

The controller on Runway 18C turned AAL699 left and climbed the aircraft. The pilot of AAL677 turned very slowly and continued to descend. At this point the controller of AAL677 instructed the aircraft to turn left and descend. However, when this instruction was issued the aircraft had begun a climb resulting in the aircraft climbing into UAL518. AAL677 passed within 418 feet slant range of UAL518 (417 feet vertical - 24 feet lateral) with an API of 91.

The slow response of UAL518 contributed to the controller's actions. Therefore, both pilot and controller contributed to this situation.

RUN 19 9/20/90 10:35 PM LCL

RUNWAY	CONTROLLER
18L	D
18C	C
18R	F

0044:30	USA680	Rwy 18R	Turned left - NORDO
	AAL608	Rwy 18C	Turned left

The controller on Runway 18C turned AAL608 left. The pilot of AAL608 responded very slowly.

USA680 passed within 356 feet slant range of AAL608 (280 feet vertical -220 feet lateral) with an API of 59.

The pilot of AAL608 may have contributed to this situation.

RUN 22 9/21/90 06:00 PM LCL

RUNWAY	CONTROLLER
18L	D
18C	C
18R	B

This run ended at approximately 0017:00 minutes. The video mapper became inoperative and caused the map to rotate approximately ninety degrees each antenna sweep. The Technical observers do not have a record of DAL2270 and AAL709. Therefore, it is believed that this blunder occurred immediately after the video mapper became inoperative.

RUN 25 9/24/90 04:35 PM LCL

RUNWAY	CONTROLLER
18L	D
18C	C
18R	B

0031:03	MSE615	Rwy 18L	Turned right - NORDO
	TWA406	Rwy 18C	Turned right and climbed (100 FT - 1/2 NM)
	AAL238	Rwy 18R	Turned right and climbed

The controller on Runway 18C turned TWA406 right and climbed the aircraft. The controller on Runway 18R turned AAL238 right and climbed. The pilot of AAL238 responded very slowly to the instructions and made a left turn into both TWA406 and MSE615. AAL238 passed within 224 feet slant range of TWA406 (208 feet vertical -- 82 feet lateral) with an API of 83.

Pilot error was the contributing factor in this situation.

APPENDIX F

ADMINISTRATIVE ASSESSMENT

MULTIPLE PARALLEL APPROACH TECHNICAL WORK GROUP
ADMINISTRATIVE ASSESSMENT

The triple, simultaneous approach simulation was conducted at the Federal Aviation Administration (FAA) Technical Center, Atlantic City International Airport, New Jersey, from September 17, 1990 through September 28, 1990. The goals were to demonstrate the safety and feasibility of conducting triple simultaneous ILS operations to triple parallel runways.

The simulation included 43 triple ILS runs in which 1 percent of the blunders resulted in less than a 500-foot (ft) slant range distance. This required detailed evaluation of those situations which resulted in 500 ft or less slant range distance. The closest point of approach was computed to have a 267-ft slant range distance.

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

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.

Because of the small percentage of blunders that resulted in less than a 500-ft slant range miss distance, the TWG believes that triple ILS approaches spaced 5000 ft apart with current technology radar (ASR-9) and displays (ARTS IIIA) is acceptable, achievable, and safe.

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. The Implementation Strategy used prior to any airport conducting triple approaches with runways spaced 5000 ft apart shall consist of a graduated, sliding scale weather minimums criteria. This strategy will facilitate a smooth transition period to permit adequate training and to develop requisite competency. The recommended required meteorological conditions to be satisfied are categorized as follows:

a. Basic VFR - Ceiling greater than 3000 ft and visibility greater than 5 miles.

b. MVFR (Marginal VFR) - Ceiling 1000 to 3000 ft and visibility 3 to 5 miles inclusive.

c. IFR - Ceiling 500 to less than 1000 ft and visibility 1 to less than 3 miles.

d. LIFR (Low IFR) - Ceiling less than 500 ft and visibility less than 1 mile down to the lowest minimums authorized for the approach.

In addition, facilities must develop experience levels of 1000 approaches or 60 days, whichever occurs first, in conducting operations in each weather category. Once the required experience level has been acquired, they will be authorized to conduct approaches during conditions in the next, more restrictive weather minimums.

DOT/FAA CT-91/31
Evaluation of triple simultaneous parallel ILS approaches spaced 5000 feet apart: phase IV.b
00013281

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