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Evaluation of Triple Simultaneous Parallel ILS Approaches Spaced 4300 Feet Apart-Phase IV.a

September 1991

Test Report

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16. Abstract

This study was part of an ongoing 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 was to evaluate the ability of experienced controllers to handle approach traffic during Instrument Meteorological Conditions (IMC). The proposed configuration consisted of triple parallel runways 10,000 feet (ft) long, spaced 4300 ft apart with even thresholds.

The controllers were able to satisfactorily resolve more than 90 percent of the blunders in this simulation. Of the 244 blunders simulated, only 23 blunders resulted in aircraft violating the criterion miss distance of 500 ft.

The controllers stated that they were able to maintain the 500-ft miss distance with the exception of a few 30° blunders (appendix A). The controllers indicated that a departure monitor position would be unnecessary because all of the functions of the departure monitor controller could be provided by local and departure control positions. Finally, the controllers reported that higher update rate radar sensors and improved displays would enhance their performance.

The Multiple Parallel Technical Work Group (TWG), based on their observations during the simulations and their understanding of the contingencies that must be accounted for in such an operation, determined that triple simultaneous parallel approach operations spaced at 4300 ft would not be acceptable if controllers were required to use 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, Flight Standards, Aviation Standards, Air Traffic (including Regional and Field Facility personnel). 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-120, 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, Research and Development Program Manager and Archie Dillard, AAC-950C, Aviation Standards Branch, FAA Academy.

Support of this effort is provided by individuals from the FAA Technical Center: Lloyd Hitchcock, Technical Program Manager, Air Traffic Control (ATC) Technology Branch, who supervises the development of ATC simulations at the Technical Center; George Kupp, Simulation Manager; Hank Smallacombe, Assistant Simulation Manager; Mark McMillen, ATC Coordinator; Jeff Richards, Test Director; Hugh D. Milligan, Manager, ATC Facilities Operations Branch; Rene' A. Matos, Supervisor, Simulation Operations Section; and Daniel Warburton, Supervisor, Simulation Systems Support Section.

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, Kimberly Reardon, and Barbara Startzel-Dehel.

TABLE OF CONTENTS

DTIC QUALITY INSPECTED 6

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LIST OF ILLUSTRATIONS

LIST OF TABLES

EXECUTIVE SUMMARY

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, using a real-time interactive air traffic control (ATC) simulation, the ability of experienced controllers to handle approach traffic during Instrument Meteorological Conditions (IMC) to a proposed triple parallel runway airport configuration. The proposed configuration consisted of triple parallel runways 10,000 feet (ft) long, spaced 4300 ft apart with even thresholds (i.e., 18R, 18C, and 18L). The simulated traffic consisted of turbojets, turboprops, and props on all runways.

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. Some of the blundering aircraft also simulated a total loss of radio communication (NORDO) with the controllers. 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. Additionally, a few runs were conducted which evaluated the missed approach procedures with the controllers monitoring both departing and missed approach aircraft. Missed approaches were initiated to evaluate the controllers' ability to maintain distance between missed approach aircraft and departing aircraft on the adjacent departure path. Three questions were to be answered:

1. Can the controllers prevent conflicts from resulting in a miss distance of less than the test criterion (500 ft)? Simply stated, can the controllers issue corrective actions so that a blunder does not result in a test criterion violation (TCV)?

2. In the event of a missed approach, could the controllers maintain the test criterion miss distance of 500 ft between departing aircraft and the missed approach aircraft on an adjacent parallel runway in the proposed airport configuration?

3. Do the controllers, controller observers, and ATC management observers agree that the operation of the proposed triple simultaneous parallel ILS approaches is acceptable, achievable, and safe using the proposed runway configuration?

This simulation investigated triple parallel ILS approaches spaced 4300 ft apart. The controllers were able to resolve more than 90 percent of the blunders initiated in the simulation. Of the 244 blunders resulting in conflicts, only 23 blunders resulted in aircraft violating the criterion miss distance of 500 ft.

The controllers stated that they were able to maintain the 500-ft miss distance with the exception of a few 30-degree blunders (appendix A). The controllers indicated that a departure monitor position would be unnecessary because all of the functions of the departure monitor controller could be provided by local and departure control positions. Finally, the controllers reported that higher update rate radar sensors and improved displays would enhance their performance.

The Multiple Parallel Technical Work Group (TWG), composed of individuals from the Office of System Capacity and Requirements, Flight Standards, Aviation Standards, Air Traffic, including Regional Organizations and operations personnel, participated in the conduct of the simulation and evaluated the simulation findings. The TWG believes that the poor resolution of the current radar displays significantly detracted from the ability of controllers to effectively resolve blunders with this configuration. In about 30 percent of the blunders controllers were not able to determine the distance between two merging targets. In many of these cases there was more than 500 ft. *The TWG determined, based on observations during the simulations and the full range of contingencies that must be accounted for in such an operation, that triple simultaneous parallel approach operations spaced at 4300 feet would not be acceptable if controllers were required to use ASR-9 radar and the ARTS IIIA displays*.

In an effort to resolve the problem described above, the TWG recommends that high resolution color displays and alert algorithms be utilized. The TWG believes that the addition of the high resolution color displays and alert algorithms will enable controllers to detect blundering aircraft sooner, and thereby reduce conflict severity. The controllers also stated in their recommendations that "We believe a faster update rate and improved technology radar scopes would enhance the effectiveness of final approach monitoring."

The TWG recommends that a follow-on simulation study be conducted to investigate triple simultaneous parallel ILS approaches, spaced 4300 ft apart, using the new displays and their associated controller alerts. Based upon their review of the new display/alert systems, the members of the TWG are optimistic that triple simultaneous parallel ILS approaches can be conducted satisfactorily at the 4300 ft runway spacing if the upgraded display configurations were to be implemented.

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 both existing and/or new technology equipment. The objective of this study was to evaluate the ability of the controllers to handle traffic while monitoring triple simultaneous parallel ILS approaches with runways spaced 4300 feet (ft) apart. A current technology radar sensor, Airport Surveillance Radar (ASR-9), and radar display, Automated Radar Terminal System (ARTS) IIIA, were examined through a real-time air traffic control (ATC) simulation. The results of this study will be used toward the establishment of national standards using triple simultaneous ILS parallel approaches with 4300 ft runway spacing as a benchmark.

2. BACKGROUND.

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

2.1 AIRPORT LIMITATIONS.

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

At a minimum, triple and quadruple simultaneous parallel ILS approaches, at least 4300 ft apart, would be subject to the same limitations as dual simultaneous parallel ILS approaches. Special procedures required for simultaneous ILS approaches are described below [3]:

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.

These requirements have been studied by the FAA for a number of years. Operations research based models of the system have been used to study various safety restrictions and capacity limitations. [1, 4, 5, 6, 7, 8, and 9] Analyses have considered controller and pilot response times, navigational accuracy on the localizers, radar accuracy, and update rates, etc. [10]

2.2 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. Reliable field data are essential for successful modeling and simulation. Real-time ATC simulation, flight simulation, and flight testing are needed to generate estimates of the operational parameters used for modeling and fast-time simulation. Modeling provides a framework for collecting and analyzing field data.

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

2.3 PREVIOUS MULTIPLE PARALLEL RUNWAY STUDIES.

Early studies of multiple runways concentrated on reducing separation between aircraft during simultaneous parallel approaches. [1, 2, 4, 5, 6, 7, and 8] These studies have indicated that the reduction of separation between aircraft is dependent upon many factors including, e.g., pilot/aircraft navigational accuracy (flight technical error (FTE)), radar update rate, radar accuracy, and controller displays.

A simulation conducted in 1984 investigated runway spacing, modified radar displays, improved radar accuracy, and higher update rate radar. [11] The study did establish the importance of navigational accuracy in determining system capacity and 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. [12 and 13] The data from these surveys, which directly considered simultaneous parallel approaches under IMC, were used in the development of the FTE model for the present simulation.

Additional real-time ATC simulations have been conducted at the FAA Technical Center to investigate parallel runway proposals. [14, 15, 16, and 17] These studies are an important complement to the models cited above since they generate estimates of the model parameters and, more importantly, they allow direct observation and recording of criterion measures related to safety and capacity. These simulations are of direct interest to the ongoing effort since they addressed most of the issues unique to multiple runway operations.

2.4 MULTIPLE SIMULTANEOUS ILS APPROACH PROGRAM.

This program consists of six phases which are described in the following sections 2.4.1 through 2.4.6. The schedule for the program is shown as figure 1.

2.4.1 Phase I.

The Dallas/Fort Worth (DFW) Phase I simulation was conducted at the FAA Technical Center from May 16 to June 10, 1988. This was a

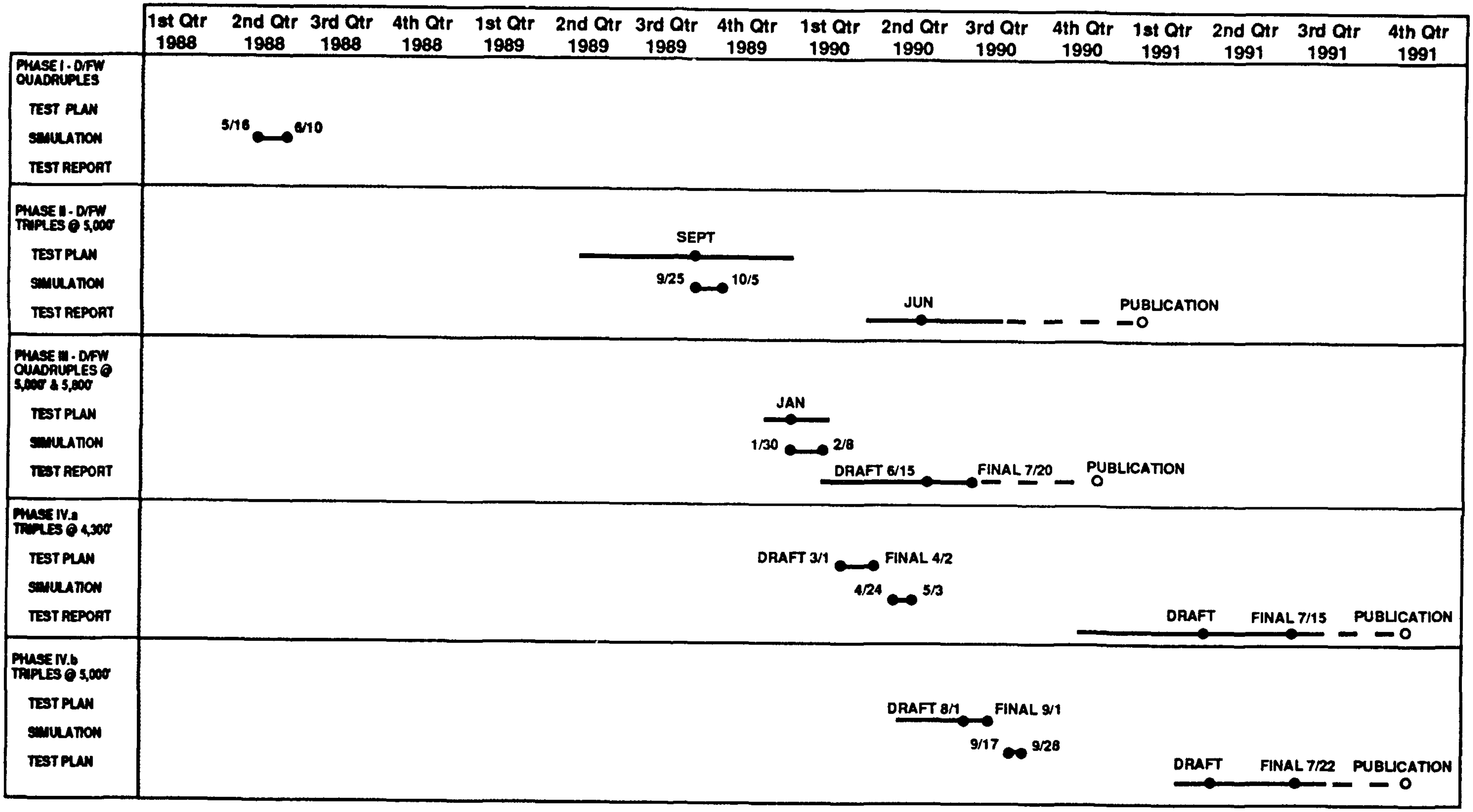


FIGURE 1. MULTIPLE SIMULTANEOUS ILS APPROACH SIMULATION SCHEDULE (SHEET 1 OF 2)

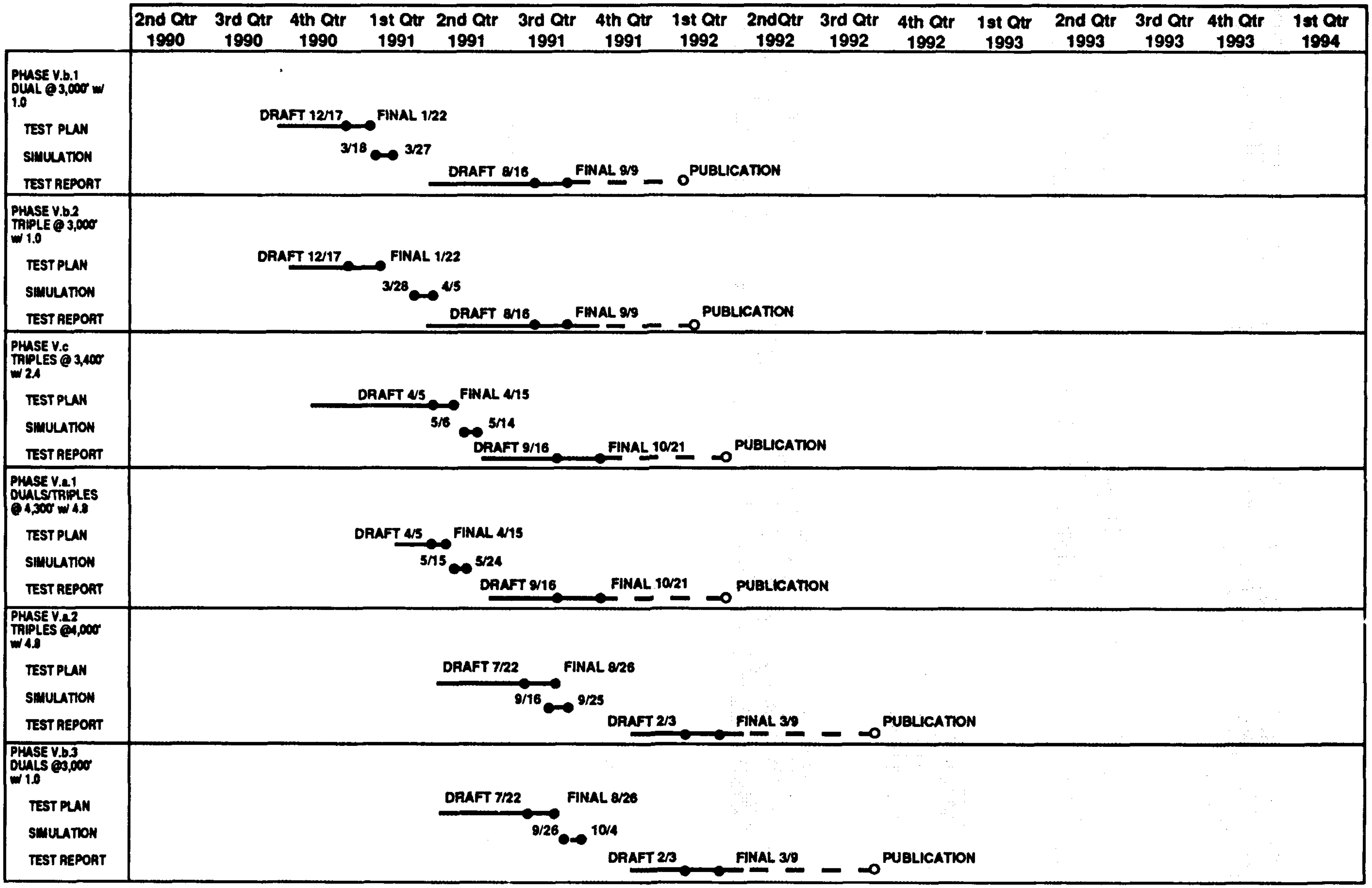


FIGURE 1. MULTIPLE SIMULTANEOUS ILS APPROACH SIMULATION SCHEDULE (SHEET 2 OF 2)

two-part study designed to test selected aspects of the quadruple approach operation. The first part of the simulation evaluated concepts for using additional routes, navigational aids, runways, En Route and Terminal Radar Approach Control (TRACON) Facility 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. [15] Based upon this simulation, triple parallel ILS approaches were approved for DFW with only turboprop aircraft landing on 16L.

2.4.2 Phase II.

This simulation was conducted from September 25 to October 5, 1989, at the FAA Technical Center. 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, in the triple approach operation, controllers were able to intervene in the event of a blunder and provide distances between conflicting aircraft that were comparable to the distances achieved in the dual approach operation. No blunder in either the dual or triple approach operation 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, achievable, and safe. [16] 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. Runway 16L was 8500 ft long and 16R was 9900 ft long. The traffic samples included props, turboprops, and turbojets on the outer runways and turbojets only on the inside runways. Findings of the simulation indicated that air traffic controllers were able to maintain miss distances between aircraft in excess of the 500 ft test criterion. There were no operational differences between the dual and quadruple approach operations. Controllers, controller observers, and ATC management concluded that the quadruple approach operation is a "safe, acceptable, and achievable procedure." [17]

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, ASR-9, and a current display system, ARTS IIIA. Phase IV was conducted in two simulations:

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

b. Phase IV.b assessed triple simultaneous ILS approaches with 5000 ft between runway centerlines with even thresholds. This simulation included the integration of two Phase II B-727 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 currently being analyzed.

2.4.5 Phase V.

Phase V simulations will incorporate the SONY 20 x 20 inch color displays with enhanced graphics capabilities and audio conflicts alert algorithms. Phase V will be conducted 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 a radar with an update rate of 1.0 s. This subphase was conducted March 18 to 27, 1991 and the results are currently being analyzed.

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 results of this simulation are also currently being analyzed.

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

d. Subphase V.a.1. Assessed triple and dual simultaneous parallel ILS approach operations to runways spaced 4300 ft apart. It was conducted from May 15 to 24, 1991, using radar with an update rate of 4.8 s. The results of this simulation are currently being analyzed.

e. Subphase V.a.2. Assess triple simultaneous parallel ILS approach operations to runways spaced 4000 ft apart using radar with an update rate of 4.8 s. This subphase is scheduled to be conducted September 16 to 25, 1991.

f. Subphase V.b.3. Assess the effects of 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 is scheduled to be conducted September 26 to October 4, 1991.

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.a EVALUATION OF TRIPLE SIMULTANEOUS PARALLEL ILS APPROACHES SPACED 4300 FT APART.

This section describes the simulation performed April 24 through May 3, 1990. An overview of the simulation, a description of the controllers, the simulation facility, data collection, simulation procedures, and the approaches used in the analysis are presented in sections 3.1 through 3.6.

3.1 SIMULATION OVERVIEW.

The Phase IV.a simulation evaluated triple simultaneous parallel ILS approaches with runways spaced 4300 ft apart. 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 or departure monitor positions to monitor traffic movement in accordance with established procedures. [3] Approach aircraft were scripted to execute blunders toward aircraft on adjacent approaches. The controllers issued instructions, via voice communications, to the pilots to maintain adequate distances between aircraft at all times. The simulation addressed three questions:

a. Can the controllers prevent conflicts from resulting in a miss distance of less than the test criterion (500 ft)? Simply stated, can the controllers issue corrective actions so that a blunder does not result in a test criterion violation (TCV)?

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

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

3.1.1 Controller Activities.

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

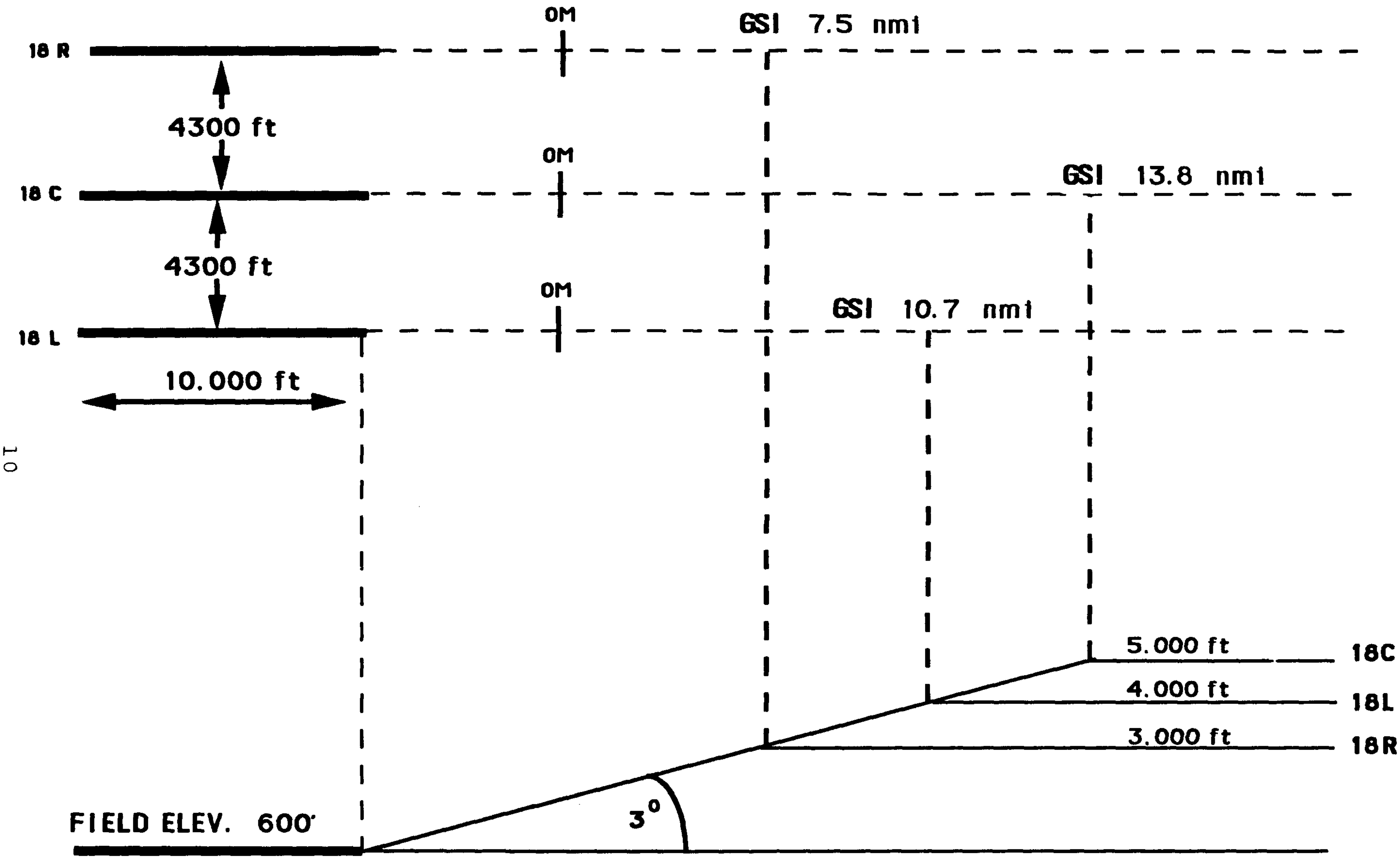
3.1.2 Blunders.

Blunders occurred when an aircraft established on the localizer deviated from its intended course. The deviations usually resulted in aircraft coming into conflict with each other. Depending on the degree of blunder, controllers either instructed the blundering aircraft to rejoin the localizer, or they instructed the blundering aircraft and aircraft on adjacent runways to make changes in heading and/or altitude. Thus, aircraft were vectored away from the blundering aircraft to ensure adequate miss distances between the aircraft. 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 3 degree glide slopes. 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 4300 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 a normal descent on the glide slope and decelerated at a rate appropriate to its aircraft type.



OM = outermarker at 5 nmi
GSI = glide slope intercept

FIGURE 2. AIRPORT CONFIGURATION

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

3.1.4 Traffic Samples.

Traffic samples 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) and consisted of representative aircraft types and identifiers.

Two different types of traffic samples were developed to ensure that a large proportion of the aircraft would be flying side-by-side. The first sample type was developed through a random assignment of aircraft start times, restricted by aircraft spacing requirements. The time at which aircraft would cross the outer marker was calculated based upon speed and start times. The start times were then adjusted to ensure aircraft on parallel approaches would cross the outer marker at approximately the same time. This was done to produce frequent worst case alignments. Additionally, the simulation runs included two to three speed overtakes.

The second traffic sample type had three aircraft entering the simulation in unison at the same speed. These aircraft flew the ILS in a side-by-side formation. This traffic sample was used because it provided the highest number of opportunities to initiate worst case blunders. Additionally, it caused the controllers to spread their attention over the entire display area.

3.1.5 Navigational Error Model.

A review of the Chicago O'Hare radar data (ORD), by the FAA ATC Technology Branch, ACD-340, showed that aircraft tracks generally appear to have two distinct patterns. After intercepting the ILS course many aircraft oscillate to either side of the course in a rhythmic pattern. The oscillations decrease in size as the aircraft nears the threshold. In the second pattern, aircraft gradually home in on the localizer (i.e., follow paths that are asymptotic to the localizer), rather than oscillating around the localizer.

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 the inside pseudoroutes, and 10 percent flew the outside pseudoroutes.

The navigational error model generated additional 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 randomly determined whether to give it a deviation off the localizer. This decision was made with a fixed probability at each "look." If there was to be a deviation, the deviation angle and 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 center pseudoroute were subject to "wandering."

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

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

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

3.2 CONTROLLERS.

There were nine air traffic control specialists and/or supervisors from separate control towers or TRACONs (Atlanta, Dallas/Fort Worth, Denver, Miami, Minneapolis, Orlando, Pittsburgh, Sacramento, and St. Louis). The controllers each had several years experience monitoring simultaneous ILS approaches. All controllers were volunteers and were selected in agreement with National Air Traffic Controllers Association (NATCA) offices.

The controller assignments to runway positions and duty shifts 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.

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[1] A "wanderer" is an aircraft whose navigation performance is so poor that it may deviate into the NTZ unless a controller takes corrective action. If no action is taken, the aircraft will return on its own to the localizer. Controller intervention is permitted to correct flight technical error or "wandering."

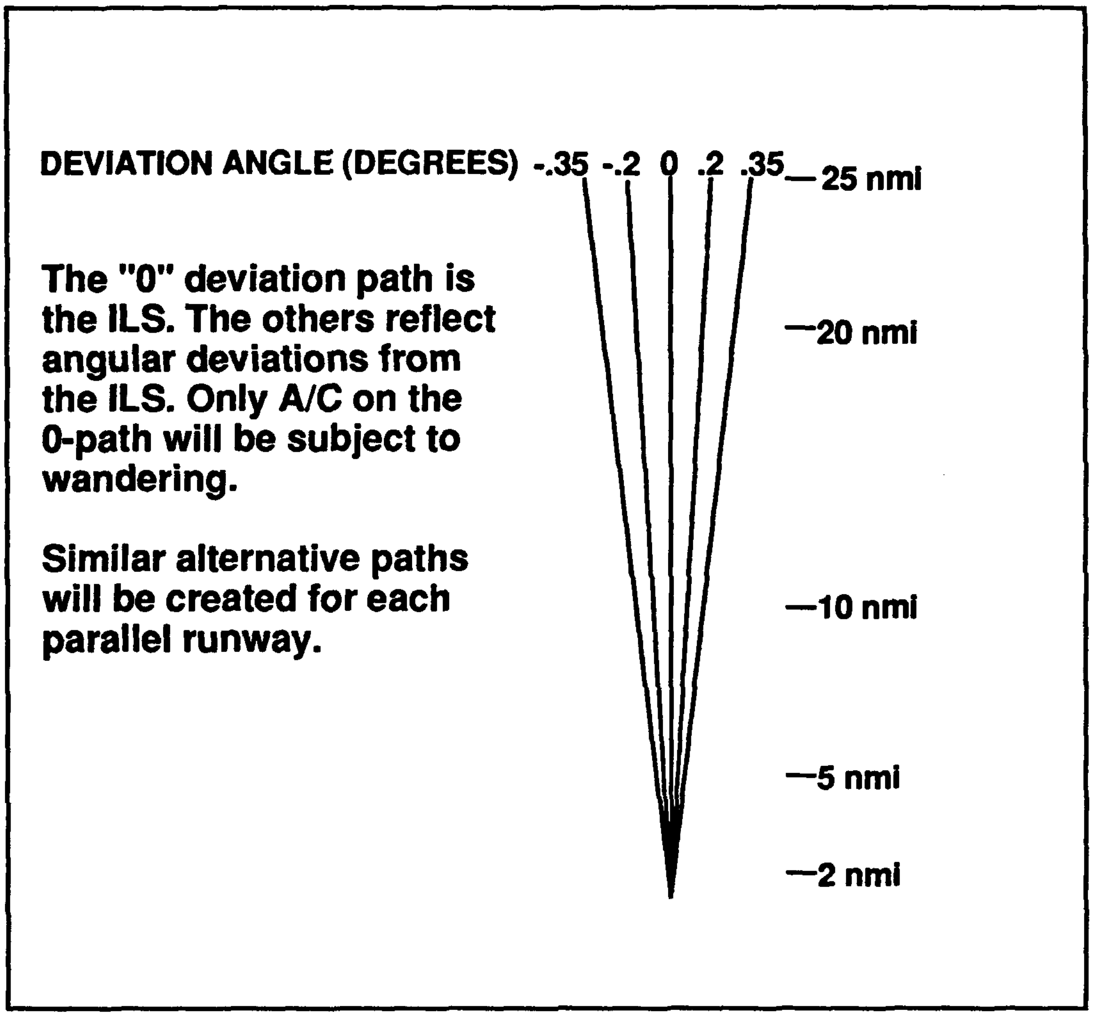

FIGURE 3. GRAPHICAL DEPICTION OF PSEUDOROUTES

b. Controller assignments were balanced among the departure control and triple approach runs.

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

3.3 SIMULATION FACILITY.

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 simulator pilot facility, the computer facility, and software used in the simulation.

3.3.1 ARTS IIIA Laboratory.

The ARTS IIIA Laboratory is located at the FAA Technical Center, Atlantic City, New Jersey. A schematic diagram of the simulation components 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 ID tags, and associated key board entry and communication equipment. The DEDS provide a background detail of the airport through phosphor persistence of the radar sweep. The laboratory is realistically configured permitting controllers to function with little or no acclimation. A communication system provides controller-to-pilot, and pilot-to-controller communication. The proximity of the controller stations to each other accommodated intercontroller communication.

3.3.2 Simulation Pilots.

The FAA Technical Center's National Airspace System Simulation Support Facility (NSSF) Pilot Complex houses the individuals 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 keystrokes onto a specialized keyboard. These actions resulted in the simulated aircraft changing heading, altitude, or speed. Each NSSF simulator pilot had the capability to control as many as 10 aircraft, but normally controlled only three or less in this simulation. Aircraft responses were programmed to be consistent with the type of aircraft being simulated.

To provide additional realism, the NASA-Ames (NA) B-727, Phase II Flight Simulator and the FAA Technical Center GAT Simulator were integrated into the Phase IV.a simulation. These simulators were flown by airline and FAA pilots resident to their respective facilities. The flight simulators assumed the configuration of aircraft flying approach on the localizer. The NA and GAT simulator pilots were in voice communication with the controllers. Additionally, the NA and GAT Simulator Coordinators were in voice communication with the ATC Simulation Coordinator, who assisted

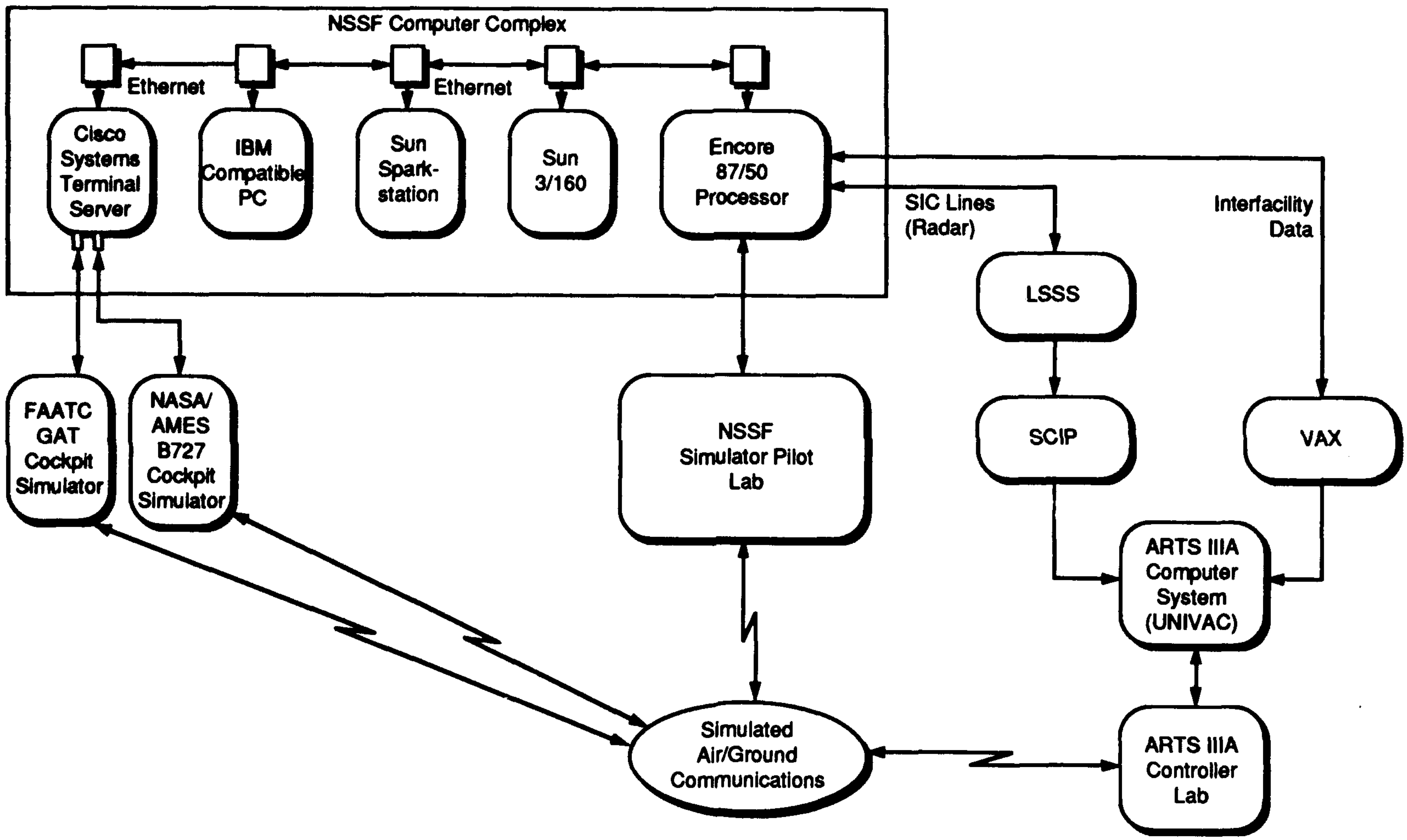

FIGURE 4. SCHEMATIC DIAGRAM OF SIMULATION HARDWARE

them prior to and following each flight. The NA and GAT simulators performed five to six flights per simulation run.

3.3.3 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 current status (i.e., turning, climbing, and accelerating). An aircraft's status was constantly monitored to reflect changes caused by predetermined flight plans, maneuvers, and/or simulator pilot inputs. In providing the functions of an ATC ground facility, the central computer simulated the radar-beacon and target detection system, and it maintained and updated information on the controller displays.

3.3.4 Software.

The NSSF Target Generation Programs (TGP) 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 included computer generated data bases, audio and visual 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 the motion characteristics of each aircraft at the start and end of the violation; the duration of the violation; the horizontal and vertical separation of the closest point of approach (CPA); and a categorization of the instructions (e.g., speed commands and vectors) issued to each aircraft.

3.4.2 Voice Communications.

Controller and NSSF, GAT, and NA simulator pilot voice communications were recorded using a 20-channel audio recorder at the FAA Technical Center. Controller and 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 an S-VHS format video recorder. Two microphones were used to record controllers' voices during each run. This would permit the analysis of interaction between controllers where it was deemed necessary.

3.4.4 Controller and Pilot Questionnaires.

Following each run, a questionnaire and a workload rating scale was administered to the controllers. The 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. Following each run, a questionnaire was administered to the NA pilots. The questionnaire assessed pilot opinions concerning pilot performance, activity level, stress level, and passenger comfort. An attempt was made to elicit pilot comments concerning the simulation.

3.5 SIMULATION PROCEDURES.

There were 14 runs conducted to examine the proposed three-runway operation, and 5 runs served to assess the effects of missed approaches on departure control operations. 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 using triple simultaneous parallel ILS approaches were conducted to familiarize the controllers with the strategies involved in the control of aircraft for the runway configurations. The practice runs were abbreviated in length, and the data from these runs were not subjected to formal analysis.

3.5.1 Blunder Scripts.

The test director and his assistant used scripts to create blunders. This was done by issuing turns to aircraft established on the localizer. 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 center approach (18C), 50 percent of the blunders 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.

Fifty percent of the blundering aircraft simulated 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. Table 2 shows the combinations of blunder degree and radio communication used for blunders in this simulation.

TABLE 2. BLUNDER DEGREE/COMMUNICATION MATRIX

Communication Condition	Blunder Degree 10	20	3
NORDO	5	21	179
RDO	8	6	25

The scripting of blunders established an average interval of 3 minutes between blunders, with maximum and minimum blunder intervals of 5 minutes and 1 minute, respectively. The blunders were random and uniformly distributed. This scripting scheme yielded an average of 17 blunders per hour.

The blunders were scripted so that aircraft either randomly maintained altitude or descended following a blunder. Blunders commenced after the glide slope had been intercepted for all approaches, approximately 10 nmi or less from the threshold. 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.

The five departure control runs were conducted with an automatic simulation of arriving traffic on all runways. Twenty percent of the arrival aircraft executed missed approaches. The missed approaches were scripted to drift 15 degrees to the right or to the left of the centerline, which simulated adverse wind effects. Assignments to drift to the right or to the left were made on a random basis. This resulted in missed approach aircraft drifting toward each other or drifting toward other aircraft.

3.6 ASSESSMENT METHODOLOGY.

The ability of controllers to resolve blunders was evaluated by analyzing factors that may have affected controller performance. An analysis was conducted to determine the influence of the number of approaches threatened by a blunder on conflict severity. A risk assessment was performed to determine the impact of the proposed operation on the level of safety currently found in approach operations.

Blunders that resulted in a TCV were assessed individually to determine factors that contributed to conflict severity. A comprehensive review of the TCVs, 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 operations, the knowledge and skills of the average controller, and the full range of traffic contingencies which must be taken into account.

4. PHASE IV.a SIMULATION RESULTS.

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

4.1 OVERVIEW OF ANALYSES.

Generally, a blunder in the triple parallel approach operation will result in two or more conflicts. For the purposes of this analysis, a conflict occurs when two aircraft are within 3 nmi laterally and 1000 ft vertically. Usually only conflicts involving the blundering aircraft and 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 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 the Analysis of Variance (ANOVA).

One-way ANOVAs were conducted on the data in this simulation. The ANOVA is a test which can detect differences between two sample distributions. The findings of the ANOVA are reported in the F statistic. 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 "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 CPA data were reviewed for this simulation. The descriptive statistics are given in section 4.2.1. Section 4.2.2 examines the blunders that resulted in a TCV, and section 4.2.3 compares blunders threatening one approach with those threatening two approaches. The controllers' performance while monitoring the missed approaches is summarized in section 4.2.4.

4.2.1 Descriptive Statistics.

There were 244 triple approach blunders in Phase IV.a that resulted in a conflict. The CPA was calculated from the center of one aircraft to the center of the other aircraft. The average CPA was 2320 ft (s.d. = 1949 ft) and the smallest CPA was 119 ft. The distribution of CPA values is shown in figure 5.

Review of the data indicated that 71 of the 244 conflicts resulted in a CPA of less than 1000 ft. Further analysis indicated that all but one of these conflicts were due to 30 degree blunders. There was one 10 degree blunder that resulted in a CPA of 564 ft. Additionally, 63 of the 71 conflicts with a CPA of less than 1000 feet were due to no communication (NORDO) blunders.

4.2.2 Review of Conflicts Resulting in a TCV.

A comprehensive review of the blunders which resulted in a TCV (a CPA of less than 500 ft) was performed. (appendix F) 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 detect the presence of common factors which contributed to conflict severity.

There were 26 conflicts (out of 244) that resulted in a TCV. Based upon the review, three blunders were excluded from the statistical analyses described above. They were excluded because they violated the test design. In one blunder, the threatened aircraft did not respond to the controller's instructions (Double NORDO). NSSF pilot input errors directly affected the severity of the other two blunders.

A number of blunders appeared to have a single factor which contributed largely to the severity of the outcome. These factors included slow responses by the controller, pilot, or both controller and pilot, controller error, pilot error, and a less than standard turn rate (< 3 degree per second). The blunders are categorized by contributing factors in table 3. Many of the blunders did not have an exclusive factor that contributed to conflict severity. These are classified by "System."

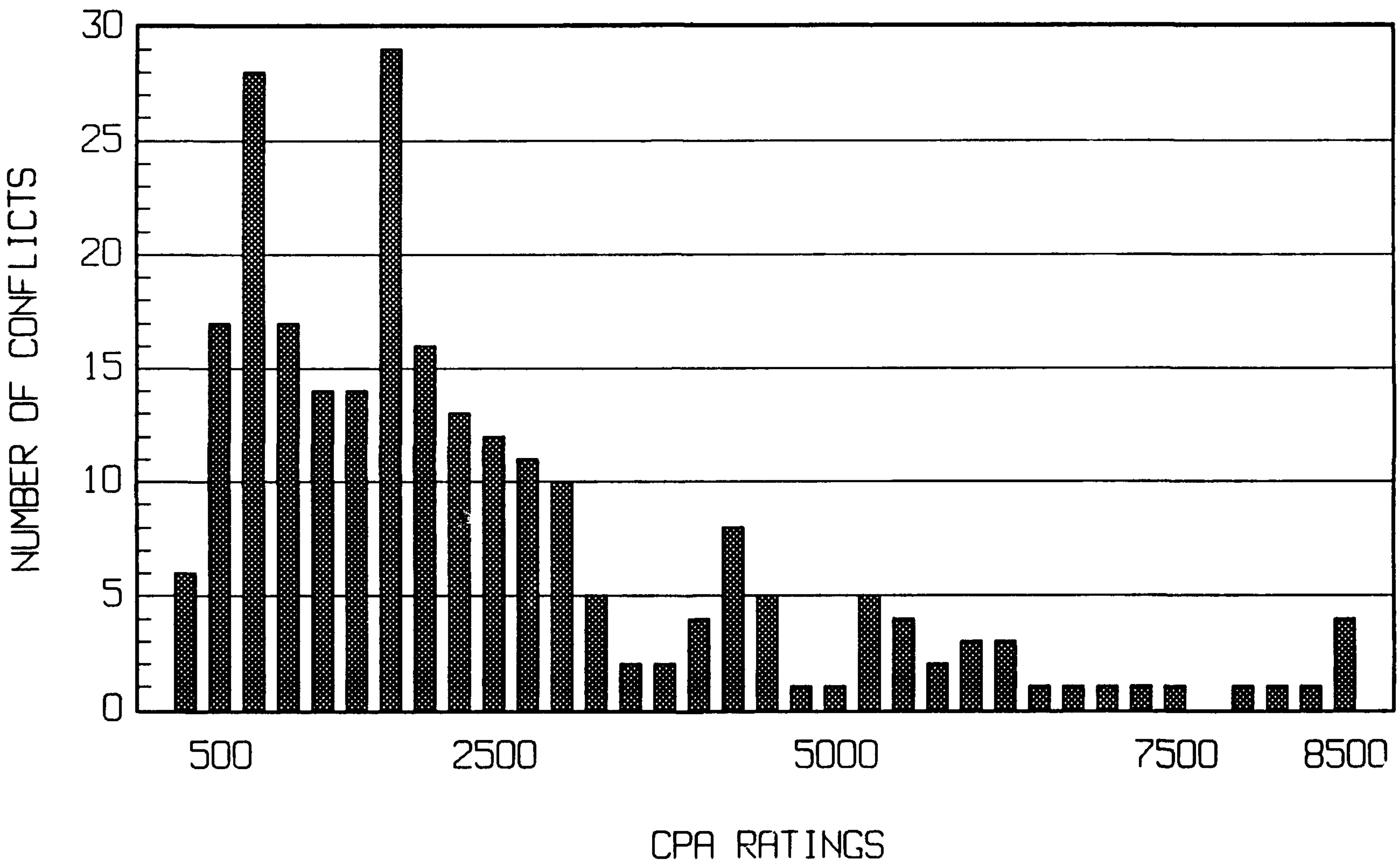

FIGURE 5. DISTRIBUTION OF CPA VALUES

A graphic plot of the aircraft tracks for the blunder with the smallest CPA (CPA = 119 ft) is shown in figure 6. The dots indicate 5-second increments. The blunder began at simulation time 1438 when NWA 684 turned left 30 degrees from runway 18R. NWA 684 was identified as being off course by the controller 14 seconds later (1452). The pilot of NWA 684 did not respond to the controllers request to return to the localizer. At simulation time 1452, the 18C controller issued the following message: "Air Wisconsin, er, Midway 613, Midway 613, uh, descend immediately and maintain 2000." The message was completed at simulation time 1461. The two aircraft crossed paths 8 seconds later (simulation time 1469) with a CPA of 119 ft. At simulation time 1470, the controller vectored Midway 613 right to heading 270.

TABLE 3. PHASE IV.a CONTRIBUTING FACTORS

Major Contributing Factor	Times of Occurrence
System	9
Slow Controller Response Time	7
Slow Pilot Response Time	1
Controller Error	3
Pilot Error	2*
Slow Controller & Pilot Response Times	2
Double NORDO	1*
GAT 2 degree/sec turn	1
* Not used in analyses	

4.2.3 Comparison of Blunders Threatening One and Two Approaches.

An ANOVA was performed to determine the effect of the number of approaches threatened on the controllers' ability to resolve blunders. This analysis compared the conflict resolution of blunders initiated from the outside approaches (18R and 18L), which caused two approaches to be threatened, and conflict resolution of blunders initiated from the center approach (18C), which caused only one approach to be threatened. The analysis indicated that there were significant differences in average CPA values, ($F(1,242) = 5.144$. $p < 0.023$), between blunders that threatened one approach and two approaches ($mean_1$ = 2674 ft, $mean_2$ = 2098 ft).

4.2.4 Missed Approach Procedure Assessment.

There were five runs conducted to assess the controllers' ability to monitor missed approach aircraft. For these runs, the departure monitor position was manned. There were 117 missed approaches

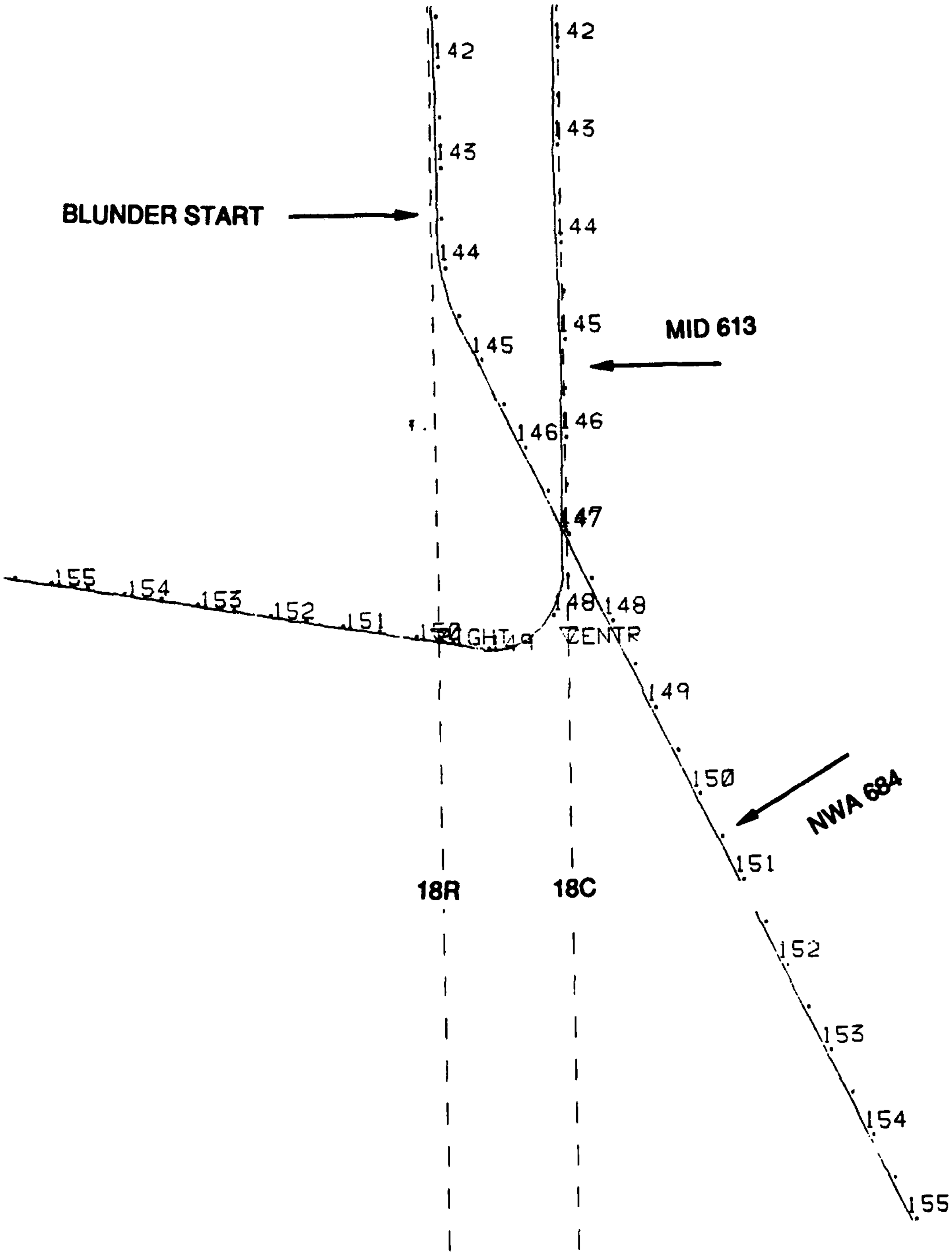

FIGURE 6. GRAPHIC PLOT OF BLUNDER WITH SMALLEST CPA (119 FT)

executed. The average miss distance between the missed approach aircraft and aircraft on the adjacent approach or departing aircraft was 8319 ft (s.d. = 315 ft). The smallest CPA was 2673 ft.

4.3 QUESTIONNAIRE ANALYSES.

This section details the findings of the controller and 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 in appendix B.

4.3.1.1 Ease of Traffic Handling.

The first question asked 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 (s.d. = 2.2), indicating an "average" amount of effort was necessary to handle the traffic.

An ANOVA was performed to investigate whether runway position (18R, 18C, 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 their 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 5.5 (s.d. = 2.1). As in the previous question an assessment indicated 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 5.3 (s.d. = 2.1). This rating indicated that controllers experienced a moderate amount of stress throughout the study. The results indicated that stress levels did not vary with runway assignment.

4.3.1.4 System Workability.

The fourth question addressed the issue of system workability using a scale ranging from 1 (strong yes) to 10 (strong no). Controllers perceived the system as "probably workable" at their present facility. The average rating was 4.3 (s.d.= 2.7). Similar to the earlier questions, an analysis indicated no significant differences in system workability related to runway assignment.

4.3.1.5 Mental Workload.

The last question asked controllers to provide an overall rating of the workload they experienced. The basis for rating workload was mental effort and ease of traffic handling. Controllers reported that a moderate to high level of mental effort (mean = 4.6, s.d. = 2.3) was required to maintain "satisfactory traffic handling." Again, analysis indicated that controller runway assignment did not affect mental workload ratings.

4.3.2 Pilot Questionnaire Data.

The pilot questionnaire included pilot performance, activity level, stress level, and passenger comfort ratings. This questionnaire is included as appendix C.

4.3.2.1 Pilot Performance.

The first question asked pilots to rate their performance following each run. The rating scale ranged from 1 (poor) to 10 (superior). Pilots rated their performance as average (mean = 6.2, n = 22) throughout the simulation.

4.3.2.2 Activity Level.

Pilots were asked to rate the level of activity required for each run. The scale for this question ranged from 1 (minimal) to 10 (intense). The average rating across runs was 6.4, indicating a moderate level of activity level was required throughout the simulation.

4.3.2.3 Stress Level.

The pilots' perceived level of stress was rated on a scale ranging from 1 (slight) to 10 (extreme). The average rating was 4.6, indicating a moderate level of perceived stress.

4.3.2.4 Passenger Comfort.

The fourth question addressed the issue of passenger comfort. Pilots were asked to determine what they perceived the level of passenger comfort was during a run. The scale ranged from 1 (unacceptable) to 10 (acceptable). Across runs the average rating was 5.8, indicating a "passable" level of passenger comfort.

4.4 RESPONSE TIME ANALYSIS.

An analysis was performed to examine the effect of blunder degree on the ability of controllers 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 ($F(2,393) = 18.11$, $p. < 0.00001$) had a significant effect on the controllers' ability to detect blunders. As would be expected, controllers detected 30 degree blunders ($mean_{30} = 14.8$ s) quicker than 20 degree ($mean_{20} = 18.2$ s) and 10 degree ($mean_{10} = 25.6$ s) blunders.

Response times were measured to assess the effect of message complexity on NSSF simulator pilots' performance. Message complexity was measured by the number of keystrokes required to enter a command. An ANOVA indicated that there were significant differences in NSSF simulator pilot performance as a function of message complexity ($F(5,310) = 11.84$, $p. < 0.00001$). The average response times are shown in table 4. The message that had 9 keystrokes, on average, took the shortest length of time to enter. This would have been a change in heading. It was also the most frequent command. The message that had 12 keystrokes, on average, took the longest length of time to enter. This would have been a change in heading accompanied by a change in altitude. It was the second most frequent command.

TABLE 4. NSSF SIMULATOR PILOT RESPONSE TIMES

Keystrokes	Typical Message	Mean	S.D.	#
7	UAL 321 CLIMB 5000	8.7	3.7	21
8	UAL 321 CLIMB 5000 IMMEDIATELY	7.1	3.3	44
9	UAL 321 TURN LEFT HEADING 090	6.2	2.6	115
11	UAL 321 TURN LEFT HEADING 090 CLIMB IMMEDIATELY	8.4	5.6	27
12	UAL 321 TURN LEFT HEADING 090 CLIMB TO 5000	11.5	5.5	86
13	UAL 321 TURN LEFT HEADING 090 CLIMB AND MAINTAIN 5000	9.5	3.9	23

4.5 NA, GAT, AND NSSF SIMULATOR PILOT ANALYSIS.

An analysis was conducted to examine differences in pilot/aircraft performance (airline pilot/B-727 flight simulator (NA), FAA pilot/GAT flight simulator, and NSSF simulator pilots/computer modeled aircraft) as indicated by CPA. An assessment was performed only when the threatened aircraft was adjacent to the blundering aircraft. The analysis indicated that no differences in the average CPA existed between the three different pilot/aircraft types.

5. DISCUSSION.

The simulation was designed to test the procedures for triple simultaneous parallel ILS approaches spaced 4300 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 simulation computer data indicated that controllers were able to achieve the test criterion, aircraft miss distance of 500 ft or greater in 90 percent of the blunders in this simulation. In almost all situations where the controller was able to communicate with the blundering aircraft, there were no TCVs.

A review of blunders that resulted in TCVs revealed several factors which appeared to contribute to the conflict severity. The controllers' inability to detect blunders immediately (slow controller response) appeared to be the factor which contributed the most to conflict severity. Controller error, pilot response time, and evading aircraft turn rate were also factors which contributed to conflict severity.

In the triple approach operation, 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 on average, blunders that threatened 2 approaches resulted in more severe conflicts than those that threatened only 1 approach.

Assessment of the missed approach procedures indicated that controllers were able to maintain spacing greater than the 500 ft test criterion. The average miss distance was 8319 ft and the smallest miss distance was 2673 ft.

In the controller questionnaires, 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 reported that a moderate to high level of mental effort was necessary to maintain "satisfactory traffic handling." The pilots rated their activity and stress levels during the simulation as moderate. The pilots rated their own performance as being average. The passenger comfort level was rated as passable.

The controllers were able to detect 30 degree blunders significantly quicker than they were able to detect 20 and 10 degree blunders. This was an expected outcome based upon human perceptual performance characteristics.

The average response times for NSSF simulator pilots were determined. The response times were analyzed according to the message complexity. The average response times by NSSF simulator pilots were from 6.2 s for moderate length messages and up to 11.5 s for complex messages.

A comparison was made between blunders which threatened aircraft simulated by the NA flight simulator, the FAA Technical Center GAT, and the NSSF simulator pilots using CPA values. The comparison indicated that there were no differences in conflict severity between blunders involving the NA, GAT, and NSSF simulator pilots. This finding would indicate that the response times of pilots and the aircraft models were comparable between the three systems.

One method of determining the impact of the proposed operation on the level of safety currently found in the air traffic environment would be to conduct a risk assessment. However, due to the lack of data on blunder occurrences and blunder rates, a risk assessment could not be conducted using the results of this simulation. Once better estimates of blunder occurrence rates have been obtained, a second volume of this document will be published. The second volume will completely describe the derivation of the risk assessment, approximations used in the assessment, and the sources of the values used in the assessment.

The Controller Report, appendix A, documented the findings of the controllers that participated in the simulation. The controllers indicated that they were effective in resolving 10, 20 and 30 degree blunders in the triple approach conditions, but were not totally effective in resolving 30 degree NORDO blunders. The controllers agreed that high update rate radar and high resolution displays with controller alerts would enhance their effectiveness sufficiently to enable resolution of 30 degree NORDO blunders when runways are spaced 4300 ft apart.

The pilots involved in the simulation at NASA-Ames commented on the simulation and on triple approach procedures after their participation (see appendix D). The pilots reported that nonstandard phraseology was used by the controllers when vectoring aircraft. The pilots were not receptive to receiving changes in heading without receiving instructions concerning altitude. The pilots indicated that controller commands to descend to an altitude below the glide slope were contrary to the standard procedures.

Overall, pilots were concerned about the differences between commands given by controllers during the simulation and commands given by controllers in the operational environment.

An operational assessment (appendix F) of the TCVs indicated that a major factor in the severity of these blunders was the inability of controllers to detect blunders early. The TWG concluded that high update rate radar, high resolution displays, and controller alerts would enhance the controllers' ability to resolve blunders. The TWG believed that all of the blunders could have been safely resolved through the use of new technology radar and displays.

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, using a real-time interactive air traffic control (ATC) simulation, the ability of experienced controllers to handle approach traffic during Instrument Meteorological Conditions (IMC) to a proposed triple parallel runway airport configuration. The proposed configuration consisted of triple parallel runways 10,000 feet (ft) long, spaced 4300 ft apart with even thresholds (i.e., 18R, 18C, and 18L). The simulated traffic consisted of turbojets, turboprops, and props on all runways.

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. Some of the blundering aircraft also simulated a total loss of radio communication (NORDO) with the controllers. 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. Additionally, a few runs were conducted which evaluated the missed approach procedures with the controllers monitoring both departing and missed approach aircraft. Missed approaches were initiated to evaluate the controllers' ability to maintain distance between missed approach aircraft and departing aircraft on the adjacent departure path. Three questions were to be answered:

1. Can the controllers prevent conflicts from resulting in a miss distance of less than the test criterion (500 ft)? Simply stated, can the controllers issue corrective actions so that a blunder does not result in a test criterion violation (TCV)?

2. In the event of a missed approach, could the controllers maintain the test criterion miss distance of 500 ft between departing aircraft and the missed approach aircraft on an adjacent parallel runway in the proposed airport configuration?

3. Do the controllers, controller observers, and ATC management observers agree that the operation of the proposed triple simultaneous parallel ILS approaches is acceptable, achievable, and safe using the proposed runway configuration?

This simulation investigated triple parallel ILS approaches spaced 4300 ft apart. The controllers were able to resolve more than 90 percent of the blunders initiated in the simulation. Of the 244 blunders resulting in conflicts, only 23 blunders resulted in aircraft violating the criterion miss distance of 500 ft.

The controllers stated that they were able to maintain the 500-ft miss distance with the exception of a few 30-degree blunders. (appendix A) The controllers indicated that a departure monitor position would be unnecessary because all the functions of the departure monitor controller could be provided by local and departure control positions. Finally, the controllers reported that higher update rate radar sensors and improved displays would enhance their performance.

The Multiple Parallel Technical Work Group (TWG), composed of individuals from the Office of System Capacity and Requirements, Flight Standards, Aviation Standards, Air Traffic, including Regional Organizations and operations personnel, participated in the conduct of the simulation and evaluated the simulation findings. The TWG believes that the poor resolution of the current radar displays significantly detracted from the ability of controllers to effectively resolve blunders with this configuration. In about 30 percent of the blunders controllers were not able to determine the distance between two merging targets. In many of these cases there was more than 500 ft. *The TWG determined, based on observations during the simulations and the full range of contingencies that must be accounted for in such an operation, that triple simultaneous parallel approach operations spaced at 4300 feet would not be acceptable if controllers were required to use ASR-9 radar and the ARTS IIIA displays*.

In an effort to resolve the problem described above, the TWG recommends that high resolution color displays and alert algorithms be utilized. The TWG believes that the addition of the high resolution color displays and alert algorithms will enable controllers to detect blundering aircraft sooner, and thereby reduce conflict severity. The controllers also stated in their recommendations that "We believe a faster update rate and improved technology radar scopes would enhance the effectiveness of final approach monitoring."

The TWG recommends that a follow-on simulation study be conducted to investigate triple simultaneous parallel ILS approaches, spaced 4300 ft apart, using the new displays and their associated controller alerts. Based upon their review of the new display/alert systems, the members of the TWG are optimistic that triple simultaneous parallel ILS approaches can be conducted satisfactorily at the 4300 ft runway spacing if the upgraded display configurations were to be implemented.

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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 nmi.

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 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 - A blunder is an unexpected turn by an aircraft already established on the localizer into another aircraft.

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

Glide Slope Intercept (GSI) - The minimum altitude to intercept the glide slope/path on a precision approach. The intersection of the published intercept altitude with the glide slope/path, 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 mandates a pilot fly his aircraft solely via cockpit instrumentation.

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 airways over the geographical United States.

National Airspace System Simulation Support Facility (NSSF) - The facility located at the FAA Technical Center, which houses individuals, who "pilot" 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 extended 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 nmi from the runway threshold on the extended centerline of the runway.

Parallel ILS Approaches - Approaches to parallel runways by IFR aircraft. These can be conducted in and dependent or in dependent manner. Dependent approaches are established inbound toward the airport on the adjacent final approach courses, and are radar-separated by at least 2 nmi. Independent parallel approaches are conducted without regard to aircraft approaches on adjacent approaches.

RDO - An aircraft with radio communication.

Standard Deviation (SD) - Provides a measurement of variability of a data set. The standard deviation is defined as the positive square root of a sample variance, s^2.

Simultaneous ILS Approaches - An approach system permitting simultaneous ILS approaches to airports having parallel runways separated by at least 4300 feet 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 and without referring to radio navigational aids.

Wanderer - 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.

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

APPENDIX A

CONTROLLER REPORT

INTRODUCTION

On April 24, 1990 a team of 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 given a detailed briefing by Ralph Dority of ATM-520on their purpose and how they were expected to evaluate the 4,300runway centerline separation standard for independent simultaneousInstrument Landing System (ILS) approaches for three runways.

OBJECTIVES

There were three objectives for the controller team.

1. Can the controllers provide miss distances, in response to blunders equivalent to those that occur in dual parallel ILS approaches.

2. Can the controllers in response to those blunders maintain a miss distance of 500 feet between those aircraft.

3. Do the controllers believe that the operation of triple simultaneous ILS approaches are acceptable, achievable, and safe.

Analysis

The controller team using present day Airport Surveillance Radar (ASR) and the Automated Radar Terminal System (ARTS), with a four point eight second update rate, had to implement control actions that would provide miss distances between blundering and nonblundering aircraft making triple independent simultaneous ILS approaches with 4,300 feet between runway centerlines. The basic criteria was that any control action had to result in at least a five hundred foot miss distance between aircraft involved in a blundering event. Aircraft were blundered off a final approach course by either ten, twenty, or thirty degrees. It was our perception that most of the thirty degree blundering aircraft were NORDO.

We were unable to effect control actions that provided the minimum miss distance for 100% of the thirty degree blunders for independent triple simultaneous ILS approaches, 4,300 feet runway centerline separation, evenly aligned runway thresholds, and using ASR-9 4.8 second update rate and current radar indicators.

The controller had to rely on intuitive skill several times to resolve some thirty degree blunders for various reasons. When a thirty blunder turned we were unable to observe the turn until the aircraft's heading was a full thirty degrees off the final approach course. At this point we gave whatever control instruction was necessary to miss the blundering aircraft. To make a tense situation more stressful, at times some of the targets merged and we were unable to determine if our control instructions provided the required resolution from the blunder. The indicators and the map did not provide enough clarity from different elements on the indicator. The primary returns could be close enough to each other, that we were unable to determine if there was any space between them. Several times during the simulation the ASR sweep visibly slowed on the indicators. The sweep slowdown caused the targets to go into COAST status from three to four sweeps. When the data blocks reacquired altitude information was not available for another four sweeps. The sweep slowdown and lack of altitude information gave no assurance that our control actions provided a resolution from the blundering aircraft.

Pseudo pilot response and reactions were noticeably slower in comparison to the National Aeronautics and Space Administration (NASA) Ames B727 simulator and the General Aviation Trainer (GAT). The NASA simulator and GAT characteristics were more indicative of real aircraft of real aircraft than the Technical Center's aircraft generator.

The departure Monitor duties could be handled by the departure controller. In these scenarios the events such as missed approaches, NORDO arrivals or go-arounds are the responsibilities and a normal function of the tower local and departure control positions.

CONCLUSION

1. We believe we were as effective in resolving blunders in triple simultaneous ILS approaches as in dual simultaneous ILS approaches.

2. With the exception of some of the thirty degree blundering aircraft, we were able to maintain a miss distance more than five hundred feet between aircraft.

3. The departure monitor position proved to be unnecessary because all of its functions could be provided by the local and departure control positions.

RECOMMENDATIONS

1. A PC computer should be available to the controllers for continuous input to the report during the experiment.

2. Create a standard TRACON/terminal laboratory for future real-time air traffic control simulations.

3. The present simulation pilot and aircraft configurations make the pseudo-pilots reaction times slower than normal in comparison to professional airline pilots. We believe the Technical Center should consider a change to the present equipment configuration and pseudo-pilot training to more closely resemble real life performance characteristics of pilots and aircraft.

4. We believe a faster update rate and improved technology radar scopes would enhance the effectiveness of final approach monitoring.

APPENDIX B

CONTROLLER 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 OR SIMULATION WOULD BE WELCOME HERE.

---

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

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

---

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

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

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

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

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

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

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

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

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

10. THE THREAT OF BLUNDERING AIRCRAFT CANNOT BE CONTROLLED.

APPENDIX C

PILOT QUESTIONNAIRE

Date ________ Time _______

Simulation of Triple Simultaneous Approaches

Pilot Questionnaire

Pilot Number ____ Total B727 Flight Time __________ hrs.

Total Flight Time ________ Total Instrument __________ (est).

Airline you fly for ________________. Captain ____ F/O _____.

---

1. RATE YOUR PERFORMANCE DURING THE PAST SESSION. CIRCLE THE NUMBER WHICH BEST DESCRIBES YOUR PERFORMNCE.

1 2 3 4 5 6 7 8 9 10

POOR AVERAGE SUPERIOR

---

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. RATE THE LEVEL OF PASSENGER COMFORT DURING THE PAST SESSION.

1 2 3 4 5 6 7 8 9 10

UNACCEPTABLE PASSABLE ACCEPTABLE

Date ________ Time ________

5. When you were directed to climb and turn, what did you use as a basis for your decision?

   a. Altitude? Yes ___ No ___ If yes, what altitude? ___.

   b. Aircraft configuration (flap schedule)? Yes ___ No ___.

   c. Please Elaborate. ________________________________

____

____

6. Does your company direct an altitude (minimum) that all turns must be made above? Yes ___ No ___. What is it? _______

____

____

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

If No, please explain. ________________________________

____

____

8. Please describe any unusual occurences during the past hour. Please include aircraft ID's and approximate time if possible. Any additional comments would be appreciated. ____________

____

____

____

____

____

____

____

____

Please complete this questionnaire immediately after completing the simulation run. Any additional questions or comments should be addressed to:

CTA Incorporated
English Creek Center, Suite 204
McKee City, NJ 08232

Attn: Terence Fischer
(609) 646-4510

APPENDIX D

NASA-AMES SIMULATOR PILOT COMMENTS

Pilot Feedback

This section reports feedback provided by the airline pilots who participated in the Phase IV.a simulation at NASA Ames. The majority of the pilots comments concerned the discrepancy between instructions given to them by ATC in the simulation and ATC instructions given to them in the real world environment.

The following is a description of the comments reported. Pilots described controllers as extremely tense and paniced, a pilot reported, "even our emergencies would never be approached as panic."

The first time there was any transmission between ATC and the pilot is when the pilot was given a go around/vector. Pilot's said, this was totally out of the ordinary, especially when no reason is given as to why the action is being taken. A pilot stated that he/she needed an "advisement on ATC intentions, so as to configure the aircraft and airspeed appropriately for the next action."

Pilots reported that controllers did not use standard phraseology when vectoring aircraft. The pilots felt very uncomfortable when they received broken messages, e.g., a heading change without any mention of altitude. An incomplete instruction like this left the pilot wondering what to do with respect to altitude. Consequently, the pilot would ask and then the controller would respond with either a altitude change or an instruction to maintain the current altitude. Pilots reported that this extra transmittion in an emergency situation, could adversely affect safety.

Pilots reported that it was a "very alien thing to do, to execute a missed approach with a turn and descent." An instruction that particularly disturbed the pilots, was an instruction to descend below the glideslope. This instruction is totally contrary to the training they had received.

Several reversal of directions were given by ATC, e.g. "right to 270 then, lets try a left to 090." In an actual emergency situation this type of transmission could result in a loss of valuable time, especially if the pilot was instructed to descend below the glideslope.

The controller issued instructions to the pilot to turn and join the localizer when there was the slightest deviation. The pilot's instrumentation, however, represented that he/she was on course. A pilot reported, "Airline transport pilot's practical test standards allows for one dot displacement on the localizer."

Given the fact that the pilots knew the type of emergency

APPENDIX E

TECHNICAL OBSERVER OPERATIONAL ANALYSIS

TECHNICAL OBSERVERS OPERATIONAL ANALYSIS OF PHASE IV A TRIPLE INDEPENDENT SIMULTANEOUS PARALLEL INSTRUMENT LANDING SYSTEM APPROACH PROCEDURES FOR NATIONAL STANDARD

FAA TECHNICAL CENTER
ATLANTIC CITY, NEW JERSEY
APRIL 22 - MAY 4, 1990

TABLE OF CONTENTS

EXECUTIVE SUMMARY

The triple parallel independent instrument landing system (ILS) simulation was conducted at the Federal Aviation Administration (FAA) Technical Center in Atlantic City, New Jersey, from April 22 through May 4, 1990. The goal was to demonstrate the feasibility of triple parallel ILS approaches and missed approaches/departures under the conditions outlined in the test plan which included 4,300 feet runway centerline separation and aligned runway thresholds.

Personnel from the Southwest Regional Office Air Traffic Division provided the staff support and served as technical observers for the simulation. The technical observers documented the actions of the controllers, simulated aircraft, and simulated aircraft pilots throughout the simulation.

The records of the technical observers indicate three types of situations occurred during the simulation: blunders, wanderers, and speed overtakes. Blunders consisted of an aircraft, which may or may not have radio communication, deviating 30 degrees or less off of the assigned localizer course. When a blunder occurred, aircraft on adjacent localizer courses were issued turns, altitude changes, or both turns and altitude changes to alleviate the situation. The wandering aircraft were a result of a simulated navigational error included in the simulation to add realism. The controllers resolved wandering aircraft situations by issuing "turn and join the localizer" instructions to the

aircraft. Speed overtake situations were resolved by assigning the aircraft a speed to ensure adequate in-trail spacing was maintained.

The test plan for the simulation of triple simultaneous parallel ILS approaches called for a detailed evaluation of all situations which resulted in a slant range distance of 500 feet or less. The simulation produced 47 situations in which a detailed evaluation was required. The technical observers also analyzed all situations in which less than 1,000 feet slant range distance was computed. These situations are described in Appendices 1-4.

The simulation consisted of 15 dual ILS runs, 15 triple ILS runs, and 6 triple ILS/missed approach/departure runs using 4,300 feet runway centerline separation. The simulation also included 2 triple ILS runs using 5,000 feet runway centerline separation.

The 15 dual ILS runs included 210 blunders. In this segment of the simulation, 46 blunders resulted in less than 1,000 feet slant range distance, 21 of which resulted in less than 500 feet slant range distance.

The 15 triple ILS runs included 227 blunders. In this segment of the simulation, 68 blunders resulted in less than 1,000 feet slant range distance, 28 of which resulted in less than 500 feet slant range distance.

The 6 triple arrival/missed approach/departure ILS runs included 32 blunders. This segment of the simulation had 1 blunder which resulted in less than 1,000 feet slant range distance. This same blunder also resulted in less than 500 feet slant range distance.

The 2 triple ILS runs with 5,000 feet runway centerline separation included 40 blunders. Of the 40 blunders, 4 resulted in less than 1,000 feet slant range distance, 1 of which resulted in less than 500 feet slant range distance.

The simulation provided strong indications that independent triple simultaneous ILS approaches utilizing 4,300 feet runway centerline separation, aligned runway thresholds, current radar displays, and 4.8 second radar update rate when evaluated against the acceptance criteria as specified in the simulation test plan appears to be unacceptable.

INTRODUCTION

Previous triple and quadruple ILS simulations have provided data and demonstrated the feasibility of implementation of triple and quadruple simultaneous parallel approaches for Dallas/Fort Worth International Airport.

This triple simultaneous parallel ILS simulation is the first of a multi-phase simulation to establish a national standard which could be applied to any airport throughout the nation or the world.

The simulation included dual and triple parallel ILS approaches to a generic airport with the following specifications:

1. Runway centerline separation - 4,300 feet.

2. Runway length - 10,000 feet.

3. Aligned runway thresholds.

4. Three degree glide slope.

5. Five mile outer markers.

In order to gain full capacity of new runways, procedures must be developed which will allow multiple (more than two), simultaneous parallel ILS approaches to be conducted during adverse weather conditions down to a ceiling of 200 feet and visibility of 1/2 mile.

The multiple, simultaneous parallel ILS approach simulations are being conducted in phases. Phases I, II, and III have been completed and were site specific for Dallas/Fort Worth International Airport.

Phase IVA, Triple Parallel Simultaneous ILS Approaches, involved nine controllers from various terminal radar approach controls (TRACON) throughout the nation which currently have simultaneous parallel approaches in operation. Personnel from the Southwest Regional Office Air Traffic Division provided the staff support and served as observers documenting the actions of the controllers, simulated aircraft, and simulated aircraft pilots throughout the simulation.

ANALYSIS

The triple simultaneous parallel ILS approach simulation consisted of three separate scenarios. The first scenario studied dual parallel ILS approaches consisting of two runways numbered 18L and 18C. The second scenario studied the triple parallel ILS approaches consisting of three runways numbered 18L, 18C, and 18R. The third scenario studied triple arrival/missed approach/departure using arrival/missed approaches to runway 18L, 18C, and 18R with departures using runway 18L and 18R only. The simulation compared the data between the dual runway runs and the triple runway runs. Throughout the simulation, the controllers encountered unexpected situations and conditions.

The simulation included the use of the NASA Boeing 727 simulator located in Sunnyvale, California and the General Aviation Trainer (GAT) located at the FAA Technical Center in Atlantic City, New Jersey. The simulators were able to accomplish approximately 5 approaches during any 1-hour simulation.

The test plan for the Simulation of Triple Simultaneous Parallel ILS Approaches included a minimum acceptable slant range distance of 500 feet between two aircraft. The technical observers analyzed all situations in which less than 1,000 feet slant range distance was computed.

The following paragraphs outline some of the general problems and situations.

TRAFFIC SAMPLES: The traffic samples in the simulation consisted of props, turboprops, and turbojets (including heavy jets) to all runways. The wide variation of speeds and required in-trail separation for heavy jets provided traffic samples in which the aircraft on adjacent ILS courses were staggered a large majority of the time.

The worst case scenario is to have two aircraft on parallel ILS courses with the faster aircraft 1/2 NM or less behind and then initiate a 30-degree non radio blunder towards the other aircraft. The traffic samples used in Runs 1 through 20 provided this situation only occasionally. In most cases, a blundering aircraft did not have another aircraft within 1/2 NM on the adjacent ILS and, in some cases, the aircraft on an adjacent ILS was more than 1 mile from the blundering aircraft. Therefore, situations in which a blunder could create a condition resulting in less than 500 feet slant range distance became obvious. In the first 20 runs the number of blunders ranged from 5 to 17 per run.

Beginning with Run 21, the traffic samples were changed to have all aircraft start on the ILS side-by-side, with the appropriate heavy jet in-trail separation. Changing the traffic samples ensured a blundering aircraft would have an aircraft within 1/2 NM on the adjacent ILS and third ILS every time. Additionally, by having all the aircraft side-by-side, the ability to predict which aircraft would blunder was eliminated. The blunders increased to a minimum of 16 and a high of 27 and created a drastic increase in the turn/join instructions.

BLUNDERS: The simulation included several types of scripted blunders, which were introduced at various times during a 1-hour run, without the prior knowledge of the controllers or observers. These blunders included 10-, 20-, and 30-degree turns with and without radio communications. Due to the navigational parameters set in the computer, the controller and observers were unable to differentiate between 10- or 20-degree blunders in which the controller had radio communications with the aircraft and other navigational errors. Further explanation of this is in the Navigation paragraph.

When the B727 and GAT simulators were proceeding on the ILS approach, an aircraft on a adjacent runway was chosen to blunder toward the simulators. The objective of this situation was to compare the response times of the simulator pilots and aircraft performance to the pseudopilots and computer generated targets.

During blunders involving non radio conditions, the controllers issued instructions to the aircraft on the adjacent ILS to turn/climb.

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

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

1. Human Error - Slow response or no response to aircraft calls and incorrect entry of control instructions.

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

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

EQUIPMENT: The simulation was conducted in the new ARTS III laboratory using data entry and display subsystems (DEDS) radar scopes with the associated video maps. During the simulation, some minor computer problems and scope failures occurred which were an inconvenience to the simulation. However, the controllers were able to handle the problems without any difficulty and the problems added realism to the evaluation.

RUNS: The information contained in Appendix I (Duals), Appendix II (Triples), Appendix III (Departure), and Appendix IV (Triples - 5,000 Feet Centerline Separation) provides a brief explanation of the occasions in which a blundering aircraft came within less than 1,000 feet slant range distance of an aircraft on the adjacent ILS course. The following is a brief explanation of the format used in this report. The first sections contain date, run number, start time, runways used, and controller assignment. The second section outlines the blunder. The aircraft call sign that follows the time is the blundering aircraft. The aircraft call signs which follow are those aircraft which were affected by this blunder. Under each of these aircraft is the minimum estimated vertical and lateral distance as viewed by the observers. The last section is a brief overview of what control actions were initiated and the results.

The Aircraft Proximity Index (API), developed by the Technical Center, is a single value that reflects the relative seriousness or danger of the situation. The API assigns a weight or value to each conflict, depending on vertical and lateral distances. API facilitates the identification of the more serious conflicts in a data base where many conflictions are present. A figure of 100 is the maximum value of the API. Therefore, the higher the API, the closer the aircraft. It should be noted that, in the dual runs, Run 4 produced the highest API of 92. In the triple runs, Run 21 produced the highest API of 98. In the departure runs, Run 25 produced the highest API of 61. In the triple runs (5,000 feet centerline separation), Run 36 produced the highest API of 79.

The triple ILS runs produced 227 blunders. 64 blunders resulted in less than 1,000 feet slant range distance, 24 blunders of which resulted in less than 500 feet slant range distance. In the triple ILS runs, controller actions may have contributed to one blunder, pilot actions may have contributed to six blunders. There were 17 situations in which no contributing factors are apparent, but the aircraft still came within less than 500 feet slant range of another aircraft.

The arrival/missed approach/departure runs produced 31 blunders. Only 1 blunder resulted in less than 1,000 feet slant range distance. This same blunder also resulted in less than 500 feet slant range distance. In this situation equipment failure may have been the contributing factor.

The triple ILS approach runs utilizing 5,000 feet runway centerline separation produced 40 blunders. 4 blunders resulted in less than 1,000 feet slant range distance, 1 blunder of which resulted in less than 500 feet slant range distance. Equipment failure was the contributing factor in this situation.

CONCLUSION

The data gathered during the independent triple simultaneous parallel ILS simulation was evaluated against the specified acceptance criteria which was outlined in the test plan and leads to the following initial conclusions:

The simulation highlighted the fact that quick and correct action on the part of the controller and pilot, using present day equipment, may not resolve a situation in a suitable manner.

The simulation indicated that the challenge which must be met in order to safely and successfully operate independent multiple simultaneous ILS approaches is to resolve separation problems which may occur between adjacent localizers. In all situations in this simulation, the aircraft on the third runway was never a factor.

The simulation provided strong indications that the operation of independent triple simultaneous ILS approaches utilizing 4,300 feet runway centerline separation, aligned runway thresholds, current radar displays, and 4.8 second radar update rate appears to be unacceptable.

It should be noted that these conclusions are the result of an analysis of all of the data which was available to the technical observers at the time this document was published. The data analyzed was only preliminary data, more data or a further analysis of this data may alter these conclusions.

APPENDIX F

OPERATIONAL ASSESSMENT

OPERATIONAL ASSESSMENT

The Operational Assessment provided a comprehensive review of all blunders that resulted in a Closest Point of Approach (CPA) of less than 500 ft. The review considered data from video and audio recordings, controller interviews/debriefings, technical observer logs, aircraft position plots and data records, and NSSF simulator pilot input records.

The Multiple Parallel Technical Work Group (TWG) reviewed the blunder data and determined whether mitigating circumstances may have contributed to the severity of the blunder. A decision was then made concerning the inclusion of the blunder into the database for analysis. There were 26 blunders reviewed in the Operational Assessment. The review indicated that three blunders should be excluded from the data analysis due to:

1. Simultaneous lack of response by the blundering aircraft and the threatened aircraft, Double NORDO (one occurrence)

2. Pilot input errors (two occurrences).

A number of the blunders appeared to have a single factor which contributed largely to the severity of the outcome. These factors included slow responses by the controller, pilot, or both controller and pilot, or a less than standard aircraft turn rate (< 3 degrees/s). The blunders investigated in the Operational Assessment are categorized in table 1. Many of the blunders, indicated by "System," did not have an exclusive factor that contributed largely to the severity of the blunder.

Three blun[illegible] that exemplify causes of blunder severity are described [illegible]e following text. All three blunders had CPAs of less than [illegible] ft (i.e., resulted in a test criterion violation (TCV)). Graphic plots and computer generated data are included to aid the reader in reviewing the blunders.

The graphic plots represent the aircraft's lateral movement along the localizer. As shown in figure 1, the localizers are indicated by vertical dashed lines and the aircraft tracks are solid lines that follow and eventually deviate from the localizer lines. The horizontal (x) and vertical (y) axes are marked in nautical miles from an imaginary origin. Simulation time (recorded along the aircraft tracks) is marked in 10-second increments. The aircraft identification is indicated at the beginning of each track.

An example of the digital data associated with a graphic plot is provided in table 2. The data include increment time (from the plot), simulation time (seconds), x coordinate, y coordinate, altitude, ground speed, heading, track status (1000 = Off-Flight-

Plan on Vectors, 1060 = Flying ILS Approach, 1061 = Homing to ILS Approach, 1068 = Deviating from ILS Approach), and the distance the aircraft traveled once the plot was initiated.

The first example, shown in figure 1, began with UAL 681. The aircraft was inbound on the left runway when it blundered 30 degrees to the right at simulation time 3337. The data for this blunder is shown in table 2. The controller for 18C identified the blundering aircraft at simulation time 3345, and the 18L controller instructed UAL 681 to rejoin the localizer. At simulation time 3348, the controller issued a vector change for AWE 427, on the center runway (18C), to heading 310. Seven seconds later at simulation time 3355, AWE 427 was directed to climb and maintain 5000 ft. The NSSF simulator pilot for AWE 427 entered both commands at simulation time 3362. The controller for 18C then vectored AWE 427 right to heading 330 at simulation time 3384. Nine seconds later, the simulator pilot for AWE 427 entered the command to heading 330. The CPA attained by these aircraft was 388 ft.

The next example, shown in figure 2, shows how indecision by a controller may have affected the severity of a blunder. The data for this blunder is shown in table 3. At simulation time 964, USA 173 was inbound on the right runway when it began a 30 degree blunder to the left. The controller for 18R noticed the blunder at simulation time 982 and directed him to rejoin the localizer. At simulation time 985, HNA 7765 on 18C was instructed to climb followed by an immediate correction to descend. The pilot for HNA 7765 entered the command to descend to 2000 ft at simulation time 995. The controller for 18C then vectored HNA 7765 immediately right to heading 270. The pilot entered the commanded heading at simulation time 1009. The CPA for these two aircraft was 463 ft.

The final blunder, shown in figure 3, demonstrates how blunder severity is affected by a controller error. The data for this blunder is shown in table 4. The controller incorrectly identified USA 721 as USA 727. The aircraft was a B-727. At simulation time 2658, NWA 970 was inbound on 18L when it began a 30 degree blunder to the right. At simulation time 2663 the controller for NWA 970 noticed the blunder and instructed it to rejoin the localizer. The controller for 18C incorrectly identified USA 721 as USA 727, and he vectored USA 727 right to heading 240 and issued a climb to 3000 ft at simulation time 2666. At simulation time 2668 the controller again issued the same vector change to USA 727. The controller commented that there was "no answer on US Air." At simulation time 2680, 14 seconds after the controller's initial vector to USA 727, the controller correctly identified the aircraft as USA 721, he abruptly stopped to comment, "I'm getting an answer," he continued with a call to USA 727, stopped, then proceeded with a corrected call to USA 721 and vectored the aircraft right to heading 240 and to climb to 3000 ft. Fifteen seconds after the controller used the correct call sign, at simulation time 2695, the pilot for USA 721 entered the command to turn to heading 240 and climb to 3000 ft. The CPA was 366 ft.

CONCLUSIONS

Based upon the review of the blunders and their knowledge of air traffic operations, the TWG indicated that high update radar, high resolution controller displays, and controller aides would have enabled controllers to resolve the worst case blunders. The improvement of the radar/controller display system would enable controllers to detect blunders quicker and initiate corrective commands. This would have enabled controllers to safely resolve all of the blunders examined in this simulation.

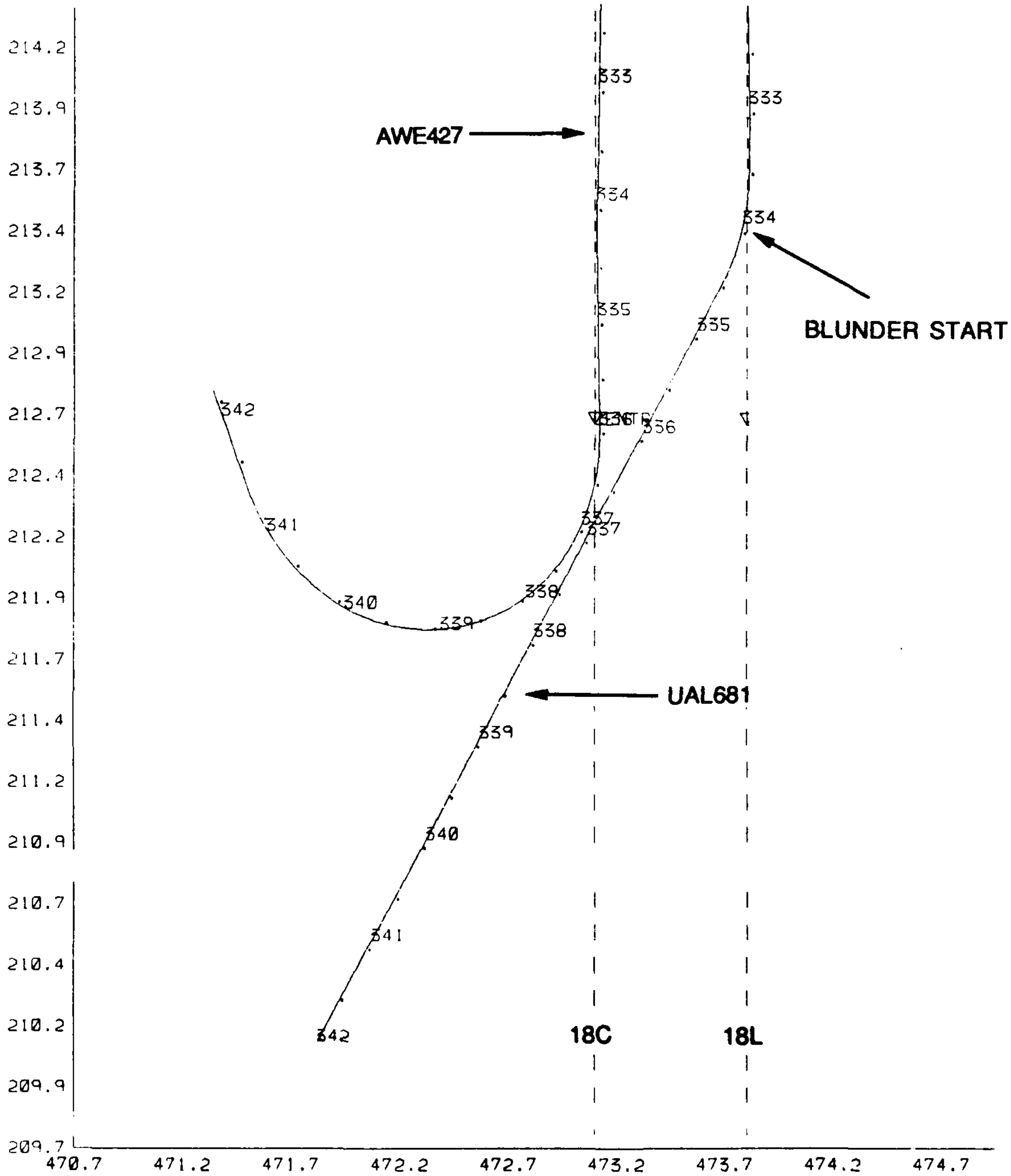

FIGURE F-1. GRAPHIC PLOT FOR EXAMPLE 1

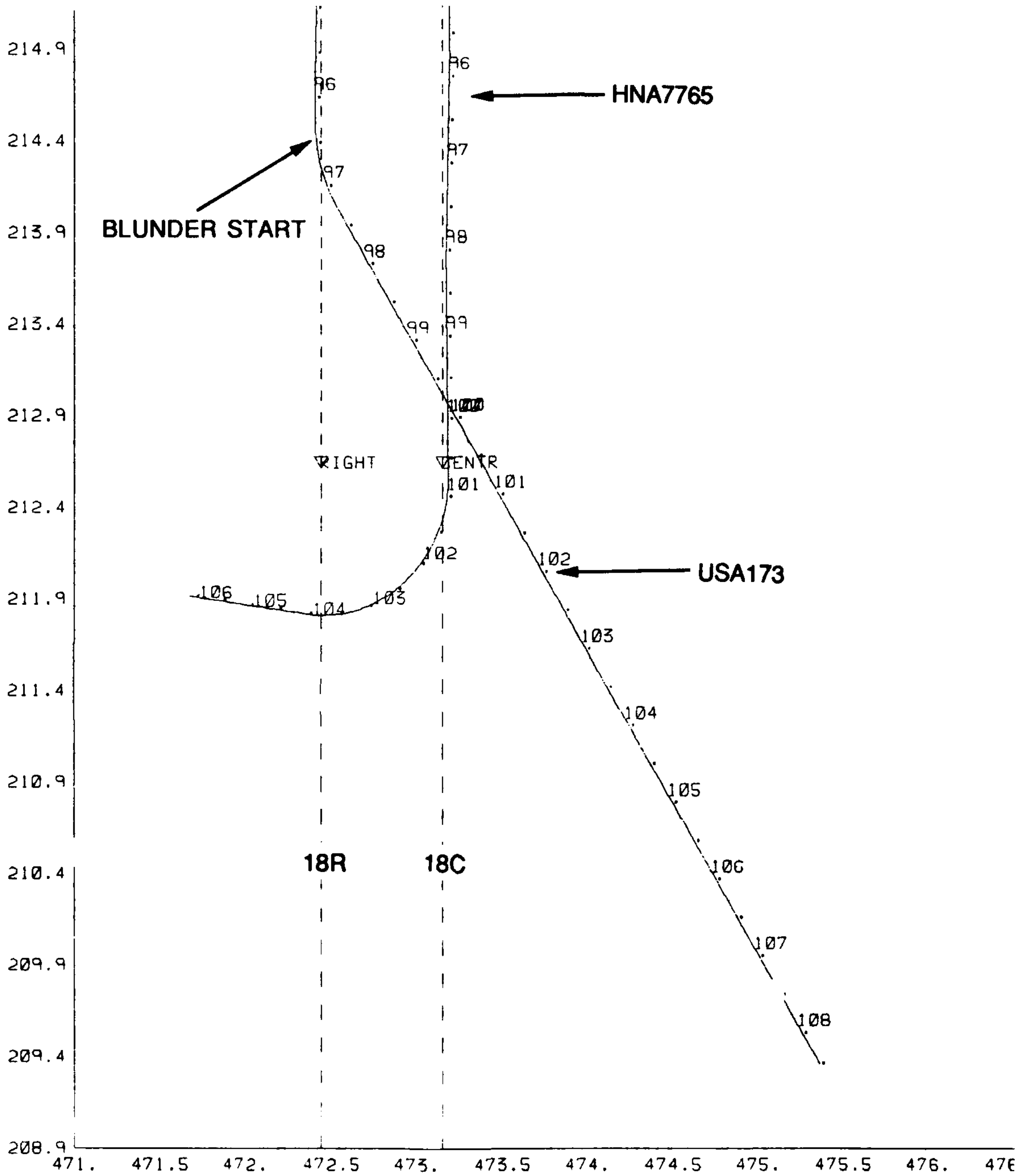

FIGURE F-2. GRAPHIC PLOT FOR EXAMPLE 2

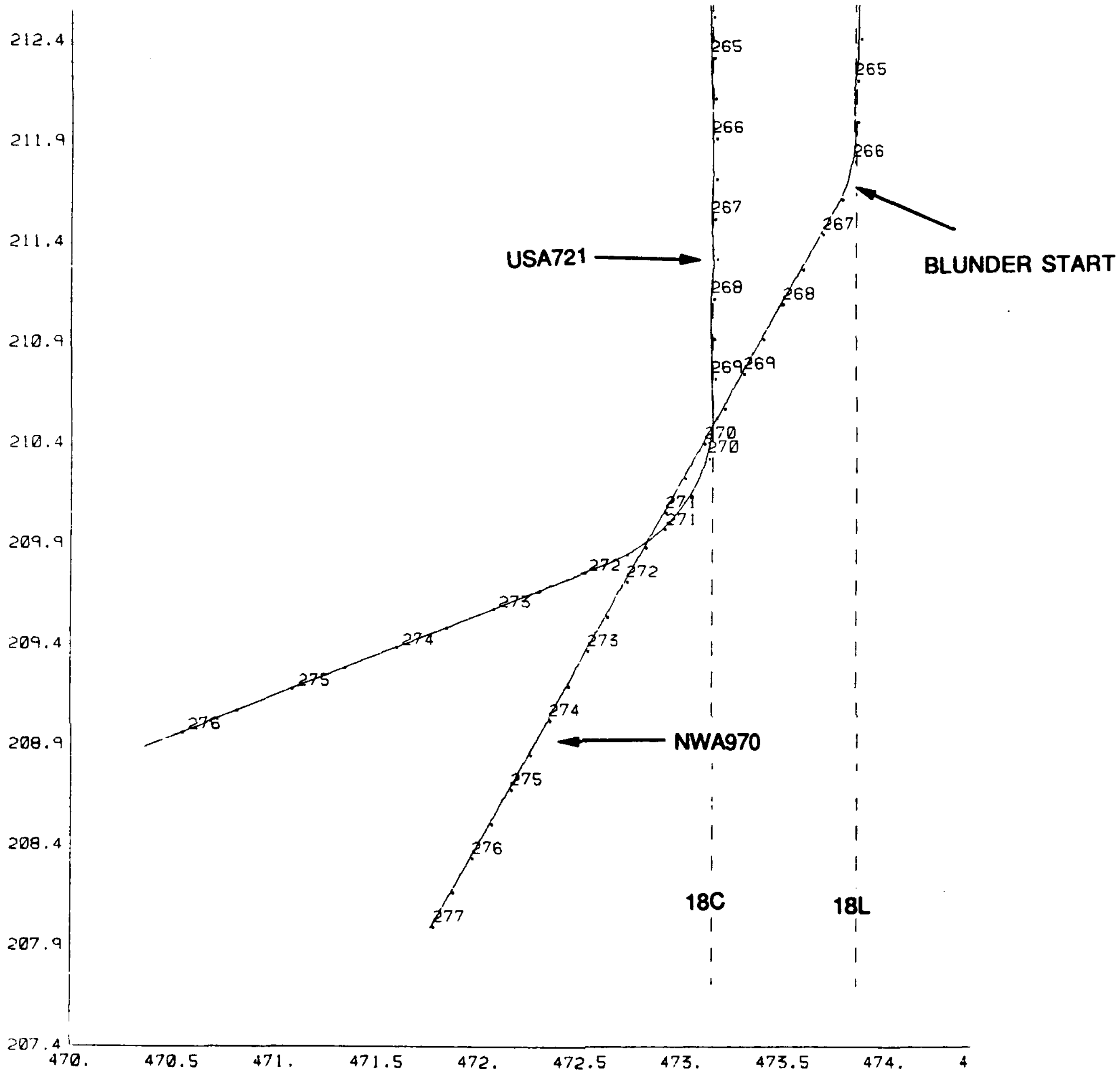

FIGURE F-3. GRAPHIC PLOT FOR EXAMPLE 3

TABLE F-1. PHASE IV.a CONTRIBUTING FACTORS

Major Contributing Factor	Times of Occurrence
System	9
Slow Controller Response Time	7
Slow Pilot Response Time	1
Controller Error	3
Pilot Error	2*
Slow Controller & Pilot Response Times	2
Double NORDO	1*
GAT 2 degree/sec turn	1
* Excluded from analysis	

TABLE F-2. DATA FOR EXAMPLE 1

UAL681 ACTUAL FLIGHT:

INC	TIME	X	Y	ALT	TSPD	HDG	TRACK	DISTANCE
330	3307	473.851	215.111	3066	178	180	1060	.00
331	3309	473.849	215.012	3034	178	180	1060	.10
332	3319	473.854	214.519	2875	178	178	1060	.59
333	3329	473.863	214.027	2716	177	178	1060	1.08
334	3339	473.836	213.538	2557	177	189	1000	1.57
335	3349	473.625	213.099	2399	176	210	1000	2.06
336	3359	473.373	212.680	2241	176	210	1000	2.55
337	3369	473.122	212.263	2082	175	210	1000	3.04
338	3379	472.871	211.846	1924	175	210	1000	3.53
339	3389	472.622	211.430	1765	175	210	1000	4.01
340	3399	472.373	211.015	1607	174	210	1000	4.50
341	3409	472.124	210.601	1448	174	210	1000	4.98
342	3419	471.875	210.188	1290	173	210	1000	5.46

AWE427 ACTUAL FLIGHT:

INC	TIME	X	Y	ALT	TSPD	HDG	TRACK	DISTANCE
330	3307	473.173	215.180	3084	175	179	1060	.00
331	3309	473.174	215.083	3053	175	179	1060	.10
332	3319	473.181	214.597	2896	175	179	1060	.58
333	3329	473.171	214.112	2739	175	181	1060	1.07
334	3339	473.161	213.628	2583	173	181	1060	1.55
335	3349	473.166	213.160	2431	165	179	1060	2.02
336	3359	473.173	212.714	2286	157	179	1060	2.47
337	3369	473.092	212.303	2361	150	203	1000	2.89
338	3379	472.833	212.006	2694	148	233	1000	3.29
339	3389	472.439	211.873	3027	159	263	1000	3.71
340	3399	472.000	211.961	3360	171	293	1000	4.16
341	3409	471.641	212.278	3693	182	323	1000	4.65
342	3419	471.431	212.748	4026	193	338	1000	5.16

TABLE F-3. DATA FOR EXAMPLE 2

USA173 ACTUAL FLIGHT:

INC	TIME	X	Y	ALT	TSPD	HDG	TRACK	DISTANCE
93	934	472.415	216.005	2994	176	178	1060	.00
94	939	472.419	215.759	2994	176	178	1060	.25
95	949	472.415	215.268	2994	176	180	1060	.74
96	959	472.407	214.777	2950	176	180	1060	1.23
97	969	472.459	214.293	2850	176	163	1000	1.72
98	979	472.697	213.864	2850	176	148	1000	2.21
99	989	472.950	213.445	2850	176	148	1000	2.70
100	999	473.204	213.025	2850	176	148	1000	3.19
101	1009	473.458	212.605	2850	176	148	1000	3.68
102	1019	473.712	212.186	2850	176	148	1000	4.17
103	1029	473.966	211.766	2850	176	148	1000	4.66
104	1039	474.220	211.347	2850	176	148	1000	5.15
105	1049	474.474	210.927	2850	176	148	1000	5.64
106	1059	474.728	210.508	2850	176	148	1000	6.13
107	1069	474.982	210.088	2850	176	148	1000	6.62
108	1079	475.236	209.668	2850	176	148	1000	7.11

HNA7705 ACTUAL FLIGHT:

INC	TIME	X	Y	ALT	TSPD	HDG	TRACK	DISTANCE
93	934	473.184	216.082	3372	172	179	1060	.00
94	939	473.186	215.844	3295	172	179	1060	.24
95	949	473.191	215.367	3141	172	179	1060	.72
96	959	473.192	214.891	2987	171	181	1060	1.19
97	969	473.132	214.416	2834	171	181	1060	1.67
98	979	473.173	213.943	2681	171	181	1060	2.14
99	989	473.176	213.472	2529	167	179	1060	2.61
100	999	473.180	213.021	2371	159	179	1068	3.06
101	1009	473.182	212.593	2204	151	182	1000	3.49
102	1019	473.044	212.217	2050	143	212	1000	3.90
103	1029	472.751	211.972	2000	135	242	1000	4.28
104	1039	472.396	211.911	2000	127	272	1000	4.65
105	1049	472.056	211.958	2000	120	278	1000	4.99
106	1059	471.738	212.003	2000	113	278	1000	5.31

TABLE F-4. DATA FOR EXAMPLE 3

NWA970 ACTUAL FLIGHT:

INC	TIME	X	Y	ALT	TSPD	HDG	TRACK	DISTANCE
262	2628	473.866	213.268	2466	168	190	1060	.00
263	2629	473.865	213.222	2451	167	180	1060	.05
264	2639	473.867	212.772	2305	159	180	1060	.50
265	2649	473.851	212.345	2166	151	186	1060	.92
266	2659	473.839	211.939	2034	144	184	1000	1.33
267	2669	473.692	211.572	1905	143	208	1000	1.73
268	2679	473.499	211.224	1775	143	208	1000	2.13
269	2689	473.306	210.877	1646	143	208	1000	2.52
270	2699	473.114	210.530	1517	143	208	1000	2.92
271	2709	472.921	210.184	1388	142	208	1000	3.32
272	2719	472.731	209.839	1258	142	208	1000	3.71
273	2729	472.541	209.495	1129	142	208	1000	4.10
274	2739	472.350	209.150	1000	142	208	1000	4.50
275	2749	472.160	208.807	871	141	208	1000	4.89
276	2759	471.969	208.465	741	141	208	1000	5.28
277	2769	471.779	208.122	658	141	208	1000	5.67

USA721 ACTUAL FLIGHT:

INC	TIME	X	Y	ALT	TSPD	HDG	TRACK	DISTANCE
262	2628	473.154	213.354	2513	164	178	1060	.00
263	2629	473.155	213.308	2498	163	178	1060	.05
264	2639	473.142	212.869	2356	155	186	1060	.49
265	2649	473.141	212.452	2220	147	179	1060	.90
266	2659	473.148	212.052	2090	144	178	1060	1.30
267	2669	473.142	211.653	1962	144	182	1060	1.70
268	2679	473.145	211.256	1833	143	183	1060	2.10
269	2689	473.145	210.858	1705	143	178	1060	2.50
270	2699	473.126	210.460	1636	147	190	1000	2.90
271	2709	472.926	210.100	1939	158	220	1000	3.32
272	2719	472.547	209.869	2272	169	248	1000	3.76
273	2729	472.102	209.690	2605	180	248	1000	4.24
274	2739	471.629	209.499	2938	191	248	1000	4.75
275	2749	471.120	209.293	3000	202	248	1000	5.30
276	2759	470.534	209.076	3000	212	248	1000	5.88

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