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AN INVESTIGATION OF ATC PROCEDURES FOR IFR APPROACHES TO TRIPLE PARALLEL RUNWAYS

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MAY 1973

FINAL REPORT

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16. Abstract

This activity was conducted to investigate air traffic control (ATC) procedures applicable to the conduct of simultaneous instrument flight rules (IFR) approaches to a set of three parallel runways. A dynamic simulation was conducted to examine the various aspects of such an operation, including ATC procedures, monitoring requirements, general controller workload limits, and a comparison of the effect of greater and lesser percentages of Mode C-equipped aircraft on monitoring procedures. Results show that the concept of conducting simultaneous instrument approaches to a set of triple parallel runways is feasible using standard ATC procedures and separation standards (except on the final approach course).

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PREFACE

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INTRODUCTION

PURPOSE.

The purpose of this activity was to investigate air traffic control (ATC) procedures for simultaneous instrument flight rule (IFR) approaches to triple parallel runways.

BACKGROUND.

This project is the third and final phase of a three-phase study included in Subprogram 142-177, "Measurements and Procedures for Multiple Runway Configurations." Since time did not permit a dynamic simulation of sufficient magnitude to investigate more than one variety of multiple runway configurations, this activity was limited to an investigation of ATC procedures for IFR approaches to triple parallel runways.

The activities of this effort concerned the dynamic simulation of ATC procedures required to conduct simultaneous IFR approaches to a set of three parallel runways. The mechanics of vectoring traffic to the final approach courses and monitoring these approaches were examined under several conditions. The monitoring controllers' workload limitations and their ability to respond to erratic aircraft flight performance were examined.

DISCUSSION

GENERAL.

The conduct of simultaneous instrument approaches to a set of three parallel runways could be limited or enhanced by several aspects of the geography, airspace, runway configuration, and location and type of various aids to navigation. Each of these variables, in addition to the density and mix of the traffic using the airport, could, of itself, become an important variable. In order to conduct this study within the time allotted, certain assumptions were made concerning a hypothetical airport. These were:

1. The three runways were of equal length, parallel with even thresholds and laterally separated by a distance of 5,000 feet.

2. The instrument approach to each runway was an identical instrument landing system (ILS) with a 3° glide slope.

3. A traffic sample of mixed jets (90 percent) and props (10 percent) was evenly distributed over four feeder fixes which were ideally located (Figure 1).

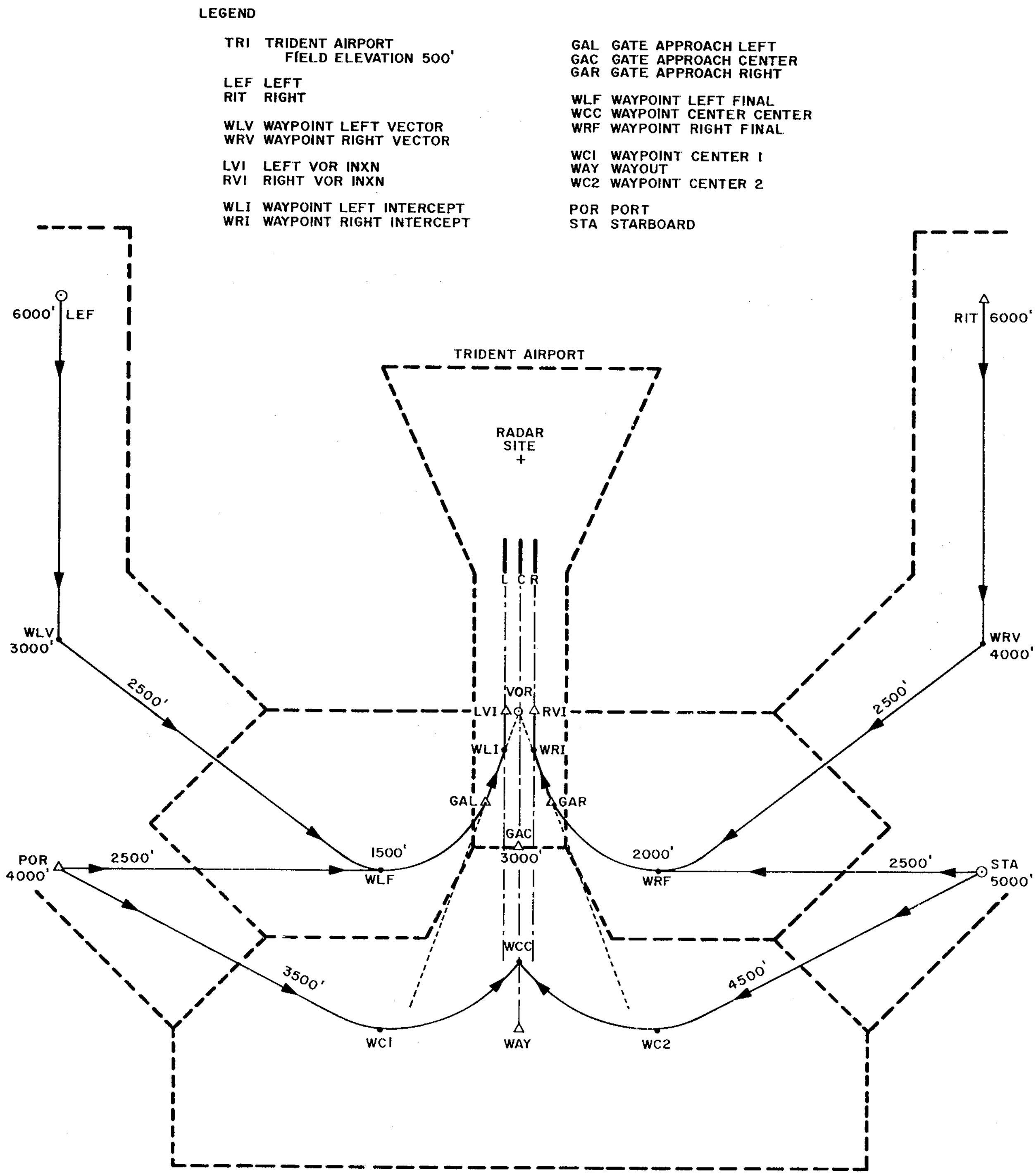


FIGURE 1. TRAFFIC FLOW FOR "TRIDENT" AIRPORT

4. Standard IFR separation was applied at all times except that only 500 feet of vertical separation was required during turn-on to the ILS final approach course. There were no heavy jet aircraft in the sample so that a minimum longitudinal separation of 3 miles was applicable between successive aircraft on the same ILS course.

5. There were no restrictions imposed on the use of the airspace in the approach control area.

6. Ideal radar coverage was simulated, that is to say that there were no areas of noncoverage, no precipitation, no radar errors or false returns.

7. Departure operations were not simulated.

8. All aircraft targets had standard, automated radar terminal system (ARTS) data blocks. Further, all tracking functions (target acquisition, handoff, termination, etc.) were automatic so that few keyboard entries were required by the controllers.

These assumptions created a practically ideal climate for the conduct of simultaneous triple-parallel instrument approaches. Any alteration of these conditions would impact the overall performance of the system which was simulated.

The design of the airspace environment used in this simulation was developed after consultation with several terminal air traffic control specialists. It was felt that the four-fix or "cornerpost" layout, widely used in the field today, would adapt easily to a three-runway operation.

The idea of using very high frequency omnirange station (VOR) radials to guide the aircraft to the ILS course was developed as an aid to the monitor controllers. First, it established a fixed turn-on point so that the monitor controller knows exactly where to look for each successive aircraft. Second, it provides the pilots with a precise intercept angle, regardless of wind conditions. Third, it reduces the possibility of overshoot due to blocked or missed transmissions.

METHOD OF APPROACH.

This activity was guided by input from and coordination among the following elements: Systems Research and Development Service (SRDS), Air Traffic Service (ATS), and the National Aviation Facilities Experimental Center (NAFEC).

The airspace simulated was a 20-mile radius of a hypothetical airport called "Trident" (Figure 1). The test environment consisted of the Digital Simulation Facility (DSF) located at NAFEC (Figures 2 and 3).

Eight operating positions were simulated in the control and monitoring of the air traffic within the designated approach control area (Figure 4). These positions included: two initial vector (or "feeder") controllers,

FIGURE 2. ATC POSITIONS - DIGITAL SIMULATION FACILITY - ATC LABORATORY

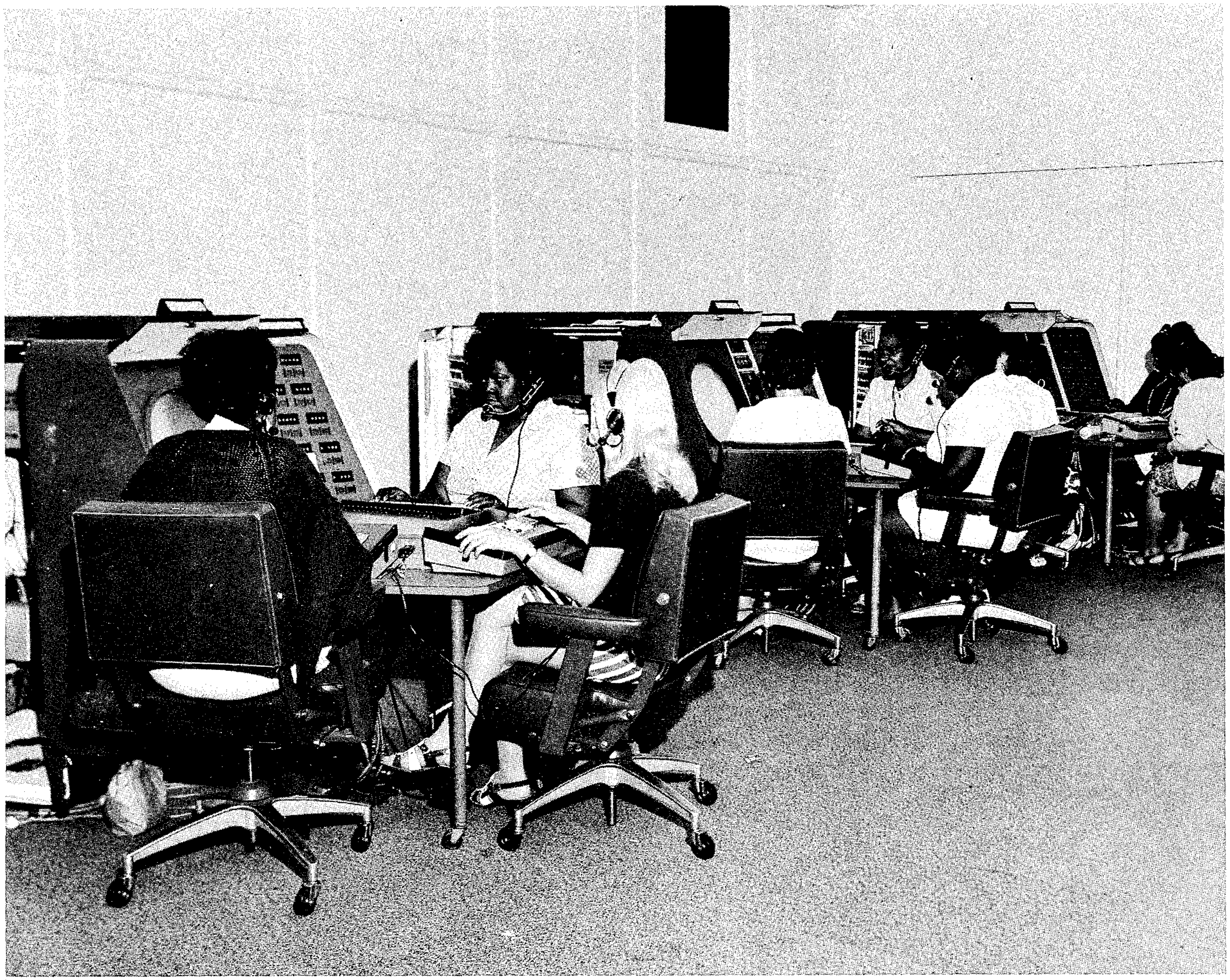
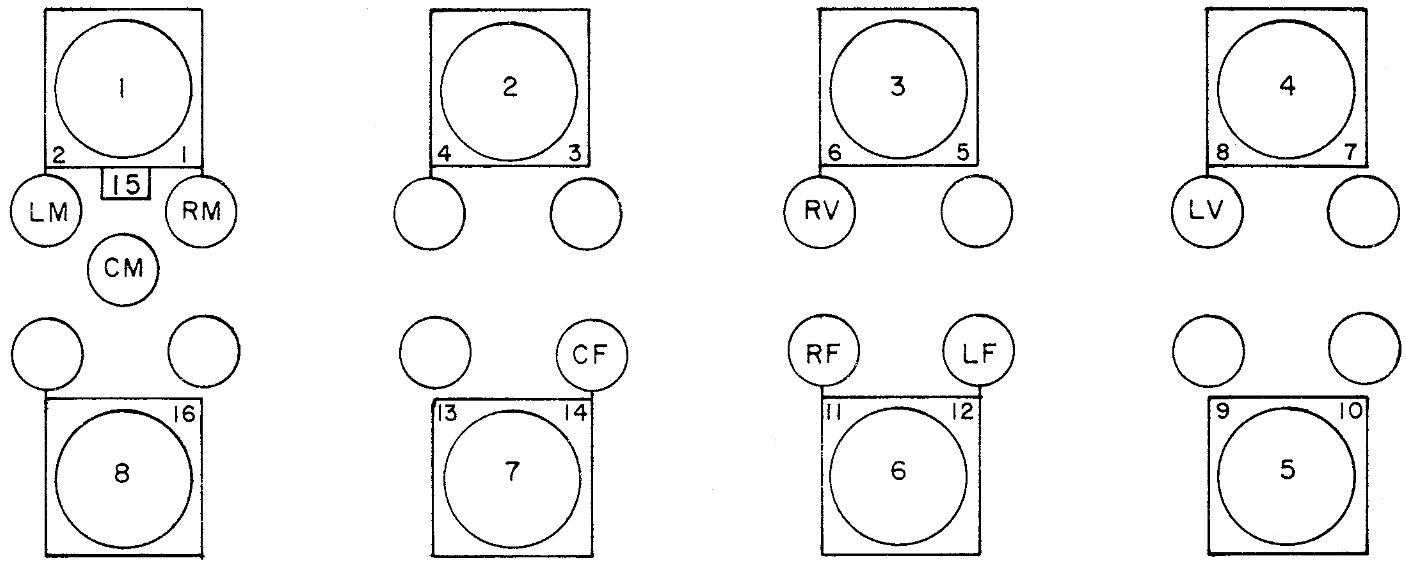


FIGURE 3. PILOT CONSOLES - DIGITAL SIMULATION FACILITY

CONTROL ROOM CONFIGURATION



POSITION	FUNCTION
1.	RIGHT MONITOR
2.	LEFT MONITOR
6.	RIGHT VECTOR
8.	LEFT VECTOR
11.	RIGHT FINAL
12.	LEFT FINAL
14.	CENTER FINAL
15.	CENTER MONITOR

FIGURE 4. CONTROL ROOM LAYOUT

three final vector controllers, and three final approach course monitors. Ten air traffic control specialists assigned to the project were rotated through all eight positions. The duties specified for each position were as follows:

RIGHT VECTOR POSITION. Responsible for starting traffic at Right (RIT). All RIT traffic was started at 6,000 feet and descended to 2,500 feet, crossing Waypoint Right Vector (WRV) at 4,000 feet or below. Speed control was exercised in this area. All RIT traffic was handed off to the right final controller passing WRV. This position was also responsible for starting traffic at Starboard (STA). All STA traffic was started at 5,000 feet and was either cleared to Waypoint Right Final (WRF) or Wayout (WAY). WRF traffic was descended to 2,500 feet and handed off to the right final controller as soon as possible after starting. All WAY traffic was descended to 4,500 feet and handed off to the center final controller as soon as possible after starting.

LEFT VECTOR POSITION. Responsible for starting traffic at Left (LEF). All LEF traffic was started at 6,000 feet and descended to 2,500 feet, crossing Waypoint Left Vector (WLV) at 4,000 feet or below. Speed control was exercised in this area also. All LEF traffic was handed off to the left final controller passing WLV. This position was also responsible for starting traffic at Port (POR). All POR traffic started at 4,000 feet and was either cleared to WLF or WAY. WLF traffic was descended to 2,500 feet and handed off to the left final controller as soon as possible after starting. All WAY traffic was descended to 3,500 feet and handed off to the center final controller as soon as possible after starting.

CENTER FINAL POSITION. Accepted handoffs from the right vector controller at 4,500 feet and from the left vector controller at 3,500 feet. Traffic was vectored to the final approach course for Runway 36C and descended to cross Gate Approach Center (GAC) level at 3,000 feet. When ILS approach clearance was acknowledged by the pilot, the aircraft was instructed to monitor the 36C monitor controller's frequency.

LEFT FINAL POSITION. Accepted handoffs from the left vector controller at WLV and POR. The aircraft were vectored to the VOR 200 radial, prior to Gate Approach Left (GAL) for an ILS approach to Runway 36L. All traffic was level at 1,500 feet prior to passing GAL. When ILS approach clearance was acknowledged by the pilot, the aircraft was instructed to monitor the 36L monitor controller's frequency.

RIGHT FINAL POSITION. Accepted handoffs from the right vector controller at WRV and STA. The aircraft were vectored to the VOR 160 radial, prior to Gate Approach Right (GAR) for an ILS approach to Runway 36R. All traffic was level at 2,000 feet prior to passing GAR. When ILS approach clearance was acknowledged by the pilot, the aircraft was instructed to monitor the 36R monitor controller's frequency.

CENTER MONITOR POSITION. Responsible to monitor the final approach path from GAC to the end of Runway 36C. This controller must take whatever action is necessary to prevent a confliction between an aircraft on approach to Runway 36C and any other aircraft.

LEFT MONITOR POSITION. Responsible to monitor the final approach path from GAL to the end of Runway 36L. This controller must take whatever action is necessary to prevent a confliction between an aircraft on approach to Runway 36L and any other aircraft. When only two monitor controllers were utilized, the left monitor assumed the duties of the center monitor in addition to his own.

RIGHT MONITOR POSITION. Responsible to monitor the final approach path from GAR to the end of Runway 36R. This controller must take whatever action is necessary to prevent a confliction between an aircraft on approach to Runway 36R and any other aircraft.

COORDINATOR. Responsible for balancing the flow of traffic to the three runways. This was accomplished by diverting traffic from over POR and STA to WAY for approach to the center runway. This position was responsible for assigning intervals to the right and left vector controllers which would permit a smooth and uninterrupted flow of traffic through the three final positions. He must be ready to stop traffic whenever the approach system is about to become overloaded.

The above position (coordinator) was utilized during shakedown and training runs, but eliminated during data collection periods when it was found to be unnecessary.

The air traffic control specialists were briefed on the project objectives and shown the hypothetical geography in which they would operate. They then made 16 trial simulations which served both to train the controllers in the system and debug the DSF programs.

There then followed 20 simulation runs during which data were taken. Since the controllers were encouraged to refine the ATC procedures, some of the statistical data which were collected are not as valid as they would have been had the ATC procedures remained constant throughout. However, had the controllers not been given some latitude in this area, their comments, which form the basis of this report, would not have been nearly as meaningful. Such statistical data which are significant to this project are included in the appendix.

Five simulation runs were made under each of the following set of conditions:

- Phase I. Two monitor controllers;
  80 percent Mode C radar beacon data available.

- Phase II. Two monitor controllers;
  90 percent Mode C radar beacon data not available.

- Phase III. Three monitor controllers; 80 percent Mode C radar beacon data available.

- Phase IV. Three monitor controllers; 90 percent Mode C radar beacon data not available.

Controller comments and observations were collected during and after each run. The runs were 1 hour and 15 minutes long. The first 15 minutes were allowed for traffic buildup. Some measurements of controller workload, communications, and flight delays were collected during the last 60 minutes. These data were reduced and analysed by the existing DSF data reduction and analysis (DR&A) programs.

RESULTS.

These results are entirely subjective and were obtained from controller observations and debriefings during the simulation activities and several comprehensive post-project conferences which followed. Each aspect of these results is a consensus of all controller input.

All the controllers agreed that, using the ATC procedures stipulated for this evaluation, a set of triple runways could be saturated with arrival traffic. This conclusion was supported by a count of arrivals which averaged 118.6 aircraft per hour in Phases I and II and 113.4 in Phases III and IV. The overall average for each of the three runways for all phases is 38.7 arrivals per hour which represents a fairly high volume of traffic.

The arrival rate on the center runway was found to be substantially lower than either of the two outer runways.

This was because aircraft approaching the outer runways flew shorter final approaches allowing for more opportunity to exercise speed controls and vector techniques prior to turn-on which resulted in closer intervals between arrivals.

The following corollaries concerning simultaneous instrument approaches were developed by the controllers after this simulation experience.

AIRSPACE. The airspace provided for the conduct of simultaneous approaches during this simulation was satisfactory. Any other airspace arrangement which would provide similar latitude for vectoring and spacing traffic would suffice.

VECTORING OPERATIONS. As long as the traffic entering the approach control airspace has descended below 10,000 in altitude, reduced airspeed to 250 knots or less, and some interval between aircraft has been established, the vector controllers were able to perform their designated functions. Namely, they could provide the final controllers with air traffic which was at the altitude, speed, and interval specified. The final controllers had no difficulty in maintaining a proper flow of traffic and initiating final approach clearances.

MONITORING OPERATIONS. In commenting on this aspect of the test, the controllers indicated that the following conservative attitudes were no doubt a result of the abnormal number of breakouts and missed approaches which occurred throughout the simulation, due to equipment malfunction. They felt that an "ideal" monitoring operation (Figure 5) would function in the following manner:

1. Aircraft approaching the outer runways would be vectored to VOR radials which would guide them to the ILS courses. These radials need not be associated with a VOR located on or near the airport--as it was in this simulation. The VOR(s) need only to be close enough to provide radials which would ensure accurate intercept angles of 20 ° or less. In a sense, these radials then become an angular extension of the ILS courses. Aircraft could be vectored to any point on a radial, or vectored to it from either side. This provides the latitude for a vector controller to extend the turn-on point along a radial while the ILS intercept point remains constant. It is essential to the monitoring operation that the monitor controller know exactly where the aircraft will turn on the ILS in order to be able to properly monitor the turn-on. Aircraft landing on the center runway may be vectored to the ILS course from either side in the manner used for single ILS approaches.

2. Turn-on points should be staggered with aircraft separated by 1,000 feet vertically (as opposed to the 500-foot vertical separation used during simulation) until established on the ILS course. The highest aircraft would be 3,000 feet above ground level (AGL) when turned on at a distance of at least 15 miles from the runway threshold. The next aircraft should be turned on at 13 miles from the runway threshold at 2,000 feet AGL. The last aircraft would turn on at 11 miles from the runway threshold at 1,000 feet AGL. These figures assume 3° glide slopes to three runways with level thresholds, and could be varied as these assumptions vary. The staggered turn-on points produced by this configuration increased controller confidence in the system by eliminating the chance of simultaneous overshoots. The controllers felt strongly that this feature should be included in any triple parallel situations until actual experience indicates it is not necessary.

3. In the case of the center runway, the monitoring controller's responsibility would begin 15 miles from runway threshold or on the center ILS, which may or may not include the turn-on. The left and right final controllers would be responsible for the last 15 miles of an aircraft's approach, including the turn-on. These procedures would ensure that a monitoring controller would not be responsible for more than five aircraft at any one time--a strong recommendation of the subject controllers. The monitor controllers should be in close physical proximity to each other to facilitate coordination, possibly situated around a single horizontal radar display. Each monitor should have a discrete frequency and should check communications with each aircraft on that frequency in order to ensure that each aircraft can be positively controlled by the appropriate monitor. Because triple approaches are far more critical to monitor than dual approaches, this frequency should not be shared with a local controller.

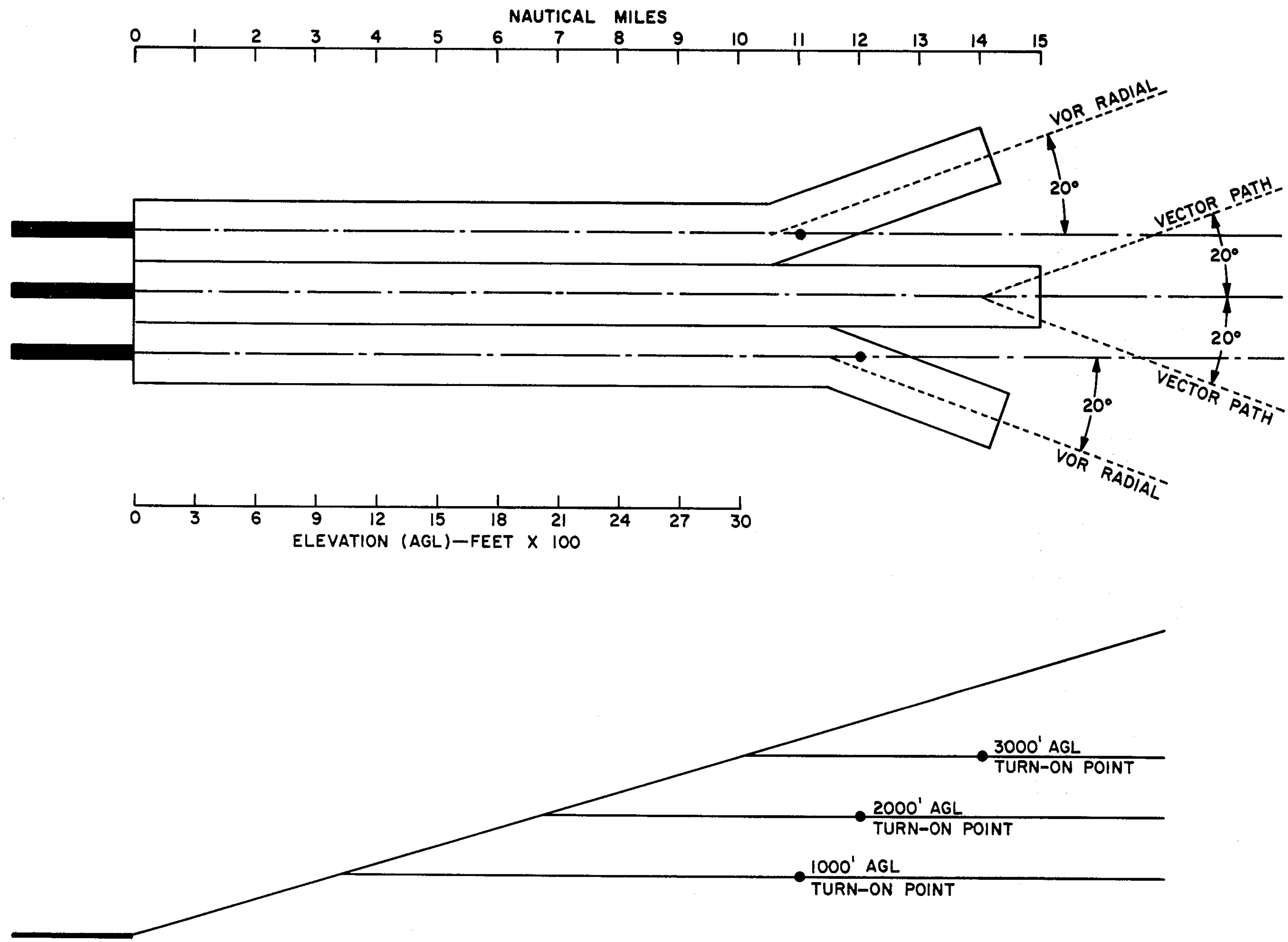


FIGURE 5. IDEAL MONITORING OPERATION

4. In the case of a relatively small departure from the ILS course, radar advisories are issued to the pilot. If an excursion from the course is not corrected, an aircraft on an adjacent course which might be endangered by the erratic aircraft must be diverted from his course. The controllers found that once all three aircraft were descending along the glide path, the Mode C altitude readout on the data tags was of little or no value. Aircraft must be vectored clear of one another regardless of indicated altitude. If some form of vertical separation was found to exist, it was considered a bonus.

SUMMARY OF RESULTS

It was determined that by the use of normal ATC procedures, three parallel runways could be simultaneously saturated with arrival traffic. This operation could be easily conducted within the boundaries of airspace normally associated with a terminal arrival area.

Aircraft-derived altitude data, presented to the controllers as part of alphanumeric tags, were found to be most useful in the vector airspace. Once the aircraft were established on the glide path, and each aircraft's altitude was constantly changing, the monitor controllers could not assimilate and evaluate the relative altitudes quickly enough to use them for safe separation of traffic.

The controllers felt that the use of VOR radials to provide navigational guidance to the outboard ILS final approach courses greatly enhanced the safety of the system.

CONCLUSIONS

Based on the simulation tests and controller opinions it is concluded that:

1. Simultaneous IFR approaches to triple parallel runways can be conducted.

2. Under the heavy traffic conditions simulated, each monitor controller is able to handle a maximum of five aircraft at one time.

3. Three monitor controllers are required whenever approaches are conducted simultaneously to the three runways and the number of aircraft per monitor controller is five. However, one controller is able to monitor two runways provided that the total number of aircraft under his control does not exceed five.

4. The value of Mode C (aircraft-derived altitude data) is negligible once the aircraft are established on the ILS glide slope.

5. A combination of staggered turn-ons with 1,000-foot altitude separation at turn-on improves controller confidence in the system.

6. Some aspects of multiple approaches not resolved by this study are:

   a. Procedures and separation criteria when heavy jets are included in the traffic.

   b. The effects of STOL aircraft and procedures.

   c. Segregation of arrivals destined for various areas on the airport.

   d. Segregation of arrivals based on category (i.e., STOL, regular jets, heavy jets, propeller aircraft, etc.).

   e. Effect of missed approaches, aborted approaches, and departures on arrival procedures.

   f. Configurations of more than three parallel runways.

APPENDIX

STATISTICAL ANALYSIS OF DATA

Inasmuch as the DSF programs had undergone considerable modifications just prior to the inception of this project activity, and time did not permit the complete debugging of these programs, there were many minor program problems which occurred throughout the simulation. These problems often interfered with smooth operation of the simulation and introduced spurious data in the form of an abnormal number of missed approaches and breakouts. Such data as are included here are presented to give the reader a general overlook at controller workload and traffic capacities.

The three tables show monitor controller workload. Table A-1 is associated with communications and Table A-2 is associated with number of aircraft being controlled. The tables are broken down by individual controllers and phases.

Table A-3 contains two examples of minimum and maximum number of aircraft on a monitor controller frequency at any given 1-minute interval. The top list shows right monitor controller and left monitor controller. The right monitor controller was monitoring Runway 36R and the left monitor controller was monitoring Runways 36L and 36C. The right monitor controller had a minimum of only one aircraft and a maximum of four aircraft. The left monitor controller had a minimum of five aircraft and a maximum of 10 because he was responsible for two runways.

The bottom list shows all three monitor controllers, each responsible for only one runway. Controller Number 15 (center monitor) had a few more aircraft because his turn to final point was 8 miles further from the end of the runway than the other two monitor controllers.

TABLE A-1. MONITOR CONTROLLER WORKLOAD

	Right Monitor		Left Monitor		Center Monitor
	Phase I & II	Phase III & IV	Phase I & II	Phase III & IV	Phase III & IV
Total Number of Contacts During 10 Hours	590	260	990	*	300
Average Contact Time (Seconds)	2.1	2.6	2.4	*	2.8
Average Number of Contacts per Aircraft	12.8	5.9	10.9	*	7.5
Average Talk Time per Aircraft (Seconds)	2.8	1.5	2.5	*	1.7
Total Vectors During 10 Hours	22	10	43	28	26
Total Altitude Changes During 10 Hours	3	5	17	17	4
Total Speed Changes During 10 Hours	172	178	324	102	147

*Communications data lost for several runs during Phases III & IV due to equipment malfunction.

TABLE A-2. TRAFFIC VOLUME

	Right Monitor Phase I & II	Right Monitor Phase III & IV	Left Monitor Phase I & II	Left Monitor Phase III & IV	Center Monitor Phase III & IV
Average Number of Aircraft Controlled per Hour	45.9	46.1	90.3	41.9	40.7
Peak Number Aircraft Controlled per Hour	47	42	93	38	50
Aircraft per Minute	3.4	3.4	7.7	3	4
Average Number of Aircraft Landed per Hour	42	43	76	37	34

SIMULTANEOUS CONTROL LOAD - ONE MINUTE INTERVALS - START TIME 12:15: 0

INTERVAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
CONTROLLER 1																														
MINIMUM	3	2	2	1	2	3	3	2	3	2	2	2	3	3	2	2	2	2	1	2	2	2	2	1	1	1	1	2	2	2
MAXIMUM	3	3	3	2	3	4	4	3	3	3	3	3	3	3	3	3	3	2	2	2	3	3	3	2	2	2	2	3	2	3
CONTROLLER 2																														
MINIMUM	6	5	5	6	6	6	5	6	7	7	7	6	7	8	7	5	5	5	5	5	6	6	6	8	7	7	7	7	6	7
MAXIMUM	7	7	7	8	8	7	7	8	8	8	8	7	9	10	9	7	8	8	5	8	8	7	8	9	8	9	9	9	8	7

SIMULTANEOUS CONTROL LOAD - ONE MINUTE INTERVALS - START TIME 9:15: 0

INTERVAL	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
CONTROLLER 1																														
MINIMUM	3	3	3	2	1	3	3	4	4	3	3	3	3	3	3	3	3	3	3	3	3	3	4	3	3	3	4	3	3	3
MAXIMUM	4	4	3	3	3	4	4	5	5	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	5	4	4	4
CONTROLLER 2																														
MINIMUM	1	1	2	2	2	2	2	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	2	2	2	2	2	2	2
MAXIMUM	2	2	3	3	3	3	3	3	3	3	3	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	3	2
CONTROLLER 15																														
MINIMUM	3	4	4	3	3	3	3	4	3	4	3	3	3	3	4	4	4	4	4	3	3	3	2	3	3	3	3	3	3	3
MAXIMUM	4	5	4	4	4	4	4	4	4	4	4	4	4	4	4	5	5	5	5	5	4	4	3	4	4	4	4	4	4	4

END OF DATA PERIOD - END TIME 10:14:59

NOTE: CONTROLLER No. 1 - RIGHT MONITOR
CONTROLLER No. 2 - LEFT MONITOR
CONTROLLER No. 15 - CENTER MONITOR

TABLE A-3. TYPICAL MAXIMUM AND MINIMUM NUMBER OF AIRCRAFT ON MONITOR CONTROLLER FREQUENCY