Simulation Tests for Army Air Traffic Control

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SIMULATION TESTS FOR ARMY AIR TRAFFIC CONTROL*

SUMMARY

This report describes the testing of a number of concepts which have been proposed to meet the specialized requirements of Army aviation during the next few years. These concepts cover such subjects as airway structures, airport designs, and navigation and scheduling procedures, to define a simplified system for the control of large numbers of logistic and support aircraft in almost complete radio silence. Some of the ideas developed specifically for this program may have future applications in the Common System of air traffic control and navigation, particularly in the handling of new types of aircraft in high-density interurban operations.

INTRODUCTION

Since the Korean War, development efforts in Army aviation have been pointed toward the goal of air mobility; that is, making the ground forces almost completely transportable by air, and creating a means for moving, supporting, and supplying them by air. In line with this objective, the air-traffic study covered by this report is the third in a series sponsored by the Department of the Army and conducted through the use of simulation facilities at the Technical Development Center (TDC) of the Civil Aeronautics Administration.

Previous simulation programs explored a number of traffic-control procedures, traffic patterns, and control displays for tactical airlift operations.[1,2] This work resulted in implementation of the "Army Freeway System," a model airway system installed in the Fort Huachuca, Arizona, test area. This airway installation was based on the use of one-way routes and conventional air route traffic control procedures. Navigation facilities consisted of low-frequency homing aids, four-course radio ranges, very-high-frequency (VHF) omniranges, and fan markers. Surveillance radar was used for terminal-area traffic control.

A representative tactical airway system connecting Army, corps, and division areas is shown schematically in Fig. 1. A system of this type experiences many of the fundamental air traffic control problems of the so-called "Common System." In the tactical airlift system many of these problems are simplified somewhat, due to the relatively small number of terminal airports and standardization of aircraft types. On the other hand, the tactical airlift must fulfill its objectives under three restrictive conditions which are not encountered in the Common System:

1. Army aviation must operate in an inherently hostile environment. For maximum security against enemy detection and jamming, air/ground communications must be reduced to a bare minimum.
2. Partly because of interservice policy agreements and partly for protection, Army aircraft must be flown at the lowest altitudes available. This inhibits the use of vertical stacking procedures and limits the utility of radar for air traffic control.
3. The shortage of military personnel and lack of time available to train the average soldier during his brief sojourn in the service make it desirable to develop drastically simplified control procedures which require only a relatively low level of controller skill for successful operation of the system.

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*Report submitted for publication March 1957.

[1] Tirey K. Vickers, "Development of Traffic Control Procedures for Tactical Airlift Operation," CAA Technical Development Report No. 235, April 1954.

[2] C. M. Anderson and T. K. Vickers, "Simulation Tests of a Tactical Airway System," CAA Technical Development Report No. 279, October 1955.

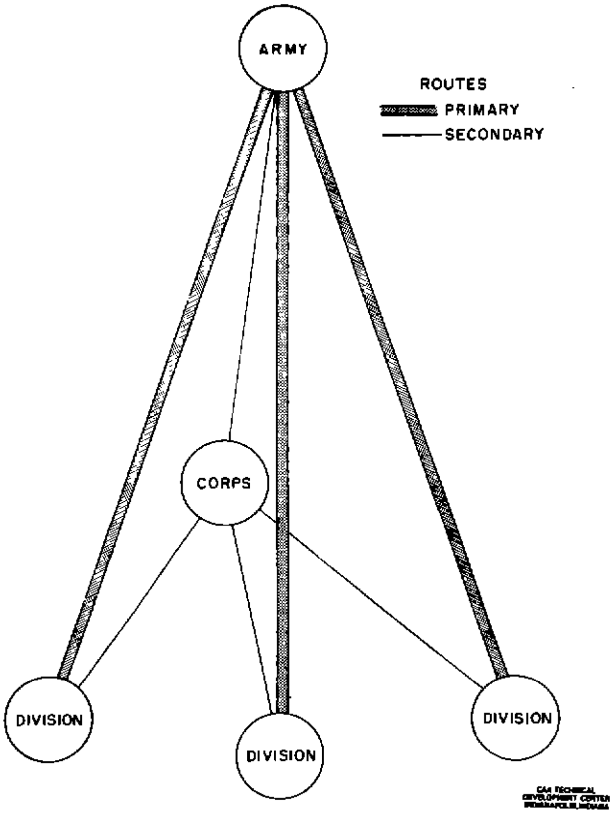


Fig. 1 Schematic Diagram of Tactical Airlift System

New concepts for future Army aviation operations include changes and improvements in the following general areas:

1. Basing all navigation on a high-accuracy area-coverage system which includes in each aircraft a pictorial navigation display for the pilot.
2. Developing route structures, traffic patterns, and airport designs to exploit the capabilities of the new navigation system.
3. Developing new airway-control concepts to eliminate routine radio communications as well as the need for an en route traffic-control center.
4. Developing new control procedures to handle air-support activities in the division areas and to integrate these operations with the logistic (airlift) operations at the division airports.

The purpose of the dynamic simulation program described in this report was to explore, develop, and evaluate these concepts prior to flight tests by the Aviation Department of the Army Electronic Proving Ground (AEPG).

TEST ASSUMPTIONS

Aircraft.

The following aircraft characteristics were simulated during this program:

Aircraft Type	Speeds Climb	 Cruise (miles per hour)	 Approach	Rate of Climb (feet per minute)	Rate of Descent (feet per minute)	Rate of Turn (degrees per second)
Conventional Fixed-Wing	100	100	100	300	500	3
Rotary-Wing	60	60	60	300	500	3
Short Takeoff and Landing (STOL) Fixed-Wing	40	120	40	600	600	3

The relatively low performance level of the first two aircraft types reflects the reduced values which have been encountered in flying present types of Army aircraft in the high-altitude, high-temperature, Fort Huachuca test environment.

During the simulation tests it was assumed that instrument flight by rotary-wing aircraft was an operational reality and that such aircraft would be able to execute instrument approaches in any direction regardless of wind, turning into the wind only for touchdown. It was assumed that conventional and STOL fixed-wing types would be able to execute straight-in approaches in upwind and crosswind directions only.

Navigation Systems.

The AEPG has installed a Decca chain to provide high-accuracy navigational coverage over the Fort Huachuca test area. This is a hyperbolic system employing one master station and three slave stations arranged as shown in Fig. 2. The Decca system was used first by AEPG as a measuring tool to check the actual navigational errors encountered in flying other systems. Because all continuously operating radio transmitters now must be considered potential targets for enemy homing missiles, it appears probable that navigation guidance for Army aviation operations ultimately will be obtained from some type of self-contained navigation system. Pending the development and production of suitable self-contained navigational equipment, AEPG has decided to use the Decca chain as a navigational system during flight tests of the new operational concepts. The present Decca system employs a pictorial navigation display for the pilot. The characteristics of this system permit three-dimensional delineation of closely spaced multilane airways which can follow valleys if necessary and can hug the contours of the terrain for protection. The cockpit display provides the pilot with a continuous position indication and, indirectly, with a ground-speed reference.

The accuracy of hyperbolic systems is illustrated generally by contour diagrams as shown in Fig. 2 where each contour represents a constant level of accuracy. In general, accuracy is highest near the center of the transmission chain and decreases with range. The coverage of the system, in terms of range from the transmitting stations, is a function of the accuracy required. In certain self-contained navigation systems, position errors can be expected to increase as a function of the distance flown as shown in Fig. 3. This characteristic may require intermittent use of external navigation aids for periodic corrections of aircraft position along extended courses or prior to starting instrument approaches.

Communications.

In the simulation tests of the new concepts, it was assumed that all airports were linked by land-line or microwave telephone or teletype. Throughout the system, except in the rear (Army) area, air/ground radio communications were relegated to emergency use only. Most traffic-control clearances were completed prior to takeoff so that the necessary transfer of information could be conducted by means of visual signals, or by the physical transfer of written records. Once airborne, it was assumed that all pilots would stand by on a common channel to intercept special instructions or to report unusual situations.

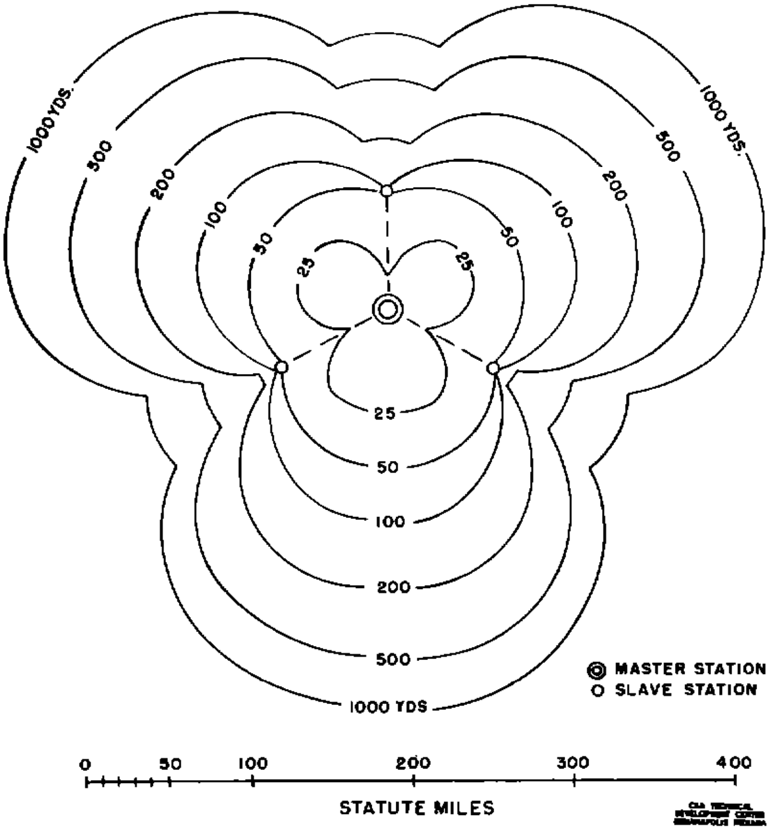


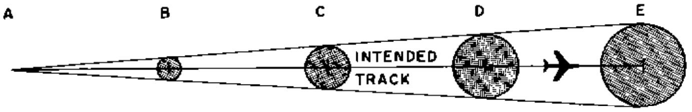
Fig. 2 Typical Day - Accuracy Contours for Hyperbolic Navigation System (Decca)

TRAFFIC-CONTROL CONCEPTS

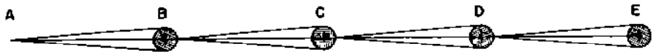
Airway-Scheduling Procedures.

Previous en route air traffic control concepts have been based on predicted airspace occupancy (moving-block principle) or on the assignment of airspace which previously has been reported vacant (fixed-block principle). Both concepts require extensive air/ground communications. Therefore, the military necessity to operate the traffic-control system in almost complete radio silence requires the development of new concepts quite different from those previously used.

The navigation system assumed for this operation includes the use of pictorial navigation displays in the aircraft. This permits the establishment of definite tracks from airport to



POSITION ERROR UNCORRECTED ON COURSE FROM A TO E



POSITION ERROR ON SAME COURSE CORRECTED AT POINTS B, C AND D.

Fig. 3 Buildup of Navigation Errors in Self-Contained System airport, incorporating the transition paths from takeoff runway to airway and from airway to landing runway. This feature completely standardizes the tracks of successive aircraft, thus eliminating one of the most important sources of flight-time variations. In addition, it is possible to standardize cruising speeds by assigning only one type of aircraft to any specific traffic lane. Using these principles, it becomes practical to design a traffic-control system based on standardized flight schedules, with aircraft separation established by the controllers prior to takeoff and maintained in flight by the pilots themselves through adjustments of flight path or power. The result is a self-contained traffic-control system which functions without any routine air/ground radio communications.

One of the most effective methods of simplifying traffic-control procedures is to establish, where possible, one-way traffic lanes which are completely independent of all other lanes from takeoff to landing. Normally such an arrangement becomes practical only with the aid of a high-accuracy navigation system permitting multilane airways.

Avoidance of converging flight paths can simplify the traffic controller's job to a single basic procedure, the provision of adequate separation between successive takeoffs to prevent overtakes along the route. The establishment of diverging traffic lanes, branching off the original route, does not complicate this simple procedure. If such lanes diverge immediately after takeoff, a single takeoff lane can feed several routes without restricting traffic flow on any of them. A typical chart, used by the controller in dispatching traffic on several independent lanes, is shown in Fig. 4.

For operations on any traffic lane which converges with another lane, the traffic-control system must perform the function of integration, or the proper merging or coordination of aircraft from different lanes into the common stream of traffic. A simple method of traffic integration developed during the previous simulation programs involves use of a flight-reservations chart as shown in Fig. 5. Here a number of definite time reservations are established at the merging point, and the scheduled flight times from the various points of takeoff to the merging point are subtracted from each reservation time to establish definite takeoff times for each route of flight.

The airway-clearance procedures developed for the simulation runs are shown schematically in Fig. 6. It will be noted that the initial separation between aircraft on independent traffic

SKED NO.	DIVISION I				DIVISION 2				DIVISION 3				ARMY					
	1A		1B		2A		2B		3A		3B		4A		4B		4C	
	IDT	OFF	IDT	OFF	IDT	OFF	IDT	OFF	IDT	OFF	IDT	OFF	IDT	OFF	IDT	OFF	IDT	OFF
1	54	1027	55	1030	71	1010	72	1011	22	1000	23	1003	19	1000	18	1001	15	1002
2	36	1032	56	1037	75	1015	49	1016					17	1005	36	1010	37	1013
1	27	1037	42	1042	77	1020	51	1021					92	1016	93	1018		
2	28	1045	48	1049	43	1025												
1	31	1050	21	1054														
2	35	1107																
1	39	1112																
2																		
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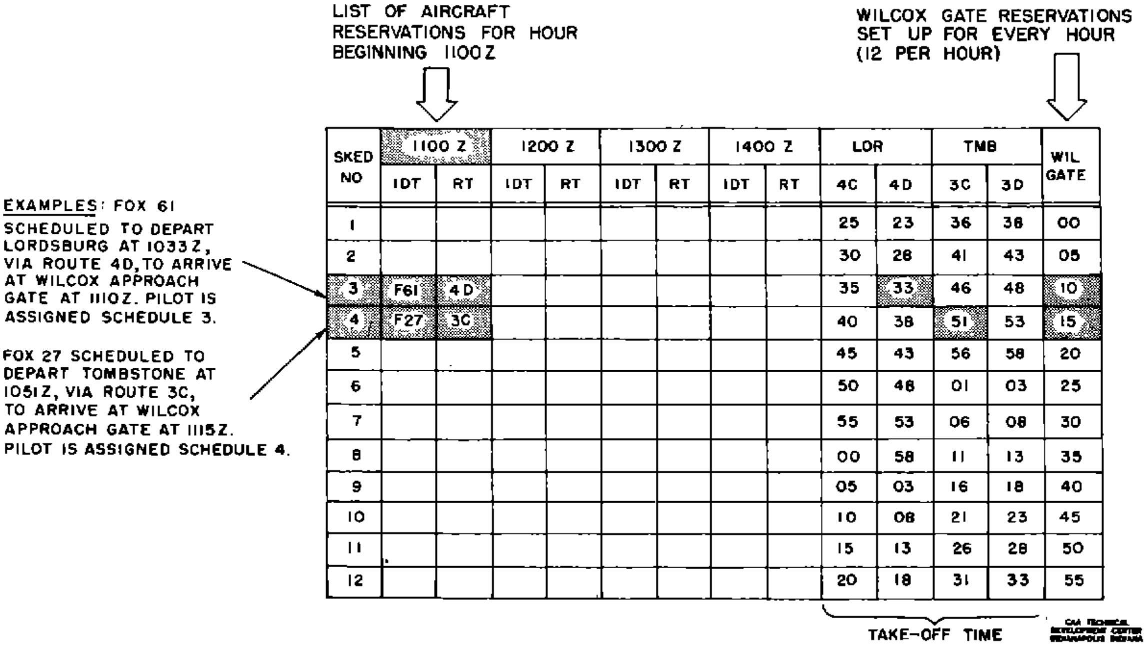
Fig. 4 Sample Departure Control Chart for Independent Airway Routes



LIST OF AIRCRAFT RESERVATIONS FOR HOUR BEGINNING 1100Z

WILCOX GATE RESERVATIONS SET UP FOR EVERY HOUR (12 PER HOUR)

EXAMPLES: FOX 61 SCHEDULED TO DEPART LORDSBURG AT 1033Z, VIA ROUTE 4D, TO ARRIVE AT WILCOX APPROACH GATE AT 1110Z. PILOT IS ASSIGNED SCHEDULE 3.

FOX 27 SCHEDULED TO DEPART TOMBSTONE AT 1051Z, VIA ROUTE 3C, TO ARRIVE AT WILCOX APPROACH GATE AT 1115Z. PILOT IS ASSIGNED SCHEDULE 4.

SKED NO	1100 Z		1200 Z		1300 Z		1400 Z		LOR		TMB		WIL GATE
	IDT	RT	IDT	RT	IDT	RT	IDT	RT	4C	4D	3C	3D	
1									25	23	36	38	00
2									30	28	41	43	05
3	F61	4D							35	33	46	48	10
4	F27	3C							40	38	51	53	15
5									45	43	56	58	20
6									50	48	01	03	25
7									55	53	06	08	30
8									00	58	11	13	35
9									05	03	16	18	40
10									10	08	21	23	45
11									15	13	26	28	50
12									20	18	31	33	55

TAKE-OFF TIME

Fig. 5 Flight Reservation Chart for Merging Routes - Lordsburg and Tombstone to Wilcox - 100 mph Schedule

lanes is established by the traffic-control agency at the departure airport; on converging traffic lanes, separation is established by the control agency at the arrival airport.

Logistically, it is advantageous to operate flight schedules at as high a speed as possible, thereby completing a maximum number of flights within a given period. In setting up flight schedules which must be followed precisely in order to maintain separation between aircraft, however, it is necessary to incorporate some "slack" in the system. This may be done by basing all schedules on the use of a reduced airspeed well within the performance capabilities of the aircraft so that the pilot normally has a margin of power which can be used to get back on schedule if he should find himself running late for any reason.

Another method is to employ a form of path-stretching for all aircraft which are not running late so that any aircraft which is slightly behind schedule can take a short cut and get back on schedule immediately as shown in Fig. 7. This procedure has the disadvantage of requiring additional airspace; therefore, it would not be recommended for use on closely spaced multilane routes.

On independent traffic lanes, takeoffs may be cleared at random times as long as sufficient separation exists behind the preceding aircraft. For this reason, detailed flight schedules used on such routes consist only of "plus times;" that is, elapsed times which the pilot adds to his recorded takeoff time to establish his scheduled times over each checkpoint. An example of this type of schedule is shown in Fig. 8.

On merging traffic lanes, the entire flight including the takeoff time is prescheduled in order to provide proper separation from other aircraft at the merging point. Detailed flight schedules for each route are made up of definite "clock times" (minutes after the hour) as shown in Fig. 8. All clocks used by aircraft in this system must be synchronized because any error would tend to compromise the safe separation of aircraft in the system.

During the simulation program pilots followed pictorial navigation displays marked off in ten-mile increments of flight distance along each route. Flight schedules were checked and adjusted at each ten-mile checkpoint. It was found advantageous to stagger the checkpoints for successive aircraft as shown in Fig. 9. This procedure prevented the accrued schedule errors of successive aircraft from reaching their maximums simultaneously. It thus tended to maintain a more positive degree of separation between aircraft.

En Route Separation Standards.

Because the capacity of a traffic lane is inversely proportional to the amount of separation between aircraft, traffic capacity can be increased by reducing the separation to some practical minimum, determined from a statistical analysis of the actual flight-time variations encountered in test runs of the system. Figure 10 shows an analysis of schedule variations encountered during simulation tests of a tactical airlift system. The data are plotted on probability paper. In such a plot a normal distribution of variations closely follows a straight line, and the standard deviation can be obtained by measuring the value of the variation plot at an ordinate 34 per cent from the mean value. Knowing the standard deviation, it is possible to set up separation standards to reduce the risk of overtake to any predetermined value on a calculated risk basis. This may be accomplished through reference to a table of probability integrals. A practical application of this principle is shown in Fig. 11.

In determining safe separation standards for actual flight operations, the results of the simulation runs cannot be applied directly because the sources of error in the two systems are quite different and the degree of correlation is not established. It appears that scheduling errors and pilot workload could be reduced by provision of a direct-reading ground-speed indicator in the cockpit.

Airborne-Spacing Devices.

The function of the scheduling procedure is to prevent overtakes in the traffic lane. Using a more direct approach, it appears that this function could be performed with considerable increase in traffic capacity through the adoption of a simple type of aircraft-proximity indicator.

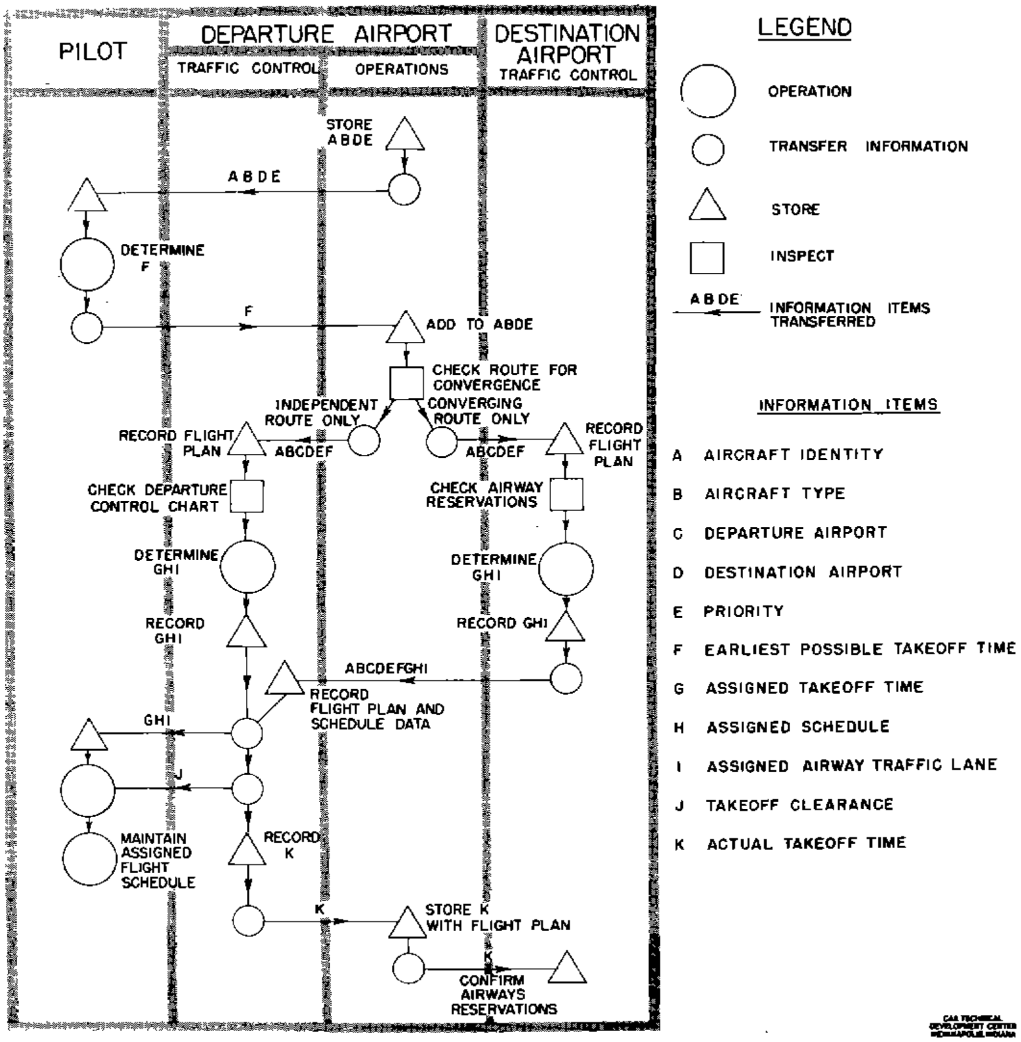


Fig. 6 Flow Chart - Airway Clearance Procedures

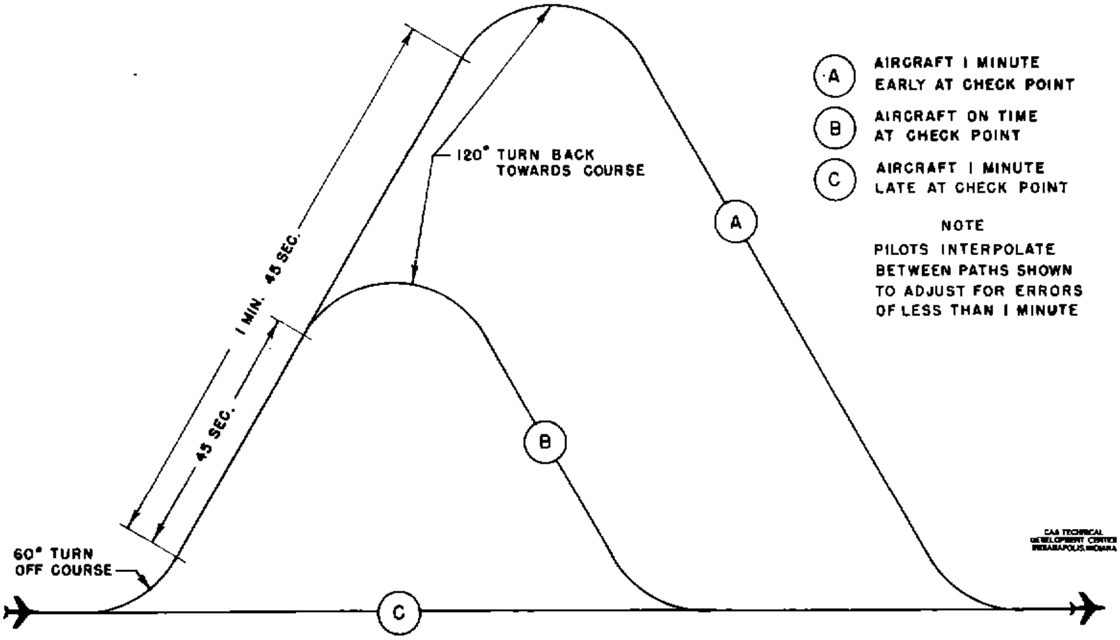


Fig. 7 Path-Stretching Maneuvers for Adjustment of Flight Schedules

INDEPENDENT ROUTES 120 M.P.H.

MILES		5	10	15	20	25	30	35	40	45	50	55	60
MINUTES	SKED 1	2.5		7.5		12.5		17.5		22.5		27.5	
FROM TKOF	SKED 2		5		10		15		20		25		30

MASTER SCHEDULE FOR ALL
INDEPENDENT TRAFFIC LANES

ROUTE 4C LORDSBURG TO WILCOX 100 M.P.H.

SKED NO	OFF LOR	MILES											WIL GATE
		5	10	15	20	25	30	35	40	45	50	55	59
1	25	28		34		40		46		52		58	00
2	30		36		42		48		54		00		05
3	35	38		44		50		56		02		08	10
4	40		46		52		58		04		10		15
5	45	48		54		00		06		12		18	20
6	50		56		02		08		14		20		25
7	55	58		04		10		16		22		28	30
8	00		06		12		18		24		30		35
9	05	08		14		20		26		32		38	40
10	10		16		22		28		34		40		45
11	15	18		24		30		36		42		48	50
12	20		26		32		38		44		50		55

ROUTE SCHEDULE FOR
MERGING TRAFFIC LANES

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Fig. 8 Examples of Detailed Flight Schedules Using Staggered Check Points

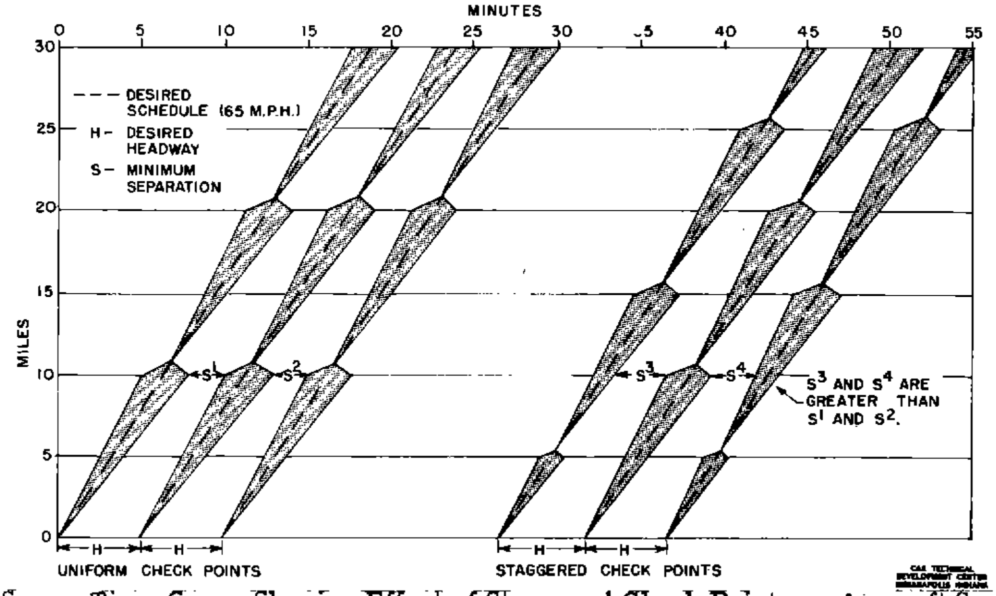


Fig. 9 Space-Time Curve Showing Effect of Staggered Check Points on Aircraft Separation

Adoption of such a device should permit aircraft to proceed along an airway, maintaining a specified minimum separation behind the aircraft ahead. The capacity of a traffic lane in such a system could be expressed:

$$C = \frac{V}{S}$$

Where

C = lane capacity, in aircraft per hour.

V = velocity (ground speed) of aircraft, in miles per hour.

S = separation between aircraft, in miles.

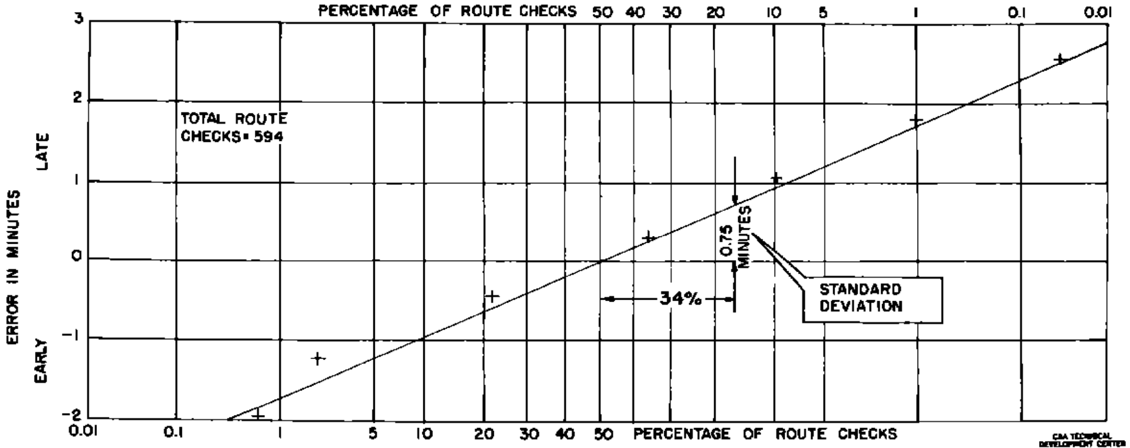
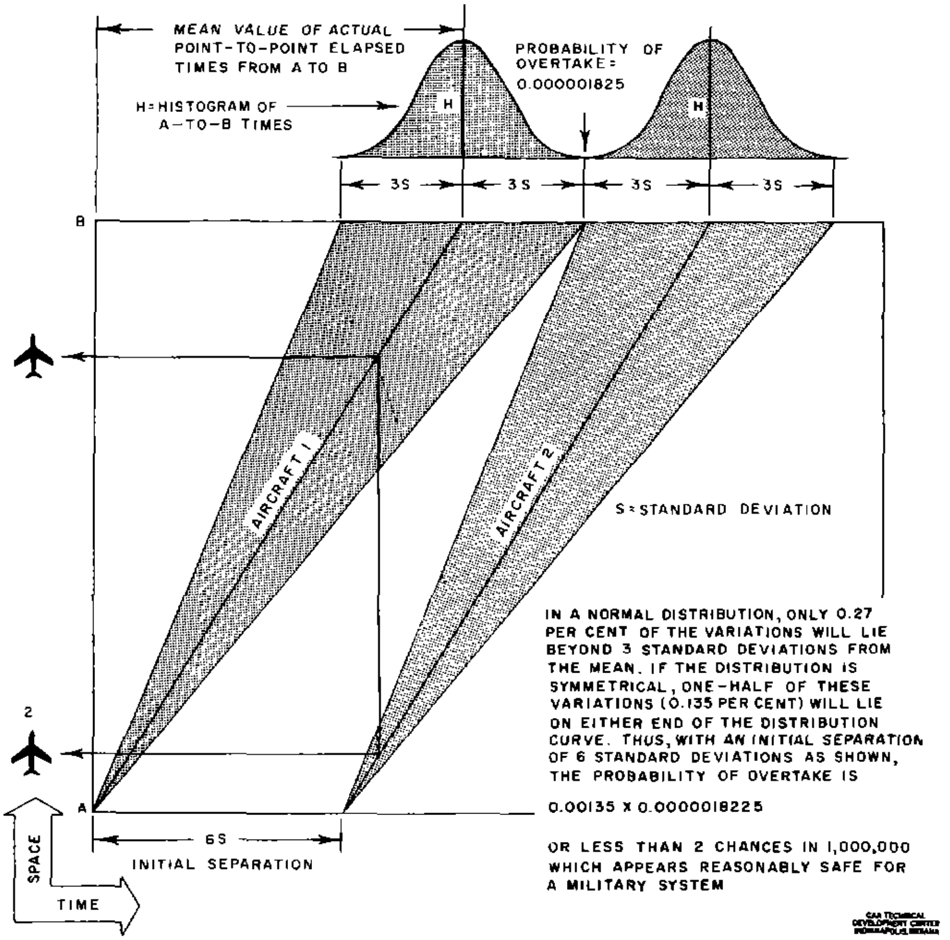


Fig. 10 Analysis of Schedule Errors Encountered at Intermediate Check Points During Two Simulation Runs



IN A NORMAL DISTRIBUTION, ONLY 0.27 PER CENT OF THE VARIATIONS WILL LIE BEYOND 3 STANDARD DEVIATIONS FROM THE MEAN. IF THE DISTRIBUTION IS SYMMETRICAL, ONE-HALF OF THESE VARIATIONS (0.135 PER CENT) WILL LIE ON EITHER END OF THE DISTRIBUTION CURVE. THUS, WITH AN INITIAL SEPARATION OF 6 STANDARD DEVIATIONS AS SHOWN, THE PROBABILITY OF OVERTAKE IS

0.00135 x 0.0000018225

OR LESS THAN 2 CHANCES IN 1,000,000 WHICH APPEARS REASONABLY SAFE FOR A MILITARY SYSTEM

Fig. 11 Space-Time Curve Illustrating Possible Statistical Approach to Determination of Longitudinal Separation Standards

Because of the extremely low altitudes flown on such missions, the use of airborne radar does not appear practicable for this purpose. The use of a low-powered radar beacon system to interrogate the aircraft ahead and to receive a reply indicating its range appears more desirable in that both the interrogation and the reply can be directional and can be coded to eliminate indications from aircraft in adjacent, nonintersecting traffic lanes. The use of such a system, particularly in forward areas, however, might be tactically undesirable due to its susceptibility to enemy detection and vulnerability to jamming.

The use of radioactive (gamma ray) emitters and detectors for aircraft spacing appears intriguing in that the emissions can be directed rearward for detection by a following aircraft. Such emissions normally would be detectable over a very short range, thus almost precluding detection by the enemy. Operationally it appears that a reliable detection range of two miles would be more than adequate for this system. The possibility of coding the emissions by mechanical modulation or other means should be explored as a method of eliminating indications from aircraft in nonintersecting traffic lanes.

TESTS AND RESULTS

Low-Capacity Combined Airport.

The first test simulated the use of a combined airport for conventional fixed-wing and rotary-wing aircraft, using one landing lane for each type. As shown in Fig. 12, two fixed-wing airport-traffic paths were used to accommodate operations under different wind conditions. It was assumed that a surveillance radar was available for monitoring purposes. The main function of the radar was to provide separation between takeoffs and landings as all fixed-wing operations had to use the same runway. Using 5-minute separation in each traffic lane and one flight altitude for each type of aircraft on the arrival and the departure airway, the capacity of this airport was 24 arrivals and 24 departures per hour, assuming full use of all fixed-wing and rotary-wing routes.

Tests indicated that (1) the departure lanes should be relocated to provide better separation between fixed-wing and rotary-wing aircraft; (2) the bypass holding pattern would be more useful for spacing adjustments if it were moved closer to the airport; and (3) the radar monitoring operation would be simplified considerably if the rotary-wing routes were offset from the fixed-wing routes. The modified layout could serve as a model for similar low-capacity combined airports.

High-Capacity Combined Airport.

Using the lessons learned from the initial tests, a high-capacity combined fixed-wing/rotary-wing airport was developed as shown in Fig. 13. Three parallel runways were used for fixed-wing aircraft. The two outer runways, which were spaced one mile apart,

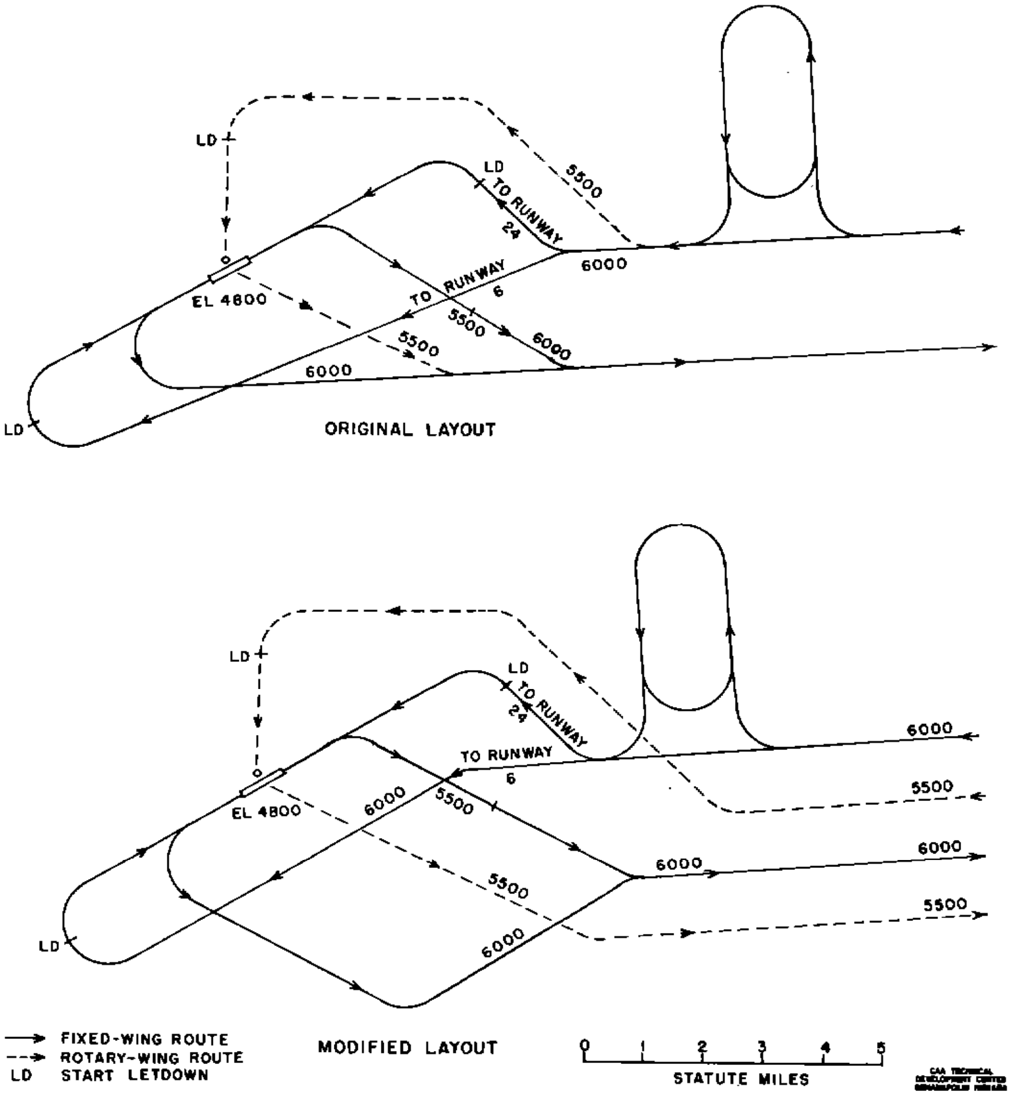


Fig. 12 Low-Capacity Combined Airport

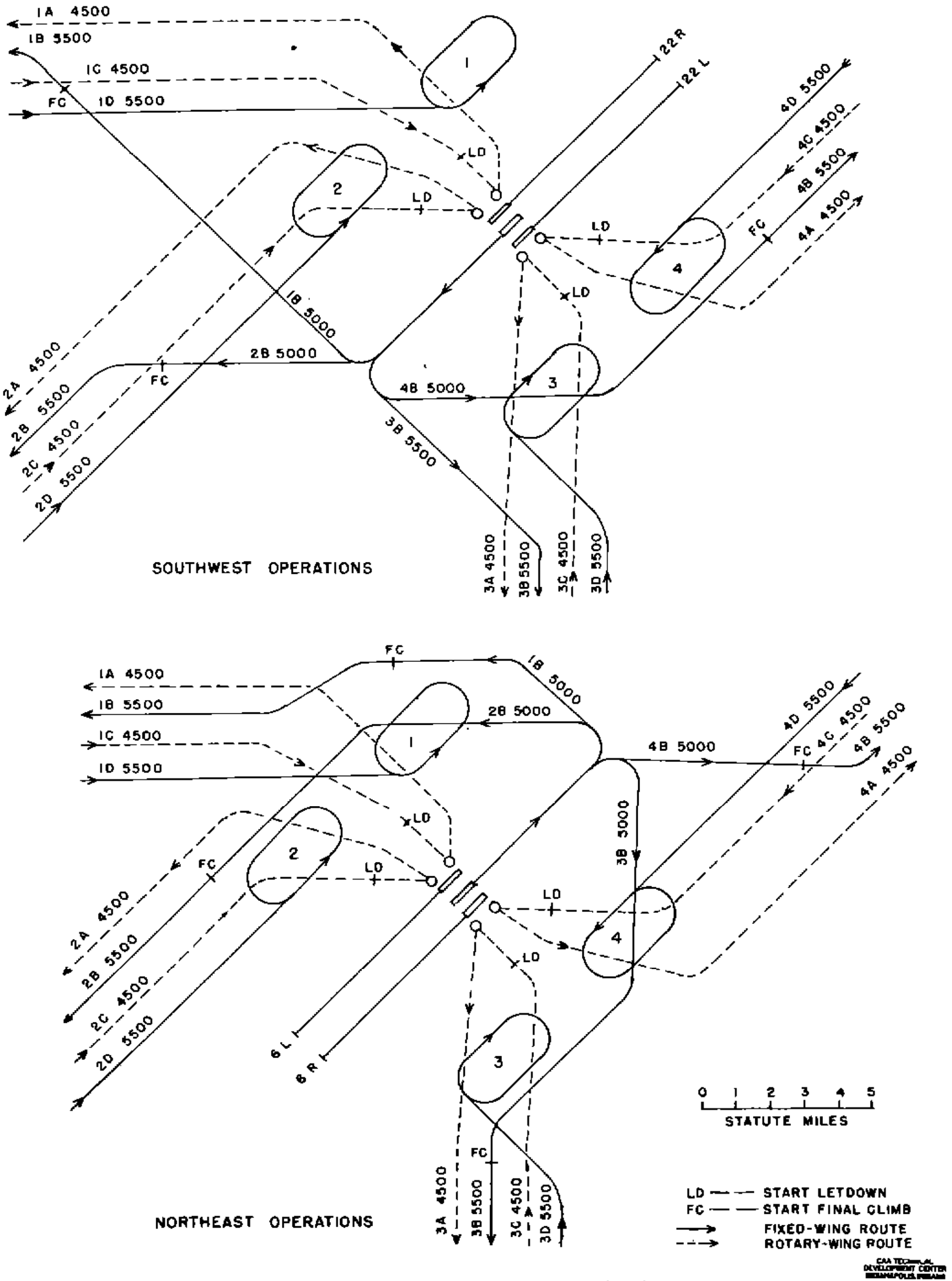


Fig. 13 High-Capacity Combined Airport

were used for landings. The center runway was used for takeoffs. Two radar-approach controllers handled fixed-wing arrival traffic, using radar-vectoring procedures. Obviously this feature required a deviation from the basic objective of operating the system in radio silence. Normally, however, the need for radio silence would be less important at the Army end of the line than anywhere else in the tactical airlift system.

The terminal area was split into two approach-control sectors, with the line of jurisdiction extending along the centerline of the takeoff runway. The workload was simplified by having each approach controller handle only the aircraft arriving in his sector and feed them into the runway on his side of the boundary line. This arrangement permitted the approach controllers and the departure controller to work independently of each other.

Rotary-wing aircraft used four landing pads. Because a separate landing pad was associated with each inbound rotary-wing route, there was no convergence of traffic in any part of the traffic lane and no traffic control was required for rotary-wing approaches. It was assumed that visual signals would be used to clear rotary-wing aircraft from one landing pad to the other. Takeoffs were handled by one or more departure controllers who established time separation on each departure route. Rotary-wing routes had altitude separation from fixed-wing routes, and they were offset from fixed-wing routes to simplify the radar presentation in the terminal area. This airport layout, which could serve as a model for an Army or corps facility, had a theoretical capacity of 96 arrivals and 96 departures per hour, assuming full utilization of all fixed-wing and rotary-wing routes. Yet, each approach controller handled a maximum of only 24 fixed-wing aircraft per hour. This corresponds to an average landing interval of 2 1/2 minutes.

Tangential Stoliport.

In view of a possible trend toward replacement of rotary-wing Army aircraft by STOL fixed-wing types, simulation tests were run on a special type of landing field for STOL aircraft. This field layout, known as a stoliport, served four arrival and four departure lanes. Each lane terminated in a separate runway to avoid in-flight convergence of traffic lanes and the necessity for in-flight traffic control by a ground agency.

Each runway was approximately 500 by 100 feet in area. Runways were arranged tangentially with approach paths separated by 30° as shown in Fig. 14. The stoliport

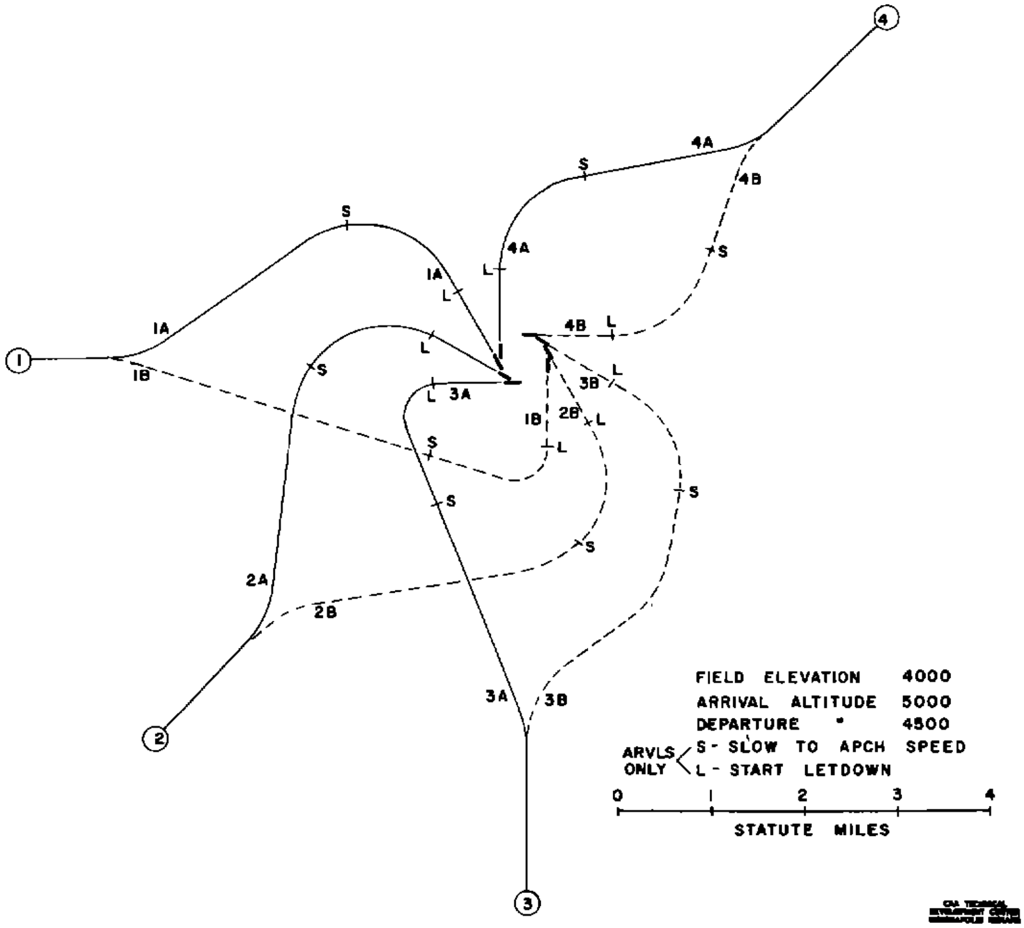


Fig. 14 Tangential Stoliport

incorporated two sets of runways to accommodate traffic in opposite wind conditions, thus avoiding a downwind component on the landing or takeoff path. The two sets, designated as A and B, were shown on pilot charts as solid and dotted lines, respectively. The plan view of these paths formed arrival and departure patterns at different altitudes. When the A set was used for landings, the B set was used for takeoffs, and vice versa. Arrival routes always entered the terminal area at a higher level, with the departure routes going out underneath. Between terminal areas, this type of route structure required an arrangement known as a half-twist which is shown in Fig. 15.

Using 5-minute separations on each route, the maximum capacity of the stoliport was 48 arrivals and 48 departures per hour, based on full utilization of all routes. Comparative simulation tests of parallel versus tangential layouts of multirunway configurations indicated that normally the tangential layout provided greater in-flight separation of approach and departure paths with less airport area. In the tangential stoliport the only point of lane convergence was at the airport itself where convergence would occur only in case of a missed approach. In view of the extremely low forward speed and the steep descent characteristics of STOL aircraft, the possibility of a missed approach appears very low indeed when a high-accuracy navigation system is used. In the operation of this layout, it was assumed that surveillance radar monitoring would be available on a preventive basis.

Radial Heliport.

Exploiting the high accuracy of the navigation system as well as the ability of rotary-wing aircraft to make approaches in any direction, turning into the wind only for touchdown, a high-capacity landing facility known as the radial heliport was developed as shown in Fig. 16, using 12 radial paths for approaches and departures. The radials were spaced 30° apart. In the layout tested, 9 radials were used for approaches. Letdowns were started far enough out so that all aircraft would reach visual contact with the ground at a point at least 1/2 mile away from any aircraft on any other radial path. When visually contact the arriving aircraft could proceed at reduced speed straight in to its landing pad, using visual landmarks, lights, or the navigation system for guidance.

The three departure radials fed a total of 9 airway-traffic lanes, making use of the diverging course principle previously described. Based on 5-minute separations between aircraft on the same route and 1-minute takeoff separations between aircraft on routes which diverged immediately after takeoff, the capacity of this layout was 216 aircraft operations per hour. The ultimate development of this layout would use 10 radials for approaches and 2 radials (each feeding 5 routes) for departures. With the same separation standards, the capacity of this layout would be 240 aircraft operations per hour.

Dual-Lane Fixed-Wing Airway.

Figure 17 shows an airway layout which was tested extensively during the simulation program. This represents a proposed airway between Lordsburg, Wilcox, and Tombstone, which may be established for flight operations in the Fort Huachuca test program. Each airway was used in two directions at different altitudes. It was assumed that a surveillance radar was used at each airport to monitor aircraft movements on a preventive control basis. All operations were prescheduled in accordance with the converging airway-reservations procedure shown in Fig. 6. Pilots adjusted their airspeeds en route to make good their assigned schedules over each checkpoint.

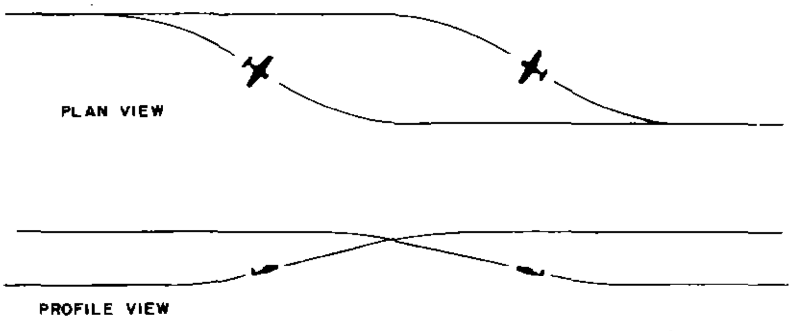


Fig. 15 Half-Twist (Altitude Interchange)

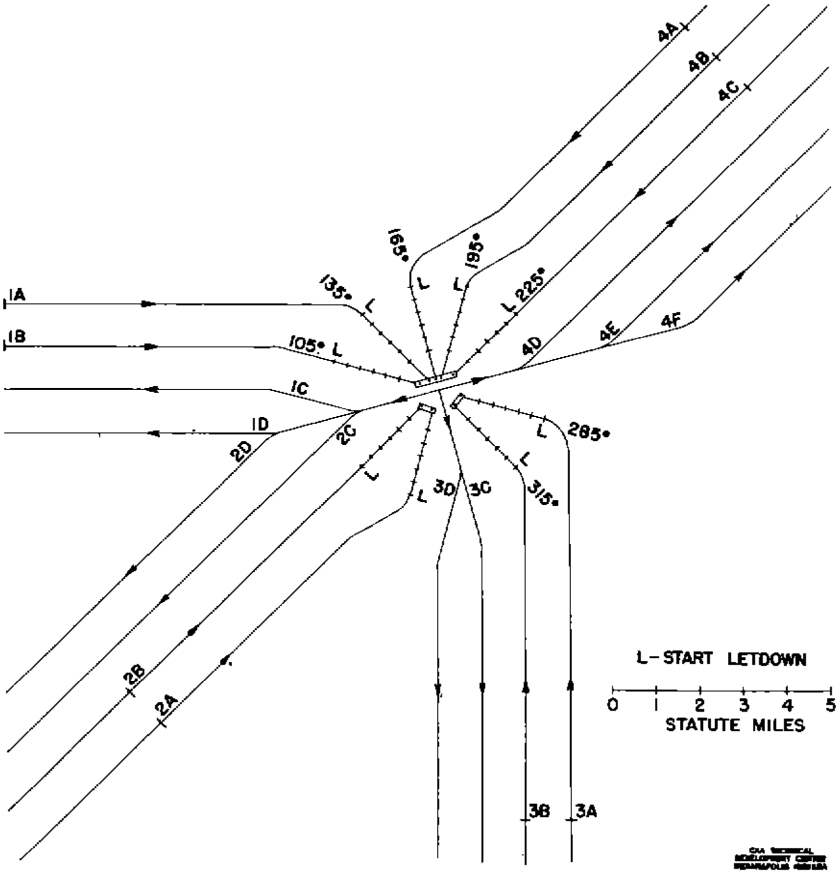


Fig. 16 Radial Heliport

Between the approach gate and the runway at each airport were three approach paths. This arrangement was made to permit pilots to adjust their own approach intervals, monitored by the radar controller who took no action as long as separation appeared satisfactory. As shown in Fig. 18, aircraft from the various routes crossed the approach gate at slightly different altitudes, and each pilot checked his time over the gate. If he was on schedule, he flew the middle path; if he was one minute late, he flew the short path; if he was one minute early, he flew the long path. For smaller schedule errors, he interpolated between the appropriate paths before turning on the final approach. Tests indicated that this adjustment procedure would work as long as pilots followed the same airspeed program between the approach gate and the touchdown point.

Multilane Rotary-Wing Airway.

Figure 19 shows a multilane airway connecting 4 radial heliports. Operation of this layout simulated a tactical airlift between Army (Steins), corps (Wilcox), and 2 division fields (Valley and Tombstone). Exploiting the capabilities of high-accuracy pictorial navigation, all lanes were independent of each other, permitting (with 5 minutes separation on each lane) 48 operations per hour between Army and each of the other airports and 24 operations per hour between corps and each division airport. Additional lanes could have been added as necessary to serve other fields or to increase traffic capacity on any route.

The low-altitude traffic lanes followed valleys and also crossed a mountain pass between Wilcox and Steins. Altitude separation was used where the airways overlapped through the pass. One-mile separation was used between traffic lanes over most of the system. No difficulties were encountered in simulating the operation of this layout.

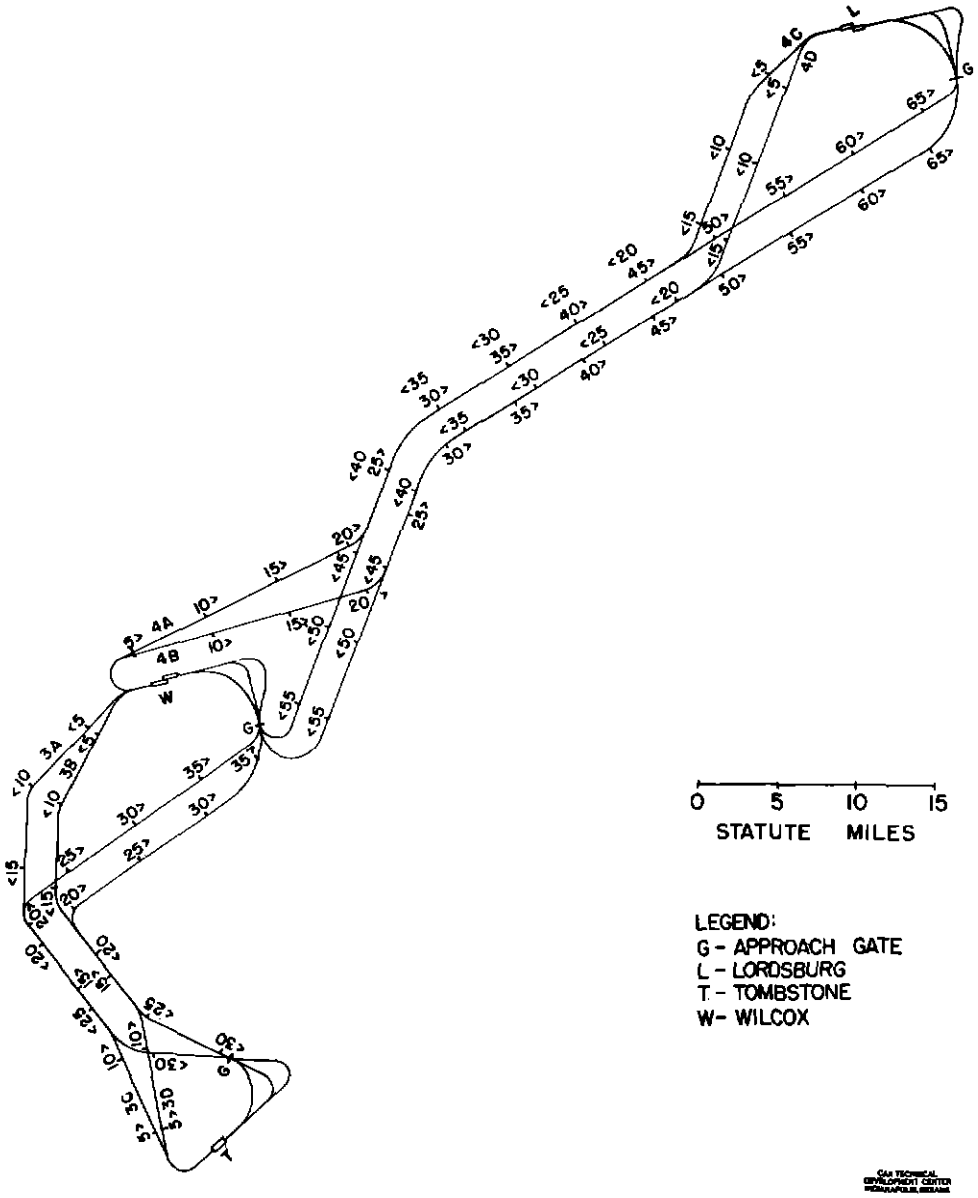


Fig. 17 Dual-Lane Fixed-Wing Airway

Forward-Zone Control.

An important Army aviation problem which had not been tackled previously, due to the lack of a suitable low-altitude area-coverage navigation system, was to control reconnaissance, liaison, evacuation, and forward supply traffic over a large area forward of the division airports. As some type of grid pattern is basic to all area-type navigation systems, it was decided to use the grid structure itself to define a system of air routes over the desired area as shown in Fig. 20.

One set of arbitrarily designated gridlines was used alternately for flight in opposite directions at one altitude. Similarly, an intersecting set of gridlines was used for opposite direction flights at an adjacent altitude level. The spacing between the designated gridlines in each set was such that aircraft assigned to adjacent lanes would have separation from each other, and aircraft making a transition from one line to an intersecting line would have sufficient time to start the necessary altitude change after passing the last grid intersection

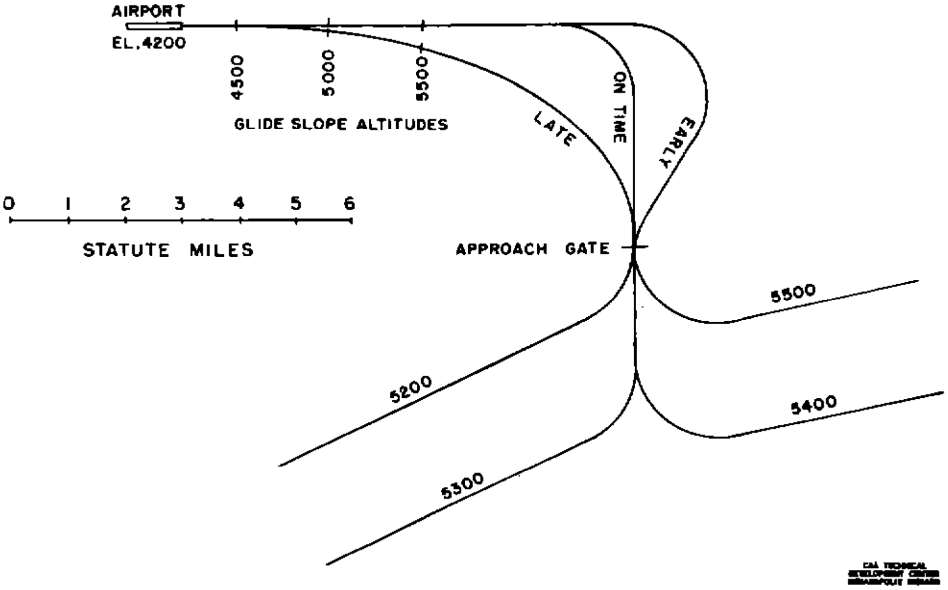


Fig. 18 Approach Interval Adjustment Pattern

and complete it before reaching the next grid intersection. Thus, aircraft assigned to different lanes had separation from each other. Using this principle it was possible to dispatch and control a large number of flights over the entire area, using only two altitude levels.

Using the radial heliport previously described, the support (forward zone) traffic operated independently of the logistic (airlift) traffic from a different group of traffic lanes. Standard grid routings were set up for flights to and from the battalion heliports at X and Y. All forward-zone flights were cleared by reference to the grid numbers; for example, 20-76-16. The simple chart shown in Fig. 21 was used in assigning traffic lanes. All lane assignments were marked in the appropriate columns as soon as a flight was cleared, and they were crossed off when the lane could be reassigned. Any lane could be used again as soon as it was vacated or with at least 5 minutes separation behind a preceding flight if no vacating report was received, assuming that all aircraft in this part of the system had similar flight characteristics. This method of traffic control worked very well during the simulation tests.

CONCLUSIONS

1. Air traffic control operations can be simplified drastically if the system can accept a high degree of regimentation in aircraft types, flight procedures, and navigation tracks. It appears that the degree of regimentation simulated in these tests would be easier to achieve in a tactical system than in the Common System in which the airspace must be assigned on a more democratic basis to civil and military interests operating a wide variety of aircraft types on a wide variety of missions. It may be advantageous someday, however, to adopt these basic concepts for certain restricted portions of the Common System such as on low-altitude, high-density, rotary-wing routes between interurban terminals.
2. The simulation tests demonstrated the importance of the navigation system in simplifying the air traffic control problem through the establishment of multiple, noninterfering traffic lanes, and through provision of a pictorial navigation display which enabled the pilot to follow curved transition tracks precisely and to check his progress continuously.
3. During this program the effects of aircraft flight characteristics on airport acceptance rates became quite apparent. In particular, it was found that the ability to fly slowly in congested terminal areas offers increases in traffic capacity which may be impossible to achieve by any other means. Exploiting this characteristic, the radial heliport accommodated

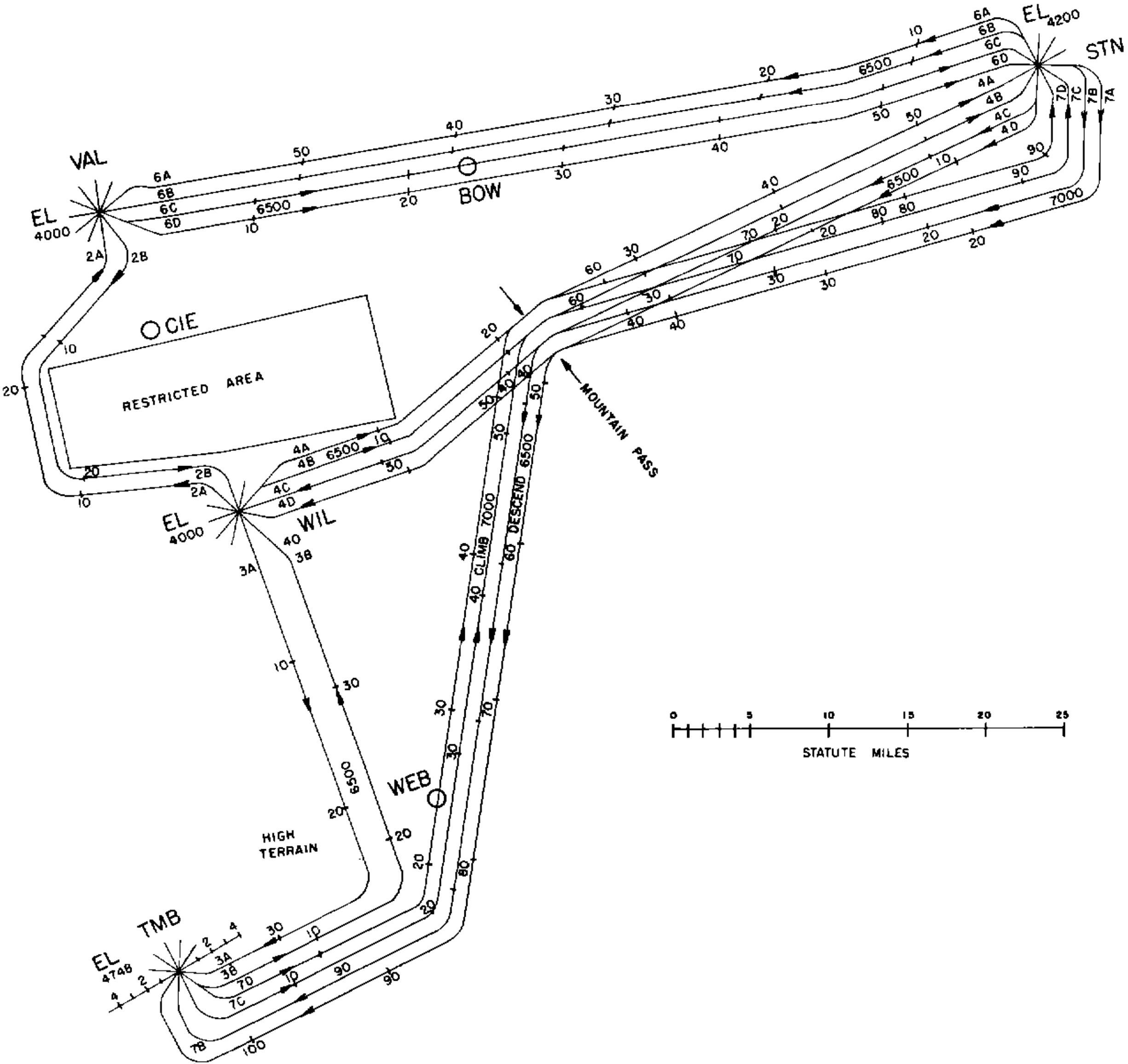


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Fig. 19 Multi-Lane Rotary-Wing Airway

more than 200 operations per hour within a total transition area less than one-third the size of a standard Common System holding reservation.

4. Simulation tests indicated that the airport configurations described in this report functioned satisfactorily within the rated capacity for each type. It was noted that the airport layouts and traffic patterns could be simplified considerably if the facility had to accommodate only one type of aircraft (such as fixed-wing or helicopter) rather than a combination of types.

5. The traffic-control procedures, as well as the forms and charts developed for this purpose, functioned satisfactorily during the simulation tests.

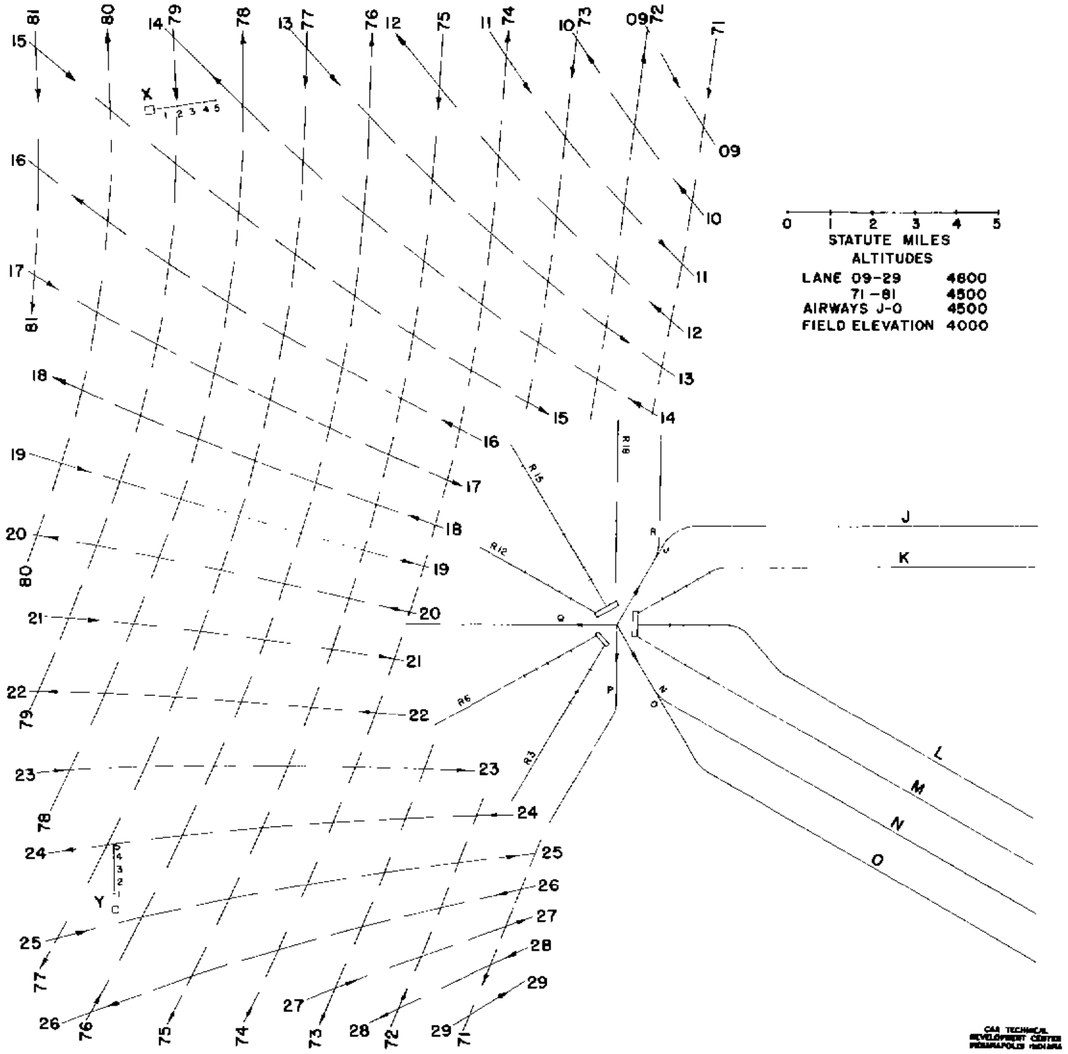

Fig. 20 Navigational Grid System Used for Forward Zone Control

GRID LANE OCCUPANCY CHART

DATE ________

ACFT IDENT	DPTR TIME	RUNWAY	N					S					E										W										RUNWAY	ARVL TIME
			72	74	76	78	80	71	73	75	77	79	09	11	13	15	17	19	21	23	25	27	10	12	14	16	18	20	22	24	26	28		
H42	1007	R																							X									
E29												X				X																	18	1019
H21	1011	Q				X																						X						
H33											X						X																15	1019
H11	1015	P																													X			
M17	1016	Q								X																		X						
E52																				X													6	1023
H17	1021	P							/																						/			

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Fig. 21 Example of Chart for Control of Forward Zone Traffic

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