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DYNAMIC SIMULATION TESTS OF SEVERAL TRAFFIC CONTROL SYSTEMS FOR THE CHICAGO METROPOLITAN AREA

FOR LIMITED DISTRIBUTION

by

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SUMMARY

This report describes the evaluation of several proposed route structures for increasing the traffic capacity of the Chicago metropolitan area through the use of a second major commercial terminal (O'Hare International Airport) to supplement the present major terminal (Chicago Midway Airport). This study was conducted at the CAA Technical Development and Evaluation Center through the use of the dynamic air traffic simulator.

In these tests, it was assumed that Midway Airport would continue to handle 100 per cent of its present traffic load, while O'Hare Airport would handle an additional volume equivalent to 30 per cent of the present Midway traffic load. Simulation tests showed that the present configuration of traffic routes would be inadequate to handle the additional complications in traffic flow imposed by the second major commercial airport. Numerous changes in traffic routings and feeding systems were evolved and tested throughout the simulation program to secure the most effective configuration of flight paths.

The most important basic changes involved the regrouping of arrival and departure routes to make them as independent of each other as possible. Although it was geometrically impossible to segregate all departure and arrival routes in this manner, most of the heavily traveled routes were so arranged to permit uninterrupted climb-outs and descents within 80 to 100 miles of the terminal area with a minimum of tunneling in the terminal area.

It was found that most of the desired route changes could be accomplished through the use of previously installed or proposed VOR facilities. The elimination of LF airways greatly simplified the route layout, although in some areas it is possible to parallel the VOR routes with existing LF ranges.

The routing problem was complicated somewhat by the presence of the Glenview restricted area and by the necessity to set aside an area for jet penetrations to O'Hare Airport and Glenview Naval Air Station. These factors resulted in sizable detours for the traffic routes between Midway and Milwaukee. Assuming that these detours could be tolerated from the flight operations standpoint, the tests indicated that the Glenview restricted area would not seriously hamper the operation of the traffic control system, provided the shape of the area could be modified to permit a civil airway to be extended across what is now the southern tip of the area.

Final tests were made simulating operations which might be expected within five years, with Midway handling 100 per cent of its present

capacity, and O'Hare handling an additional volume equivalent to 100 per cent of the present Midway traffic load. During these tests, procedures were developed for handling shuttle flights between Midway and O'Hare.

Simulation tests indicated that the use of suitable large horizontal plotting scopes in the Air Route Traffic Control Center would result in considerable improvement in handling large volumes of traffic.

INTRODUCTION

The nature of the air traffic in any particular area will dictate to a large extent the route structure required. The present air traffic in the Chicago area is predominantly arrival or departure, with approximately five per cent of overflights. Of these overflights, many are of the long-distance variety and would not be affected adversely by a route which would by-pass the critical Chicago metropolitan area. In addition, the altitudes at which these flights traverse the area are sufficiently high as to be of little concern to the Chicago metropolitan area controllers. The airway configuration in the Chicago area has been developed to handle this particular mixture of traffic.

Experience has demonstrated that one of the limiting factors in the number of flights scheduled at Midway Airport has been the availability of gate space on the ramp. Although there are many periods during the day when ramp gates could accommodate additional aircraft, airline schedules are designed to fit the demands of the passenger, and the scheduling of periodic flights during off-peak times would not satisfy the need of the public which generates these peak-hour demands for air transportation. The scheduled airlines are aware of this situation and it is likely that, as certain flights are transferred to O'Hare Field, other flights will be scheduled in their place at Midway Airport to cope with the demand for air transportation during the peak periods. Also, as additional ground facilities become available at O'Hare Field, the scheduled air carriers may increase operations at O'Hare at a rate more rapid than the rate at which operations at Midway are diminished. The end result of the foregoing assumptions will be a net increase in the number of operations within the Chicago metropolitan area. Since any appreciable increase in operations at Midway Airport (during peak periods) would tax the present air route structure, the division of such a schedule between two airports in such proximity as O'Hare and Midway would present many complexities in the form of lengthy delays to arrival and departing aircraft, in addition to imposing circuitous routings and altitude restrictions of long duration.

The establishment of a second major air terminal in the Chicago metropolitan area creates several air traffic control problems which extend beyond the immediate terminal area. These problems deal principally with the route pattern and traffic flow involved in mixing high-density IFR traffic to and from a multiple-airport terminal area. The present air route structure in the Chicago control area has been quite adequate to handle a maximum number of operations at Chicago Midway Airport, and a small amount of itinerant and military operations at O'Hare and Glenview. However, this route pattern was designed specifically for the handling of the Midway traffic. Flights operating into or from O'Hare Field today are restricted to a greater degree than are those operating at Midway. Any appreciable increase in the volume of operations at O'Hare Field would introduce some very serious delays in the terminal area as well as potential traffic conflictions at many of the critical intersections in the en route area. The proposed move of 30 per cent of the scheduled air carrier operations from Midway Airport to O'Hare Field is expected to exceed the capabilities of the present route system, even though the level of operations at Midway does not climb above the remaining 70 per cent.

It has been realized that the presence of the Glenview restricted area constitutes an obstacle to the maximum utilization of air space in the Chicago area. To date, this obstacle has not been considered serious, since the predominant routes to and from the metropolitan area lie to the south of the Glenview restricted area. The implementation of O'Hare Field as a major terminal demands that a further study be made of the Glenview restricted area, with the possibility that the area should be modified or eliminated entirely.

At the time of this study, the Third Regional Office of the CAA had programmed certain VOR stations around the Chicago area as follows:

1. Chicagoland Airport (north of O'Hare Airport)
2. Dixon, Illinois
3. Peotone, Illinois
4. Coyne, Illinois
5. Chicago Midway Airport
6. Benton Harbor, Michigan
7. Rockford, Illinois

Also, equipment was available for the installation of one additional homing facility for the area. All of these equipments were considered in the development of the various route arrangements tested. A surveillance radar also was in the process of installation at the O'Hare Airport. The Chicago Midway Airport and the Glenview NAS are equipped with surveillance radar.

The Chicago simulation tests described in this report were directed toward the development of a traffic control system possessing the following characteristics:

1. The route structure should provide a means of feeding a high volume of IFR air traffic into Midway, O'Hare, and Glenview Airports, permitting relatively free climb and descent paths within 80 miles of the terminal area. The airway system should have a sufficient degree of flexibility to permit the orderly transfer of scheduled operations from Midway to O'Hare without requiring a major realignment each time an additional percentage of the scheduled flights change from one field to the other.

2. The system should provide suitable terminal area arrangements from which to vector arriving traffic.

3. The system should provide for at least two instrument approach directions in each of the terminal areas.

4. The system should be such that coordination between controllers is minimized.

5. The system should provide a means of controlling shuttle flights between the two terminal areas in an expeditious manner.

In addition, these tests were designed to determine:

1. The adequacy of the proposed location of the Chicagoland VOR from the standpoint of air traffic control.

2. The adequacy of the present and proposed locations of other VOR range stations.

3. The degree of alteration necessary to Restricted Area No. 76 north of the Glenview Airport, in order to meet the requirements for satisfactory routings into the O'Hare area.

EVALUATION PROCEDURES

Equipment.

The basic simulation tests of the Chicago area were conducted on a dynamic simulator[1] which has been expanded to provide for a maximum of 18 radar targets and to include positions of operation in the ARTC Center. The use of additional radar displays with the simulator permitted the establishment of two distinct airport tower operations. The simulated Midway tower was equipped with radar, radio channels, and interphone communications for two approach control positions of operation. O'Hare tower was similarly equipped, the number of approach control positions being one or two, depending upon the volume of traffic operating into the O'Hare area in the particular sample. Three flight progress boards were available in the simulated ARTC Center. The operating positions were equipped with interphone boxes and direct air/ground communications. In most of the tests the area displayed on these boards was more than that presently displayed on the corresponding positions in the actual Chicago ARTC Center. It is pointed out that in these tests the inbound flights were not run simultaneously with the outbound flights due to the limited number of radar targets. Therefore, it was possible to display

[1]R. E. Baker, A. L. Grant, and T. K. Vickers, "Development of a Dynamic Air Traffic Control Simulator," Technical Development Report No. 191, October, 1953.

more area on each individual flight progress board, and allot a larger area of control jurisdiction to each ARTC controller to secure a maximum utilization of limited equipment and controller personnel. Figure 1 shows the complete simulation layout as used for these tests.*

The area covered by the fix postings on the three flight progress boards is shown in Fig. 2. It will be noted that this area comprises all or part of eight sectors as presently designated at Chicago. The simulation of the inbound flights alone, or the outbound flights alone, represents less than one-half the workload under actual operating conditions. ARTC Center radar, as tested during certain phases of this simulation, was set up on a 30-inch horizontal display, with a range of approximately 60 miles. This range was later increased to 70 miles for more adequate coverage to the west and northwest of Chicago.

Traffic Samples.

The following traffic samples were used:

Traffic Sample I
- Midway traffic at its present level.
- O'Hare traffic at a level equal to 30 per cent of Midway's present level.

Traffic Sample II
- Midway traffic at its present level.
- O'Hare traffic at a level equal to 100 per cent of Midway's present level.

Figures 3, 4, 5, and 6 indicate the amount of traffic by routes under the various conditions tested.

Maps and Charts.

A paper study of the airway configuration in the Chicago area preceded the simulation testing. Independent efforts of the Chicago ARTC Center and TDEC personnel were consolidated in the evaluation of the various route systems. The evolution of the recommended arrangement of navigation fixes and alignment of airways progressed through the steps listed below:

Map 1 The present system of airways in the Chicago metropolitan area, including both VOR and low-frequency airways. Figure 7.

Map 2 VOR System No. 1. Figure 8.

Map 3 Refinement of Map 2, particularly with respect to inbound and outbound routes west of O'Hare Field. Figure 9.

*A comparison of workload between these three simulated sectors and the three sectors in the actual Chicago Center is not valid, nor is it implied in this report.

Map 4 VOR System No. 3. Figure 10.

Map 5 A composite of Maps 2, 3, and 4, portraying the consensus of Third Region and TDEC personnel, arrived at after several simulation runs on the foregoing maps. Figure 11.

The designators applied to the various radio aids and intersections and the numbering of the Victor Airways on many of these maps are the same as the designators and numbers used today in the Chicago area. These location identifiers are listed in Table I. The carry-over of these same designators and numbers from map to map was done for convenience in simulation.

Although most of the route patterns developed during this study deal with flights to and from the terminal areas at Chicago, a pattern of airways for over-flights is easily constructed, as shown in Fig. 12. Figure 13 shows how a rearrangement of low frequency ranges can provide routes that parallel many of the VOR routes in the recommended route structure.

Arrival and departure delays for these tests are shown in Figs. 14 and 15.

Departure Tests.

The route structure and altitude allocation applied to flights departing O'Hare and Midway are depicted in the figures associated with each specific test. In an effort to reduce center-tower coordination, the following techniques were tried in the issuance of departure clearances:

1. The entire clearance was issued by the Center to the tower, and repeated by the tower to the pilot.

2. The Center issued short range clearance to the tower.

3. The tower originated and issued short range clearance to the pilot without prior coordination with the Center.

Although Item 3 represented the least amount of interphone time, there were occasions when flights cleared by the tower would be in inverse altitude order when turned over to the Center. This was largely due to the fact that the tower did not have the complete route of flight of the aircraft. The most satisfactory arrangement and the one which permitted the highest degree of flexibility was the procedure wherein a short range clearance was issued by the Center, since such clearance reflected the demands and exigencies of the complete traffic picture.

Controller Personnel.

In order to draw upon the operational experience of controller personnel at Chicago, ten controllers were detailed to TDEC to assist in the evaluation. Five controllers from the Chicago ARTC Center, three from Midway tower, and two from O'Hare tower manned the positions of operation during the simulation tests. These controllers contributed not only the operational know-how necessary to smooth and realistic conduct of a simulation study, but also participated in discussions and offered critical analyses of the systems tested.

Measurements.

These tests were made under conditions as nearly standard as possible. The basic problem data furnished the theoretical time at which each arriving aircraft should be inbound over the approach fix and at final approach altitude, if no other traffic was involved. Through the use of an Esterline-Angus recorder, the simulation pilots recorded the actual arrival times of each aircraft over the appropriate approach fix. By comparison of the theoretical arrival time with the actual arrival time, it was possible to determine the absolute delay to each arriving aircraft. This delay included all delays from approximately 100 miles from Chicago to the appropriate outer marker.

Departure tests were conducted in a standard manner. No take-off was delayed due to arriving aircraft. Departure delays were incurred only when the departure routes were saturated for the moment or when the departure radar controller felt that he could no longer accept more aircraft to control. The latter problem was more evident in the O'Hare area than at Midway due to the fact that departures were being observed and controlled from two airports instead of from one.

Due to the limitation of the number of target projectors, it was not possible to "fly" departure aircraft beyond the point of the short clearance limit. However, the ARTC controllers continued to "ghost" these aircraft through to the outer limits of the sectors to insure the proper control of succeeding aircraft.

No communications measurements were made in these tests because the present communication recording equipment was not designed to record from all of the control positions used in this simulation.

It should be pointed out that the numerical results of these tests may not necessarily be duplicated in actual operations because of unavoidable differences between laboratory conditions and actual operating conditions. Since this simulation effort was conducted on a much greater scope than any previously conducted, and since one of the primary objectives was to determine satisfactory routings, it was realized at the beginning that delay measurements alone might not be indicative of the value of a route system. Therefore, more emphasis was placed upon the opinions of the controllers than on the results of the delay measurements to determine the relative value of the systems tested.

TESTS AND RESULTS

Present Route System.

Arrangement of Navigation Aids.

Up to the present time, two distinct advantages have contributed greatly to the smooth and expeditious flow of traffic in the Chicago ARTC area. The first is that 95 per cent of the air traffic in the area at Chicago lands or takes off from Midway Airport. This type of traffic flow is readily assimilated by a route structure such as exists at Chicago today. Secondly, the ability to use right-side separation on most of the airway segments in the Chicago area has been of great benefit; however, this advantage is practically non-existent during the interim period when both L/MF airways and VOR airways are being utilized.

The arrangement of navigation aids used in these tests was the same as that in use at the present time except that one H facility was added in the area north of O'Hare Airport near Crystal Lake. Figure 16 shows this arrangement of navigation aids. In order to provide two clearance points to be used by the ARTC controllers in the O'Hare area, it was decided to use the Roselle intersection (redesignated as the southwest course of the Glenview low frequency range station and the north radial from the Naperville VOR station) and the H facility near Crystal Lake.

Position of Operation.

The portion of the Chicago control area simulated in these tests is outlined in Fig. 2. In view of personnel and equipment limitations, it was decided to confine the en route simulation to that which could be displayed on three flight progress boards. The additional workload incurred in the display of a larger area on a single flight progress board would be compensated for by the fact that the controller would not be concerned with both inbounds and outbounds during the same simulation test.

Fix postings for the three sectors of operation during simulation of the present route system were:

West Sector	Center Sector	Fast Sector
MLI RFD BDF JOT DGV	WSO WAU ORD NBU GRY	LKX MDK PMM SBN GSH
PNT	OM	BEH LAF

In each of the east and west sectors, two controllers were used. One controller in each sector simulated the coordination with adjacent sectors and ARTC Centers, and also simulated the issuance of preliminary clearances to arriving flights prior to reaching the terminal area. In the simulation of clearances, the controllers were requested to utilize average communications delays in instances wherein a reply from the pilot was anticipated, particularly in those cases where it was assumed that an indirect channel of communication was used. The second controller in each of these sectors handled the direct radio contacts with the pilots after the flight had been assigned to an individual console in the simulator until the flight was released to approach control at O'Hare or Midway. One controller operated the center sector, coordinating the activities of the east and west sectors (with respect to altitude availability at clearance limits) and forwarding data on inbound flights to appropriate towers.

In these tests one surveillance radar controller position was established for the O'Hare area. This controller controlled arriving traffic destined for the O'Hare or Glenview Airports. Figure 1 shows the physical arrangement of the control positions used in the entire series of tests. The radar controller at O'Hare was provided with an assistant controller who posted and relayed information for the controller concerning aircraft flights arriving in this area. These controllers were linked via interphone to the Midway tower position and the ARTC positions for the purpose of coordination.

Two surveillance radar controller positions were used at the Midway tower. The division of control was the same as that used in the present operation with the ILS localizer course being the dividing line between the east and west radar sectors. A flight data position was used to aid these controllers in posting and relaying information on aircraft arriving at Midway Airport. These controllers were linked via interphone to the O'Hare and ARTC controllers for purposes of coordination.

Arrival Control Procedures for Southeast Landings.

A general indication of the arrival traffic flow is shown in Fig. 16. A cursory analysis of this traffic flow along the present configuration of airways reveals a serious traffic situation with respect to delays and undue restrictions. It was important to this study that a thorough appraisal be made of the existing airway structure to provide a basis of comparison with the proposed airway systems. The blending of traffic to and from the two airports in the Chicago metropolitan area created several critical congestion points in the en route area, and necessitated altitude restrictions of long duration to many of the departure flights, particularly from O'Hare Field. Since the airway structure in the Chicago area was designed primarily to handle terminal traffic to and from Midway Airport, it is understandable that an increase in O'Hare traffic would not be as readily assimilated as would a comparable increase in Midway traffic.

Although the controller has more latitude in assignment of altitudes to the inbound flights in the metropolitan area, and therefore should be able to arrange the arrival sequence in any desired manner, the location of the airports with respect to the major airway routes would demand that the O'Hare flights generally arrive at higher altitude levels than would the Midway flights. This is true particularly of the inbounds to O'Hare arriving from the south and southeast, whose route to O'Hare must traverse the Midway radar vector area.

The metropolitan area arrangement is shown in Fig. 16, along with altitude restrictions normally imposed and areas of control jurisdiction used. A line is inscribed on the map from the Wauconda intersection to the east end of the Roselle holding pattern air space. To the west of this line O'Hare controllers could vector aircraft which were above 4500 feet. To the east these aircraft were restricted to 4500 feet or below because of holding or arriving traffic at the Wilson intersection.

The jet penetration procedures used in this test were similar to those currently in use at the O'Hare Airport today. It was assumed that Navy jet aircraft would make penetration in the restricted area north of Glenview when cleared to do so by the O'Hare Airport controllers.

Because of the possibility of confliction between O'Hare arrivals from the south en route to Roselle at 7500 feet and the traffic being vectored by the Midway controllers, this traffic was restricted to a maximum of 6500 feet in the vectoring area.

Departure Control Procedures.

Although no departure tests were made on this system, the normal routes and altitudes in use today are shown in Fig. 17. The routes which would suffer the most departure restrictions in the Chicago area are as follows:

1. Westbound departures from O'Hare Field would be routed over Roselle intersection via the southwest leg of Glenview range, over Aurora intersection, and would be restricted to a low altitude until established on Green Airway 3 west of Aurora intersection. At that point, climb to altitude could be accomplished with a restriction to remain well to right of course and with respect to westbound traffic from Midway Airport merging at Aurora.

2. Southwest-bound departures from O'Hare Field. Routing to Aurora intersection would be the same as above, thence southeast on Green Airway 3 to Joliet range, thence southwest on either Red Airway 12 or Amber Airway 5. The normal restriction is to maintain a relatively low altitude until five minutes past Joliet range. No right-side separation is applied on Red Airway 12 between Joliet and Bradford, and the five-minute restriction beyond Joliet on Amber Airway 5 puts the aircraft so close to the Pontiac intersection that additional restrictions are frequently necessary. As was the case with the westbounds, these flights are affected not only by the opposite direction traffic (on Red Airway 12 and Amber Airway 5) but also by the southwest departures generated by Midway Airport.

3. Southeast-bound departures from O'Hare Field. Routing to Joliet would be the same as the foregoing, and the flight would proceed from Joliet via Red Airway 42 to Lafayette. The restriction to a low level altitude would end shortly after passing Joliet; however, the controller has the additional problem of blending this traffic with southeast-bound traffic from Midway, merging at Momence intersection, plus the additional task of fitting the traffic into the opposite-bound traffic at Lafayette.

4. Eastbound departures from O'Hare Field. Routed east over Mid Lake intersection, thence via Red Airway 55, or Victor Airway over South Bend; via Red Airway 28 to Benton Harbor; or via Victor Airway 84 over Pullman VOR. Most of these flights would be restricted to Mid Lake intersection at a low altitude because of inbound traffic to O'Hare, but particularly because of inbound traffic to Midway Airport on Red Airway 28, which is presently an integral segment in the preferential route structure from the east.

Shuttle Flight Procedures.

No shuttle flights were included in the first level of traffic tested.

Results and Observations.

Delays to arriving aircraft in each of the terminal areas are shown graphically in Fig. 14. Results indicated that while this route and terminal area arrangement worked very well for aircraft operating into the Midway Airport, it was unsatisfactory for aircraft arriving in the O'Hare area. The greatest delays recorded for any aircraft were those in the O'Hare area.

The holding fixes from which the O'Hare radar controller vectored aircraft were very awkward to use and the flight distance to the outer marker was excessive, resulting in poor intervals at the outer marker.

The jet approach procedure did not interrupt the flow of arrival traffic at O'Hare provided the radar controllers continued vectoring aircraft toward the outer marker at O'Hare until the jet reported turning to the northeast. Once the jet was below 9000 feet, it was possible for the radar controller to see the aircraft and control it in the same manner as other traffic in the vector pattern. Should it be considered unsafe for the controller to continue with vectoring until the jet is under radar surveillance, it is probable that a jet penetration would delay other aircraft approximately ten minutes while making the descent and coming under radar surveillance.

The need for a definite buffer line south of the O'Hare Airport to define the area radar controllers at Midway may use in vectoring traffic was very apparent in these tests since these controllers frequently would clear several aircraft from the Lake Shore intersection, and were forced to vector some of them very near the O'Hare Airport. This could lead to a serious situation in case of a missed approach at O'Hare. This buffer line should provide a reasonable distance for aircraft to make a turn at O'Hare, whether it is a departing aircraft or a missed approach.

Aircraft cleared to the Wilson intersection at 5500 feet in many cases were forced to use greater than normal descent rates to arrive at the Midway outer marker at the initial approach altitude. However, no lower altitude was practical, in view of the altitude requirements of the O'Hare controllers in vectoring arrivals and departures.

VOR System A.

The following illustrations pertain to this system:

1. Airway Configuration and Navigational Aids, Fig. 8.
2. Arrival Routes, Fig. 18.
3. Departure Routes, Fig. 19.
4. Delay Measurements, Fig. 14.

A VOR site at the Palwaukee Airport was selected because the location provided a better straight-in approach to O'Hare's runway 17, and in establishing a route to the O'Hare area from the Pullman VOR, it was necessary to utilize only eight miles of the Glenview restricted area.

The advantages of this system when compared to the present system are as follows:

1. Aircraft en route to and from Milwaukee and points north were provided routes which by-pass the O'Hare-Glenview area.

2. Aircraft arriving on major routes were diverged at points a sufficient distance from Chicago to allow practically continuous descent.

3. Aircraft departing along the major routes of flight could be climbed continuously within 80 miles of Chicago.

The features of this system which are considered desirable have been incorporated in the recommended system described in more detail under VOR System D.

The difficulties found in this system were the bottleneck at Moline caused by routing traffic from the Kansas City area via Moline; the restriction to local operations at Rockford caused by the convergence of departure routes at this point; the low altitude restrictions required in routing southbound flights from O'Hare Field and the northbound flights departing from Midway.

VOR System B.

Listed below are the illustrations which pertain to this system:

1. Airway Configuration and Navigational Aids, Fig. 9.
2. Arrival Routes, Fig. 20.
3. Departure Routes, Fig. 21.
4. Delay Measurements, Fig. 14.

Major changes in the route structure over that tested in VOR System A were:

1. Reversal of the inbound and outbound routes on the west side of O'Hare. This was done in an effort to ease the bottleneck created at Rockford under the former system.

2. Routing of the Kansas City-to-Midway traffic over Pontiac and Peotone to Harlem. It was believed that the Moline area had been overloaded in VOR System A, and that traffic from the southwest destined for Midway might more easily be routed into the terminal area via Peotone.

The arrangement of fixes in the O'Hare area was an improvement over VOR System A from the radar controller's viewpoint. The flow of traffic through the Rockford area was improved. The bottleneck in the vicinity of Moline was relieved. However, in the process of relieving the Moline congestion, another point of confliction was created at the Underwood intersection. The recommended solution for this problem is contained in the discussion under VOR System D.

VOR System C.

Listed below are the illustrations which pertain to this system:

1. Route Configuration, Fig. 10.
2. Arrival Routes, Fig. 22.
3. Departure Routes, Fig. 23.
4. Delay Measurements, Fig. 14.

This system offered little advantage over the two previous systems tested. However, there were some serious disadvantages, as follow

1. Aircraft from the west destined for O'Hare and Midway shared a common route until past the Dixon VOR. Many such flights were restricted to a relatively high altitude until past this point of divergence, and were unable to descend so as to reach the desired altitude at the clearance limit.

2. Southwest-bound flights from Midway were restricted to low altitude until 15 miles past Coyne VOR due to the northbound traffic converging at Coyne. Beyond Coyne, on the routes over Peoria and Pontiac, there was insufficient distance to permit flights to make unrestricted climbs and descents.

3. The holding fixes in the terminal areas were not well suited to radar vectoring. The Wauconda intersection was particularly awkward in relation to the final approach course at O'Hare Field.

4. The jet penetration procedure was very unsatisfactory since there was insufficient area for this procedure to be accomplished between the two holding patterns in the O'Hare area.

Although this test was predicated upon the complete abolition of the Glenview restricted area, actually only the southernmost 13 miles of the area would be required. Possibly the only advantage to be gained in complete elimination of the restricted area would be a saving in route mileage between Milwaukee and Chicago. In fact, since it is possible to have Navy jet aircraft use this area for penetration, there is an advantage in retaining the northern portion of this area.

VOR System D.

Arrangement of Navigation Aids.

As a result of previous tests, it was apparent that the best of the route arrangements tested was that shown in Fig. 9. This arrangement of routes was again studied and further changes were incorporated as shown in Figs. 11 and 24.

Since the Chicagoland Airport has been under consideration by the Third Region as a site for a VOR and since tests indicated that this was a satisfactory fix from which to vector aircraft, it was retained in this route arrangement. In order to avoid possible confliction between jet aircraft during penetration and conventional aircraft holding at the Chicagoland VOR, it was decided to hold aircraft at Chicagoland east of this station. The departure route from the Chicagoland VOR to the Pullman, Michigan VOR was retained. The Navy restricted area was retained except for approximately 13 miles of the southernmost portion. The Meigs intersection was moved to a point approximately eight miles east-northeast of the Midway outer marker and was formed by the 070° radial of Naperville VOR and the 147° radial of the Chicagoland VOR. The jet penetration procedure was that shown in Fig. 24. A buffer line was inscribed on the map to clearly separate the Midway vectoring area from the O'Hare Airport area.

The route V97 to the south from Midway was modified so that traffic using this airway continued to diverge from traffic using V38 enabling aircraft on V97 to climb without regard to aircraft on V38. The Harlem intersection and holding pattern were designated as the 312° radial from Chicago Heights VOR and the 053° radial from the Coyne VOR. The Elgin intersection and holding pattern were designated as the 244° radial from the Chicagoland VOR and the front course of the Midway ILS.

Positions of Operation.

The positions of operation for the Air Route Traffic Control Center were essentially the same as those described previously. With this configuration of radio aids a new sample of traffic was used in which the amount of traffic landing and departing the O'Hare area was equal to that arriving and departing the Midway area.

Two radar control positions were established for the O'Hare area. One controller controlled arriving traffic in the area west of the O'Hare ILS course. The other controller controlled traffic in the area east of the O'Hare ILS course, and also vectored traffic to the precision radar final approach course at Navy Glenview Airport. This controller was also responsible for the control of jet aircraft during penetration and approach. The radar departure control position for the O'Hare area was retained as in the other tests. No new positions were required in the Midway area since they currently have two arrival controllers and for the purposes of these tests, a radar departure control position was established.

Control Procedures for Southeast Landings.

1. Arrival Control Procedures.

The minimum altitude at the Chicagoland VOR was 3500 feet. Traffic arriving via V42, Fig. 24, was restricted to 6500 feet until past the Winnetka intersection. These aircraft were normally changed to the control of the O'Hare east sector controller when passing the Baker intersection.

The minimum altitude at the Meigs intersection was 3500 feet. Aircraft arriving via V8 were restricted to cross the Mid Lake intersection at 6500 feet and above. The aircraft were normally changed to the control of the Midway east sector controller after passing the Mid Lake intersection. No altitude restrictions were placed on traffic arriving into Meigs from V6, except to observe the minimum altitude of 3500 feet.

The minimum altitude at the Harlem intersection was 4500 feet. Aircraft arriving from over Peotone were normally changed to the control of the west sector controller at Midway after passing the Peotone VOR, providing the aircraft could no longer conflict with arrivals destined for the O'Hare area.

The minimum altitude at the Naperville VOR was 4500 feet. Aircraft arriving at this fix were normally changed to the control of the west sector controller at Midway after passing the Big Rock intersection.

The minimum altitude at the Elgin intersection was 4500 feet. Aircraft arriving at this fix were changed to the control of the west sector controller at O'Hare after passing the Marengo intersection.

Arrival aircraft from the south destined for the O'Hare area were normally routed over Peotone VOR, Harlem to the Chicagoland VOR, or to the Elgin intersection. Aircraft from the south destined for Glenview Airport were routed to the Chicagoland VOR. Aircraft arriving on this route for the O'Hare area were restricted to cross the Midway area at 6500 feet and above, and were instructed to contact the O'Hare radar controller when passing the Midway outer marker. However, control jurisdiction did not pass to the O'Hare controller until these aircraft crossed the buffer line dividing the two areas.

Chicago Midway controllers were prohibited from vectoring aircraft from the Midway holding stacks at altitudes above 5500 feet.

2. Departure Control Procedures.

Normal departure routes are shown in Fig. 25. Before aircraft departed from the airports, the departure controllers secured a clearance from the ARTC controllers to a short clearance limit at a specific altitude. Aircraft departing from the O'Hare area eastbound on V10 or northbound on V7E were normally cleared to the Charlie intersection at 3500, 4500, or 5500 feet. Aircraft departing the O'Hare area eastbound or southeast-bound via V110 were cleared to the Mid Lake intersection at altitudes of 5500 feet or below. These aircraft were further restricted to cross the Able intersection at 3500, 4500, or 5500 feet.

Aircraft from the Midway area northbound on V7E were normally cleared to the Charlie intersection at 2500 feet. Eastbound aircraft from Midway were cleared to the South Bend VOR at any reasonable altitude with regard to other departure aircraft. These aircraft were restricted to 2500 feet until past the Easy intersection. Other eastbound and southeast-bound aircraft from Midway were cleared to the Thomaston intersection via V38 at altitudes of 7500 feet or below. No restrictions were placed on the departure in the immediate vicinity of the airport.

Aircraft southbound from Midway were cleared via V97 to the Gifford intersection at altitudes of 7500 feet or below. No restrictions were placed on these aircraft in the vicinity of the airport. Northwest-bound, westbound, and southeast-bound departures were all cleared to the Coyne VOR at altitudes of 6500 feet or below. These aircraft were restricted to 2500 and 3500 feet until past the Lockport intersection. Aircraft en route to Rockford or northwest on V53 were generally cleared over Coyne to the Big Rock intersection at altitudes of 2500 or 3500 feet.

Southbound flights from O'Hare were cleared to the X-Ray intersection at altitudes of 2500 or 3500 feet and were controlled through the Coyne area in relation to Midway traffic by the ARTC controllers. Long-range southwest-bound, westbound, and northwest-bound flights from the O'Hare area were cleared to the Fox intersection at 2500 or 3500 feet.

3. Shuttle Flight Procedures.

In this sample of traffic, several shuttle flights were scheduled between the two major airports. A shuttle flight from O'Hare was normally cleared to the Stadium intersection at 3500 feet. The information concerning this flight was forwarded to the Midway arrival controller by the O'Hare departure controller. It was not necessary to contact the ARTC controllers concerning these flights. Control of this aircraft became the responsibility of the Midway radar arrival controller in the east sector when the aircraft was approaching the Stadium intersection. Since the Midway controllers had been previously alerted, they were prepared to vector this aircraft from the Stadium intersection to the Midway outer marker.

A flight from Midway Airport to O'Hare was normally cleared to the Stadium intersection at 2500 feet. This aircraft followed the same departure route as aircraft northbound from Midway on V7E. Information concerning this flight was forwarded to the O'Hare east sector radar controller as soon as the aircraft departed the airport. Control of the aircraft was changed to the O'Hare radar controller as the aircraft approached the Stadium intersection. While this procedure seemed practical, with the aid of radar procedures, a confliction with other departing traffic in each area was possible unless these flights were coordinated not only with the arrival controller in each area, but with the departure controller as well.

Another system which was considered better was as follows:

a. A shuttle flight from O'Hare was cleared by ARTC as a normal departure and was cleared to the Xray intersection at an altitude of 2500 or 3500 feet.

b. Information concerning this aircraft was forwarded to the Midway west sector radar controller by ARTC as soon as the aircraft departed the airport.

c. After the pilot reported that his aircraft had crossed the Roselle intersection southbound, control of the aircraft was immediately transferred to the Midway radar arrival controller.

d. After the aircraft was identified by the Midway controller and was inside the radar vector area as shown by the buffer line, the altitude was released for further use for other departing aircraft.

e. A shuttle flight from the Midway Airport was cleared by ARTC to the Baker intersection at 2500 feet and the aircraft followed the normal departure route as other aircraft northbound on V7E. Information on this flight was coordinated with the O'Hare east sector arrival controller and the O'Hare departure controller since this aircraft would be vectored through the departure zone east of the airports.

f. Control of this flight was transferred to the O'Hare east sector arrival controller after the flight reported passing the George intersection. In most cases this aircraft was vectored from the vicinity of the George intersection direct to the Chicagoland VOR and occasionally the aircraft was climbed to 4500 feet to provide altitude separation between this aircraft and others departing the O'Hare area.

g. ARTC controllers were notified when this aircraft had cleared V7E airway so that the altitude could again be assigned to other departures.

4. Results and Observations.
The following results were indicated and observations were made:

a. Delays to aircraft are shown graphically in Fig. 15.

b. ARTC controllers experienced no difficulty in routing arrival aircraft to the respective clearance points even though the flow of traffic was considerably heavier than that of the first sample. The route into the O'Hare area from the south was the least desirable route and apparently no perfect solution was immediately available.

c. The Midway radar controllers were able to vector adequately in the area south of the buffer line on the map.

d. The arrangement of holding fixes in the O'Hare area was the best of those attempted in this simulation.

e. The departure routes for the major directions of flight were adequate, permitting generally unrestricted climbs to cruising altitude. The southbound route from O'Hare and the northbound route from Midway still required a considerable amount of restriction in the form of "tunneling."

f. The departure routes from Midway are such that little radar vectoring is necessary except to provide radar separation while an aircraft is climbing through the altitude of another aircraft.

g. It will be desirable for the departure controllers to have a 30-mile range radar display so that the outer radio fixes can be covered.

h. It was considerably easier, with the use of two radar controllers in the O'Hare area, to vector traffic into two airports and to control the mixture of jet and conventional-type aircraft.

i. The control of shuttle flights between the two areas was satisfactory. The two methods described are only two of many possible methods of controlling these flights. Experience here indicates that whatever method of routing and controlling the shuttle flights is agreed upon, it should remain standard at all times; otherwise the coordination time between controllers will become so great that other portions of the traffic control system will suffer from lack of attention. Additional information concerning the control of shuttle flights between airports in close proximity can be found in another report.[2]

Control Procedures for Northwest Landings.

Since the arrangement of navigation aids, just previously described, produced the most acceptable results for landing southeast, it was used as the basis for tests to determine the practicability of landing aircraft to the northwest at both airports. The back courses of the two ILS systems were used as the navigation aids for final approaches.

To implement the system, the following additions were made to the navigation layout and are shown in Fig. 26:

a. An intersection was designated as the Elmhurst intersection at a point approximately five miles southwest of the O'Hare Airport. This intersection was formed by the front course of the Midway ILS, the 035° radial of the Naperville VOR. Since it is located in the general vicinity of the present Elmhurst intersection, it was called Elmhurst. This fix was used as a clearance limit for aircraft entering the O'Hare area from the north, west, and south.

b. A homing facility was assumed in operation on the back course of the ILS approximately five miles southwest of the O'Hare Airport. Since this point is near the present Wilson intersection, this marker was designated as the Wilson marker.

c. An intersection designated as the Evanston intersection was located approximately six miles south-southeast of the O'Hare Airport. This intersection was formed by the 344° radial from the Chicagoland VOR, and the 047° radial from the Naperville VOR. Since the intersection is near the location of the present Evanston intersection, it was called Evanston. This fix was used as a clearance limit for aircraft arriving in the O'Hare area from the east and southeast.

d. A buffer zone was inscribed southeast of O'Hare Airport to clearly define the area in which the O'Hare controllers were confined in vectoring aircraft.

e. An intersection was formed by the 098° radial from the Midway TVOR and the 007° radial of the Chicago Heights VOR

[2] Clair M. Anderson and Tirey K. Vickers, "Dynamic Simulation Tests of Several Traffic Control Systems for the Fort Worth-Dallas Terminal Area," Technical Development Report No. 239, August, 1954.

and designated as the Lake Shore intersection. This intersection is not located near the present Lake Shore intersection but is located approximately seven miles southeast of the Midway Airport. Aircraft arriving from the northeast for Midway used this fix as a clearance limit.

f. An intersection designated as the Calumet intersection was formed by the 100° radial from the Naperville VOR and the 035° radial of the Chicago Heights VOR. This intersection was used as a clearance limit by aircraft arriving from the east.

g. An intersection designated as the Harvey intersection was formed by the 019° radial from the Peotone VOR and the 314° radial of the Chicago Heights VOR. This intersection was called Harvey because of its location near the present Harvey L/F range station. This fix was used as a clearance limit for aircraft arriving at Midway from the south.

h. An intersection designated as the Howell intersection was formed by the 059° radial from the Coyne VOR and the 291° radial of the Chicago Heights VOR. This fix was used as a clearance limit for traffic arriving at Midway from the northwest and west.

i. The present Kedzie homing facility was moved southeast to a point approximately five miles from the Midway airport on the back course of the ILS. This fix was called the Ryan marker.

1. Arrival Control Procedures.

The minimum altitude used at the Elmhurst intersection was 3500 feet. Aircraft from this fix were normally instructed to maintain 3000 feet until on the east side of the Midway ILS course. This was a built-in safety rule to insure at least 500 feet of separation between a northwest take-off at Midway and landing traffic being vectored from the Elmhurst intersection into O'Hare or Glenview Airports. Aircraft arriving at Elmhurst from the north were restricted to 4500 feet until passing the Elgin intersection. O'Hare radar controllers normally assumed control of these aircraft when the aircraft were clear of V7W and V10 airways.

One major change in routing traffic into the O'Hare area was made. Aircraft which were previously routed over the Peotone VOR, the Harlem intersection, and into the O'Hare area when landings were being conducted to the southeast, were now routed via Peotone, Naperville, then to Elmhurst. This was considered practical since aircraft destined for Midway were not using Naperville as a clearance limit when landing to the northwest. The minimum altitude for O'Hare arrivals using this route was 6500 feet until past the Naperville VOR. This was necessary to allow aircraft departing Midway to the southwest the use of 5500 feet altitude or below en route to Coyne.

The minimum altitude at the Evanston intersection was 3500 feet. Arrival aircraft at this fix were further restricted to cross the Baker and North Shore intersections at 5500 feet. These restrictions were added to provide altitudes for aircraft departing the area.

Aircraft destined for Glenview Airport were vectored to final approach for runway 01 from either of the two holding fixes in the O'Hare area and were changed to the control of the Glenview radar controllers when approximately eight miles from Glenview airport on final approach course.

The minimum altitude at all of the Midway clearance fixes was 4500 feet.

Aircraft en route to the Lake Shore intersection were restricted to cross the Mid Lake intersection at 6500 feet. No special altitude restrictions were applied on the other routes.

Jet aircraft in the O'Hare area made penetration in the area as shown in Fig. 26. However, descent was made to only 4500 feet. When these aircraft reported as arriving back at the O'Hare outer marker at 4500 feet these aircraft were then vectored toward the Elmhurst or the Evanston markers and placed in the normal vector pattern for a northwest landing. Navy jet aircraft would be expected to follow the same procedure as the Air Force jets when landings were being made to the north at Glenview.

The area normally used in radar vectoring and the areas of control jurisdiction are shown in Fig. 26.

2. Departure Control Procedures.

Eastbound aircraft from the O'Hare area via V10 were normally cleared initially to the Charley intersection at altitudes of 4500 feet or higher. In many instances aircraft cleared on this route crossed the Charley intersection at 11,000 feet, since a relatively unrestricted climb could be obtained from O'Hare and Glenview. East- and southeast-bound aircraft using V110 were normally cleared to the Mid Lake intersection at 5500 feet or below. These aircraft were further restricted to cross the Able intersection at 3500 and 4500 feet. Eastbound aircraft from Midway on V8N were restricted to 2500 and 3500 feet until past the Crib intersection, after which point they were able to climb. Eastbound aircraft from Midway on V38 were restricted to 2500 and 3500 feet until past airway V6. These aircraft were normally routed via the Crib intersection and the McCool marker.

As shown in Fig. 27, some of the traffic eastbound on V-38 was routed over Lockport and the 134° radial from Naperville until reaching the 100° radial from the Coyne VOR, then east to V38 airway. These aircraft were restricted to 2500 and 3500 feet altitude until reaching a point clear of the Harvey holding pattern.

Southeast-bound flights from Midway were routed over Lockport intersection and the 134° radial from the Naperville VOR to V97. West and southwest-bound flights from Midway were routed via Lockport and Coyne at altitudes of 5500 feet or below. These aircraft were restricted to 2500 or 3500 feet until passing the Lockport intersection. Northwest-bound flights from Midway were cleared via the Coyne VOR to the Big Rock intersection at 2500 or 3500 feet. Northbound flights from Midway were cleared to the Charley intersection at 2500 feet. Often after crossing the Able intersection these aircraft could be cleared to higher altitudes below 5500 feet because departures from O'Hare were normally crossing Charley intersection at altitudes above 5500 feet.

Southbound aircraft from the O'Hare area were cleared to the X-ray intersection at 2500 and 3500 feet. These aircraft were restricted to 2500 feet until clear of the Elmhurst holding pattern. Northwest and west-bound aircraft from the O'Hare area were cleared to the Fox intersection at 2500 and 3500 feet. These aircraft were restricted to 2500 feet until clear of the Elmhurst holding pattern.

Jet aircraft departing from O'Hare or from Glenview climbed straight north after take-off until reaching an altitude above other traffic before turning on course.

3. Shuttle Flight Procedures.

A shuttle flight from the O'Hare Airport was normally cleared to the Stadium intersection at 3500 feet. Information concerning this flight was coordinated with Midway controllers and the flight was released to their control as the flight approached the Stadium intersection. Since the Midway east sector controller was expecting this flight, he immediately assumed control of the aircraft and vectored the aircraft to the Lake Shore holding fix and from there to the Ryan marker.

A shuttle flight from Midway to O'Hare was normally cleared to the Stadium intersection at 3500 feet. Information concerning this flight was coordinated with the O'Hare east sector controller immediately after departure from Midway. As soon as the aircraft reached 2500 feet, control was changed to the O'Hare east sector controller. In most cases shuttle flights from Midway Airport were identified by the O'Hare controller long before reaching the Stadium intersection and were turned northwest and placed in the radar pattern with other landing aircraft.

Shuttle flights from both airports followed the normal departure channels until the exchange of control was completed.

4. Results and Observations.

The following results were indicated and observations were made:

a. Delays to aircraft are shown graphically in Fig. 15. The vectoring area used by the O'Hare controller was very restricted. However, it was believed practical, provided arrival aircraft would operate within this area at or near approach speeds.*

b. The four fixes used in the Midway area were suitably located for the purpose of vectoring traffic to the Ryan marker.

c. The control of shuttle flights was satisfactory assuming both airports were provided with good radar. Without radar these shuttle flights would probably encounter considerable delay before completing a flight.

d. Jet departures from O'Hare and Glenview were in much better position to climb to high altitude immediately following take-off than when landings were being conducted in a southerly direction. North and eastbound traffic from the O'Hare area was able to climb to high altitudes before reaching the Charley intersection. Other departure aircraft from the O'Hare area were not necessarily further restricted when landings were being made to the northwest.

e. Departures from Midway using V38 and V97 were very restricted when compared with the use of these routes when landings were being made to the southeast. However, a departure test was made with the use of radar in the ARTC Center and delays to departures using V38 and V97 were substantially reduced, as shown in Fig. 15.

f. Although it was necessary to shift aircraft to different radio fixes in the terminal area when landing northwest, it was significant that only one route was changed as far as en route traffic was concerned. That was the change in route for O'Hare arrivals from over Peotone.

*Approach speed in this case means that speed at which a pilot plans to fly while making an instrument approach.

TESTS USING ARTC SURVEILLANCE RADAR

The arrangement of navigation aids used in these limited tests was the same as that described in VOR System D. In these tests, the air route controllers were provided with a horizontal radar-type display approximately 30 inches in diameter and covering an area around Chicago Midway Airport of 60 miles radius. As in all previous tests, these controllers were provided with direct communications with all aircraft entering this radar area. There was no change in the terminal area radar control arrangement from that described under VOR System D. The sample of traffic used was the sample in which the O'Hare area traffic equalled that of the Midway area.

All previous control procedures were retained as far as minimum altitudes and routes were concerned, except that as soon as the ARTC controllers had the aircraft under radar surveillance it was often possible to take many short cuts in routings and to climb aircraft departing the area to higher altitudes through the altitudes of arriving aircraft by use of radar separation standards.

While the delays for these tests did not show a radical change from the results obtained without ARTC radar, it was the opinion of all the controllers concerned that inbound traffic was much more orderly in arriving in the terminal area at the proper altitude and sequence. Further analysis of the results showed that the greatest advantage of using radar in the Air Route Traffic Control Center was in controlling departing aircraft, particularly on the routes having a number of conflicting intersections with arrival traffic. It was the opinion of the controllers that a radar for Center use should provide a range of 70 miles or more in order that the majority of the departing aircraft could be controlled to cruising level, and arrival aircraft could be descended and properly sequenced before reaching the metropolitan area fixes. With the installation of the VOR ranges in this area it should be possible to establish designated reporting points near the edge of the radar display to serve as points where identification could be accomplished. Analysis of the delays to arrival aircraft showed that nearly all of the high delay times were caused by aircraft being delayed prior to passing South Bend, Moline, and other outer points, and not in the area of radar coverage.

EFFECT OF GLENVIEW RESTRICTED AREA ON FLOW OF TRAFFIC

The most serious deterrent to a satisfactory realignment of the airway structure lies in the present boundaries of the Glenview restricted area. Numerous route structures were considered in paper studies prior to the start of the simulation runs. One point which was paramount throughout these preliminary studies and which was confirmed in the actual simulation tests was that the Glenview restricted area, as presently constituted, created an untenable situation in the route structure east of O'Hare, Glenview, and Midway terminals. Although there exists some difference of opinion as to the extent to which the Glenview restricted area should be modified, there was complete unanimity on the part of those participating in the tests that the restricted area must be reduced to provide the route structure necessary for the O'Hare, Glenview, and Midway traffic.

An analysis of the present air traffic in the Chicago metropolitan area, based on actual traffic samples from the Chicago ARTC Center covering the period of 1630 to 1930 CST, shows that 50 per cent of the inbound flights to Midway Airport are from the east. Most of this traffic is destined for Midway Airport, and is not seriously affected by the presence of the Glenview restricted area. However, even the limited amount of traffic utilizing O'Hare and Glenview is restricted to a considerable degree through circuitous routing around the Glenview restricted area, since such traffic must share routes with the inbound traffic to Midway. The full impact of the restrictive routings generated by the Glenview restricted area will be felt when the airlines commence the transfer of their scheduled operations to O'Hare Field.

Basic to the solution of air traffic congestion in a multiterminal metropolitan area is a system of relatively independent routes serving the respective terminals. This concept has been well established in the operation of the New York and Washington control areas. The simulation study at TDEC has drawn heavily upon the experience gained in previous simulation of these areas in devising the recommended route structure for the Chicago metropolitan area. Much of the route structure philosophy applied to this study has been well tested in the operation of the Washington and New York ARTC Centers.

Illustrated in Fig. 28 is the recommended airway alignment and route structure to the east of the O'Hare-Glenview-Midway area. The shaded portion of the Glenview restricted area is the minimum by which that area should be reduced to accommodate these routes. The southern boundary of the modified restricted area would be described as a line parallel to, and five miles north of, the en route radial between the Chicagoland VOR (proposed) and the Pullman VOR. It will be noted in Fig. 28 that O'Hare and Glenview have a departure route over PMM and an arrival route over BEH, both of which are independent of arrival and departure routes utilized by Midway traffic. Fifty per cent of the arrivals at Glenview-O'Hare utilize the inbound route, and 42 per cent of the departures from Glenview-O'Hare utilize the departure route. Point A in Fig. 28 represents a clearance limit for flights inbound to Midway. This clearance limit is entirely independent of the Glenview-O'Hare traffic. In Fig. 29, with the entire restricted area retained, point A becomes the focal point for all eastbound departures from Glenview-O'Hare, all inbounds from the east destined for Glenview-O'Hare, as well as 45 per cent of the inbound flights to Midway from the east. Specifically, under a sustained flow of traffic over a route structure similar to that depicted in Fig. 29, the minimum altitude available at point A for a flight en route to O'Hare or Glenview would not be less than 12,000 feet. In such a traffic situation, subsequent flights to O'Hare and Glenview would be required to cross point A at even higher altitudes or would be held en route. In either instance, serious delays to traffic in the system would accrue.

The simulation studies of the Chicago problem proved conclusively that a single fix clearance limit would be unable to accommodate efficiently such a volume and mixture of traffic, even with the best of radar equipment. Already approaching the saturation point with only Midway traffic to contend with, such a focal point of traffic would introduce delays into the metropolitan area which would obviate any advantages expected from the use of the O'Hare terminal during IFR conditions.

CONCLUSIONS

Simulation tests indicate that the acceptance rate for aircraft operating IFR in the Chicago area can be substantially increased with the opening of the O'Hare Airport. However, in order to move a mass volume of IFR traffic, it is necessary to revise some of the routings to and from the Chicago area. It is also necessary to provide radar arrival and departure control for both the O'Hare area and the Midway area. It was the opinion of the ARTC controllers who worked on these tests that the routes as shown in Figs. 11 and 24 were the best of those tested. This system of routes worked well without the use of radar in the ARTC Center. However, the system is designed so that should radar become a part of the Center equipment, the arrival and departure aircraft will operate in relatively independent areas, at least for the most heavily traveled routes. This will do much to simplify the radar controllers display and keep coordination between arrival and departure controllers at a minimum. This route system provides relatively free descent and climb paths for aircraft up to distances of 90 miles from Chicago in directions most frequently used.

The air route traffic control was most effective when direct communications could be maintained with the majority of traffic within 90 miles of the metropolitan area. Limited tests have indicated that when more than ten per cent of arrival traffic is not in direct contact with the controller the effectiveness of direct communications is greatly reduced.

ARTC Center surveillance radar will be required to handle the volume of traffic anticipated at O'Hare and Midway Airports. The results obtained through the use of radar control procedures in the Washington ARTC Center have justified the use of center radar in that area. It is significant that an immediate solution to the New York traffic congestion problem is being sought through the medium of ARTC Center radar (the Mitchell Field radar facility is scheduled to be commissioned as a CAA-operated adjunct of the New York ARTC Center on April 1, 1955), and it should be considered that the traffic situation in the O'Hare-Midway terminal area will be similar to that which now exists in the Idlewild-LaGuardia terminal area.

Shuttle flights between the two terminal areas will be a source of delay. However, with adequate radar coverage of the areas and standard procedures to be followed, the delays can be minimized.

One O'Hare radar arrival controller will have a difficult task in vectoring traffic to two airports during peak traffic conditions.

There does not appear to be an adequate solution to the problem of providing the Glenview NAS with airspace in which to conduct independent operations. From the air traffic control viewpoint, there is some advantage in keeping the northern portion of the Glenview restricted area intact to be used as a jet climb area or a place for Navy jet aircraft to make a penetration.

The present and planned location of VOR stations was found to be adequate for routes shown in VOR System D.

RECOMMENDATIONS

It is recommended that:

1. The route pattern as presented in VOR System D be adopted.

2. A system of peripheral communications be provided to permit direct communication with all aircraft within 90 miles of Chicago.

3. The Chicago ARTC Center be provided with surveillance radar capable of a range of at least 70 miles to be displayed on large horizontal indicators.

4. The arrangement of radio aids in the O'Hare area as shown in Figs. 24 and 26 be adopted.

5. Radar arrival and departure procedures be established at O'Hare. The departure controller should be provided a radar display of at least 30-mile range.

6. The O'Hare tower be responsible for the control of IFR traffic at Glenview NAS.

7. The O'Hare tower be provided with a two-sector radar operation for the control of arrival traffic.

8. The terminal area arrangement for Midway Airport as shown in Figs. 24 and 26 be adopted.

9. Radar departure control be established at Midway tower with a radar display of at least 30 miles range.

10. The southern boundary of the Glenview restricted area be described as a line from a point 87° 47' 30" W, 42° 18' 00" N, to a point 87° 32' 50" W, 42° 19' 50" N.

GLOSSARY OF LOCATION IDENTIFIERS USED IN ILLUSTRATIONS

ABE - Able Intersection
API - Naperville VOR
ARL - Arlington

BFA - Beacon Intersection
BEH - Benton Harbor VOR
BAK - Baker Intersection
BDF - Bradford
BIG - Big Rock
BLU - Blue Island
BRL - Burlington

CGT - Chicago Heights VOR
CGX - Meigs Intersection
CHI - Chicago Midway Airport
CHY - Charley Intersection
CLD - Chicagoland VOR
COY - Coyne VOR

DIX - Dixon VOR
DOG - Dog Intersection
DUK - Crib Intersection

ESY - Easy Intersection
ELG - Elgin Intersection
ELM - Elmhurst Intersection
EVA - Evanston Intersection
EDZ - Kedzie Marker

FOX - Fox Intersection
FRK - Frankfort Intersection
FWA - Fort Wayne VOR

GFD - Gifford Intersection
GRG - George Intersection
GRY - Gary Intersection

HAR - Harlem Intersection
HIN - Heinz Marker
HTL - Hotel Intersection
HVY - Harvey Intersection and Range
HOL - Howell Intersection

IOW - Iowa City VOR

JOT - Joliet Range
JVL - Janesville VOR

LAF - Lafayette VOR
LPT - Lockport Intersection

LFD - Litchfield VOR

MCL - McCool Marker
MGO - Marengo Intersection
MID - Mid Lake Intersection
MKE - Milwaukee VOR
MLI - Moline VOR

N - North Shore Intersection
NBU - Glenview Airport

ORD - O'Hare Airport

PAL - Pal Waukee VOR
PEO - Peotone VOR
PIA - Peoria VOR
PNT - Pontiac VOR
PMM - Pullman VOR

RFD - Rockford VOR
ROS - Roselle Intersection
RST - Resort Intersection

SBN - South Bend VOR
STA - Stadium Intersection

TSN - Thomaston Intersection

VIR - Virgil Intersection

WAU - Wauconda Intersection
WIN - Winnetka Intersection

X-Ray Intersection

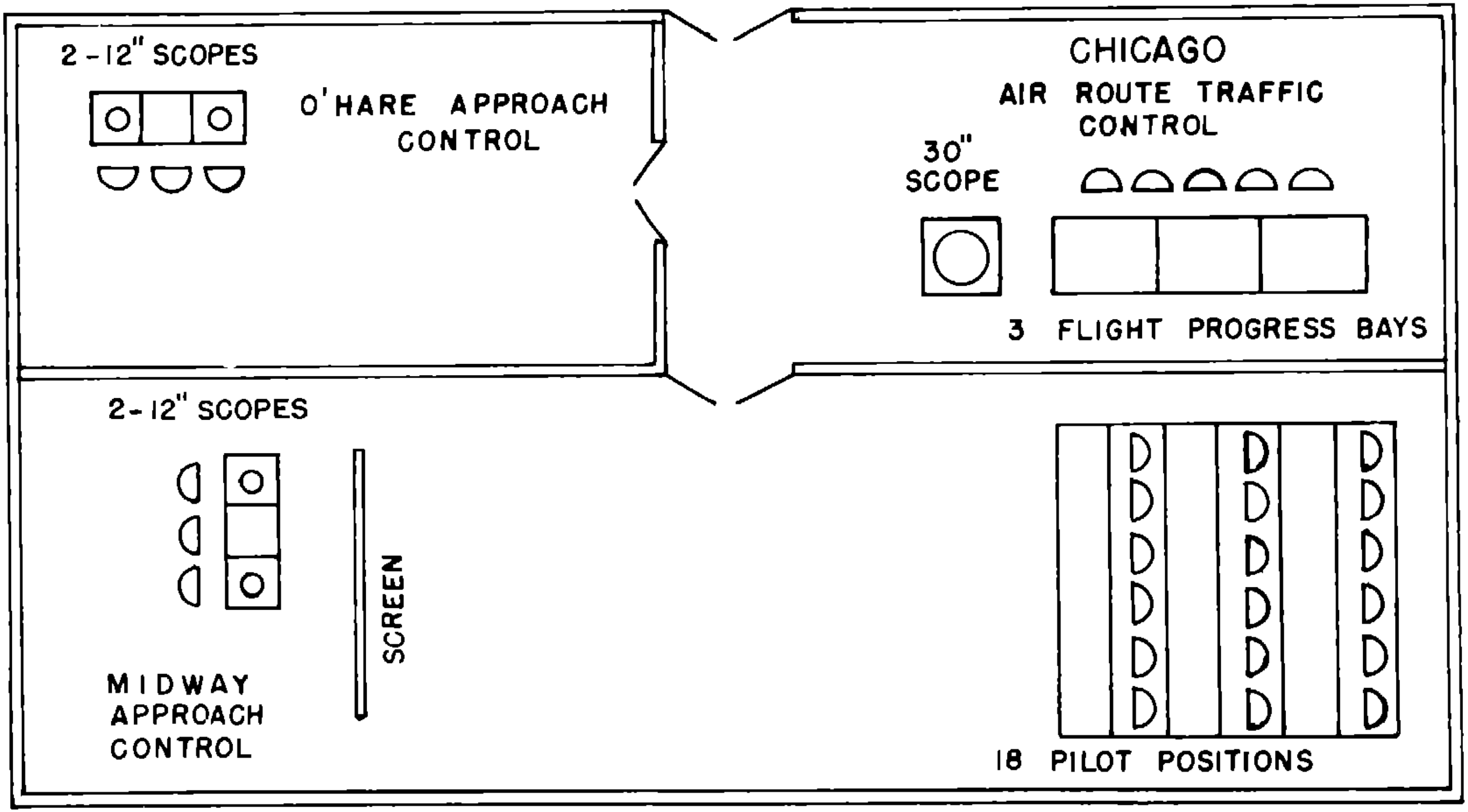


FIG I PHYSICAL ARRANGEMENT OF SIMULATION EQUIPMENT
(NOT DRAWN TO SCALE)

AA TECHNICAL DEVELOPMEN
AND EVALUATION CEN ER
INDIANAPOLIS INDIANA

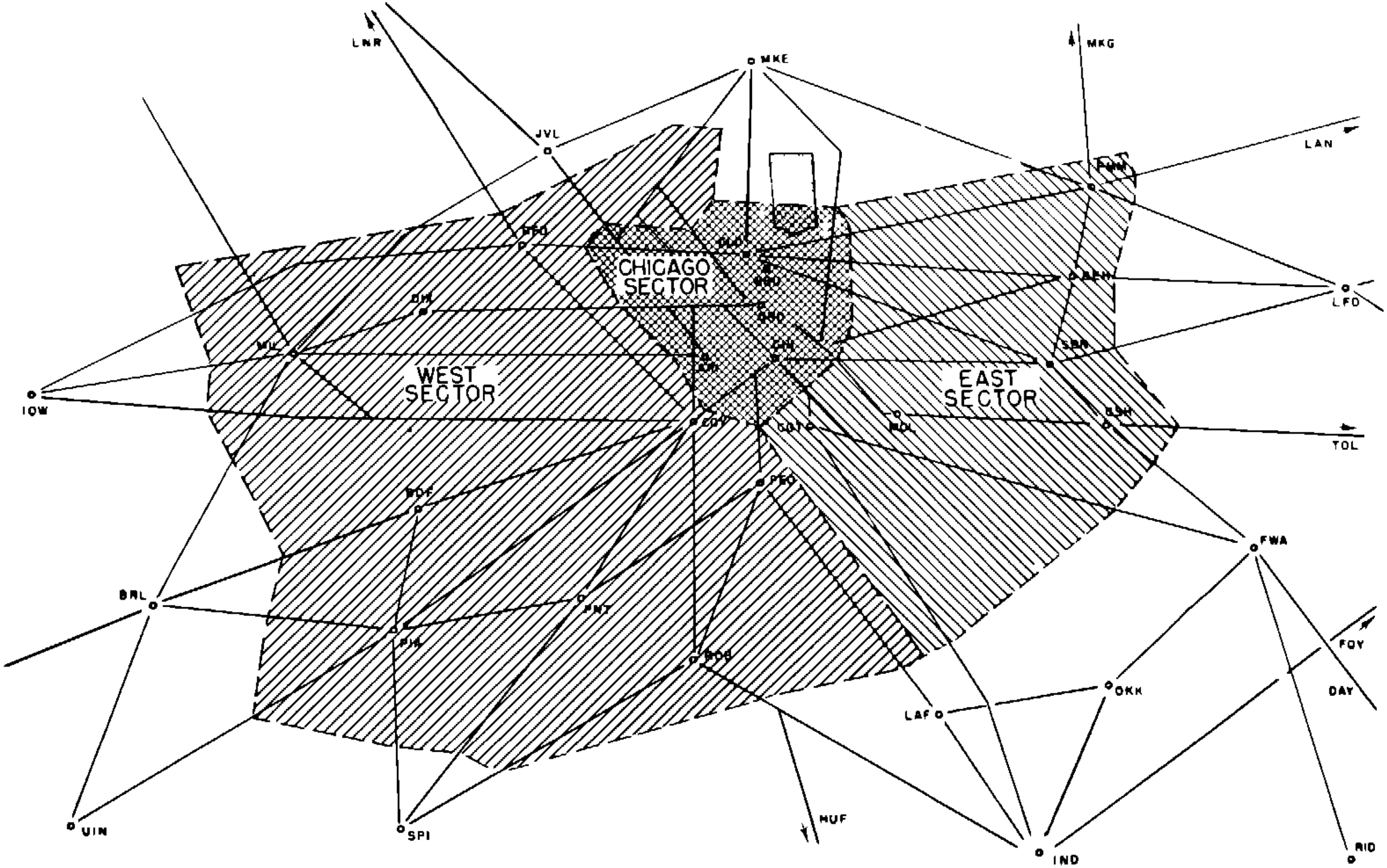


FIG 2 SECTORIZATION USED IN THE ARTC SIMULATION

CAA TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS INDIANA

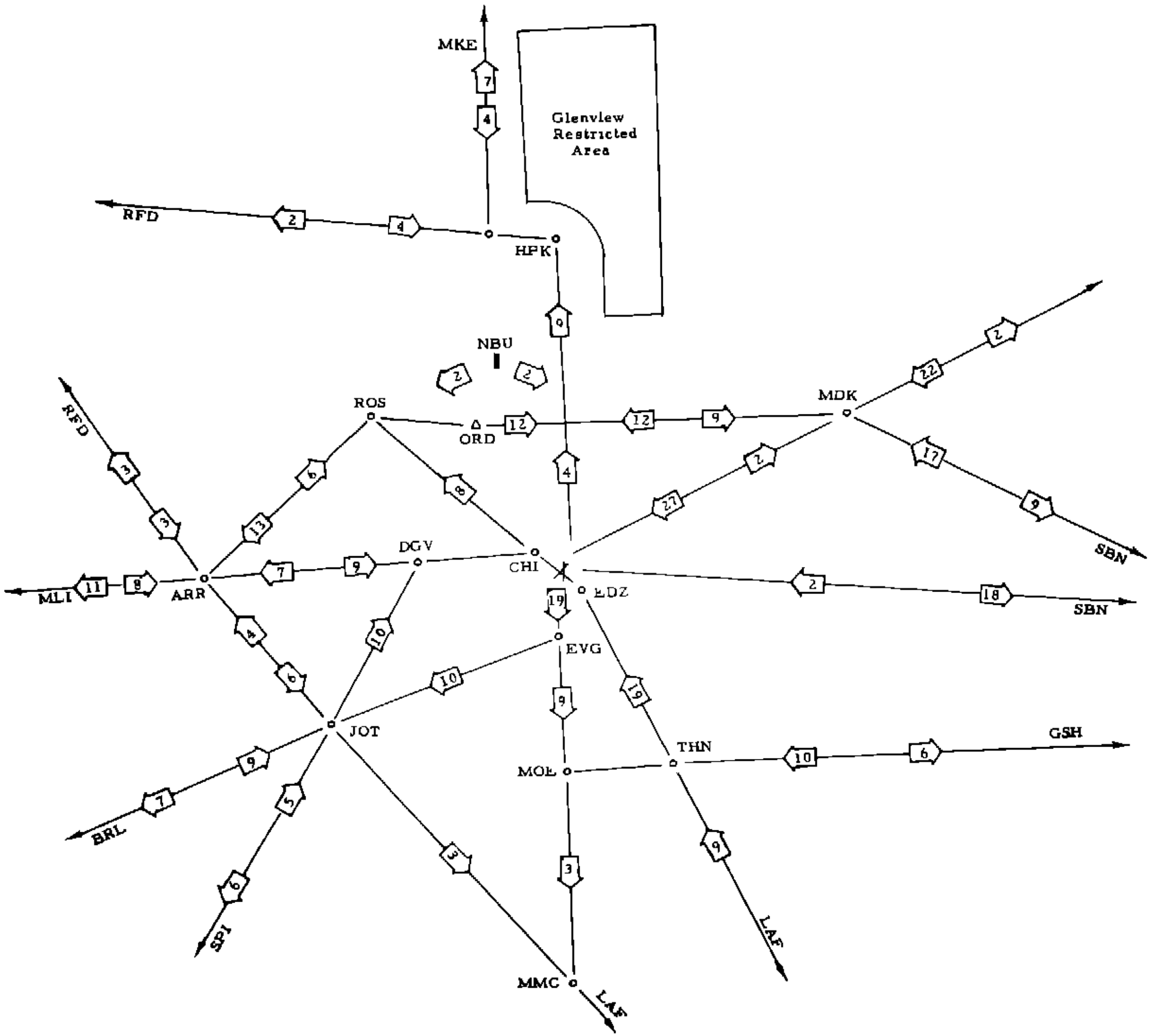


FIG. 3 TRAFFIC FLOW -- PRESENT SYSTEM (SAMPLE NO. 1)

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

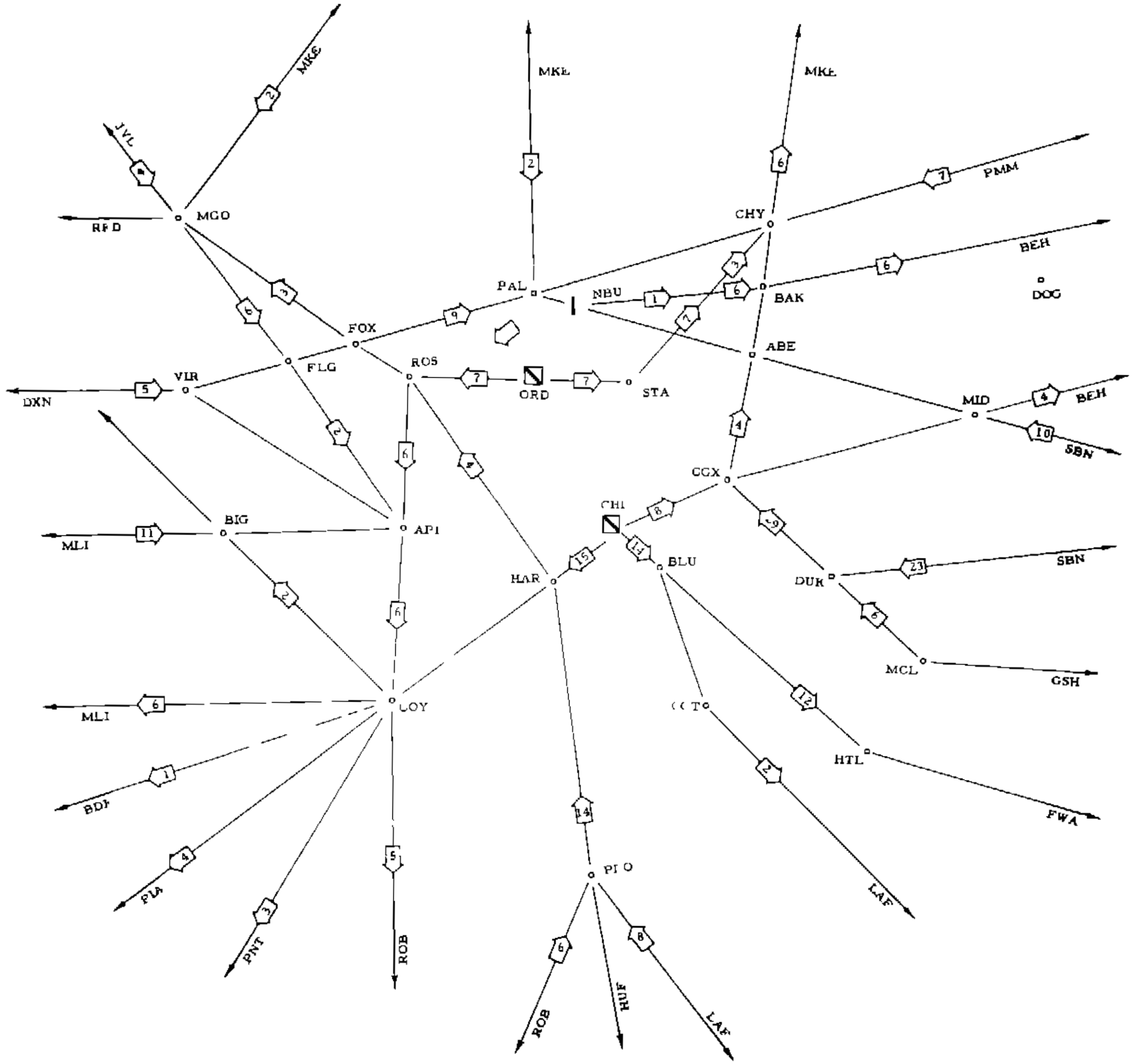


FIG 4 TRAFFIC FLOW VOR SYSTEM B (SAMPLE NO 1)

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

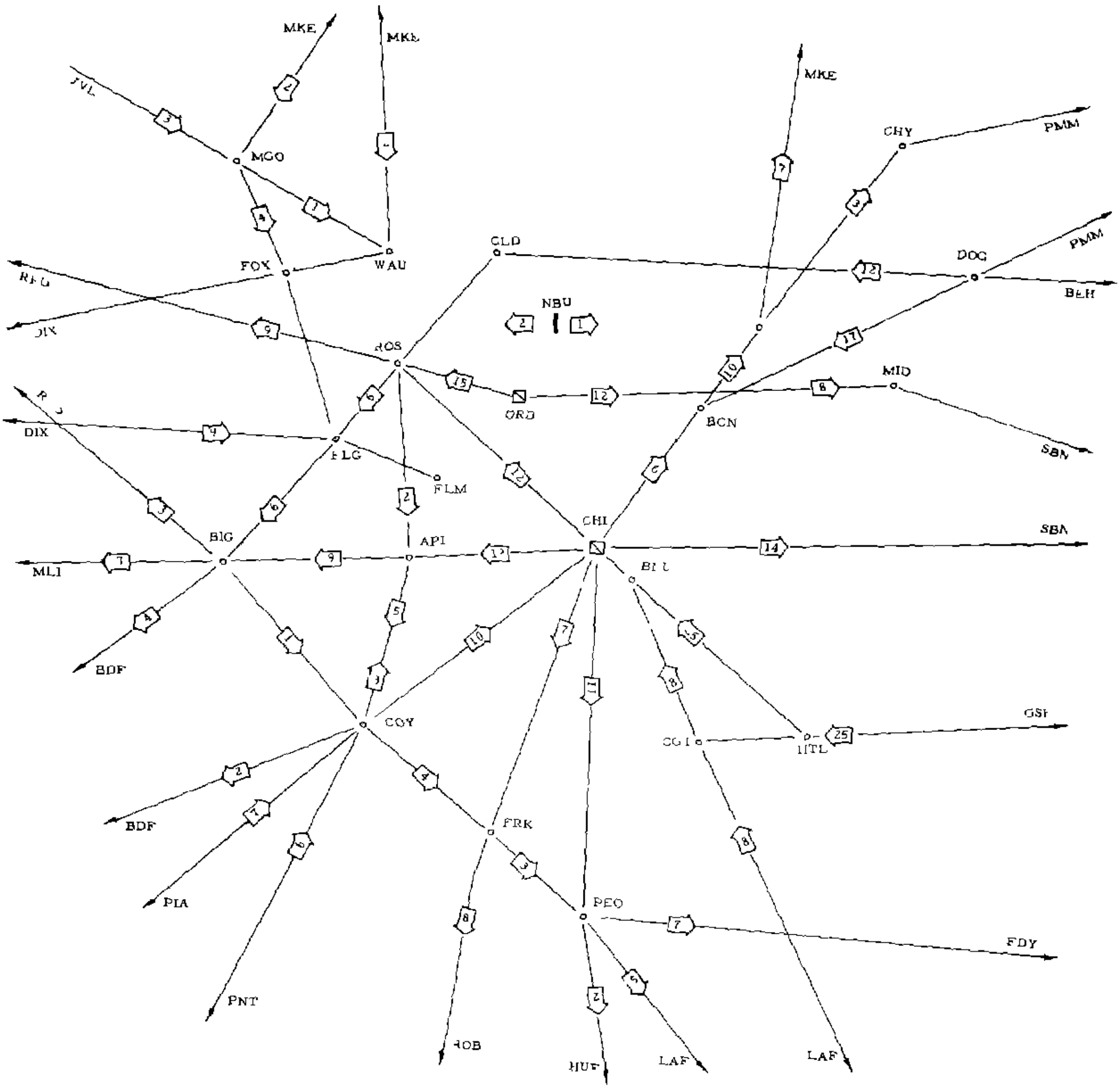


FIG 5 TRAFFIC FLOW - VOR SYSTEM C (SAMPLE NO 1)

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENT R INDIANAPOLIS INDIANA

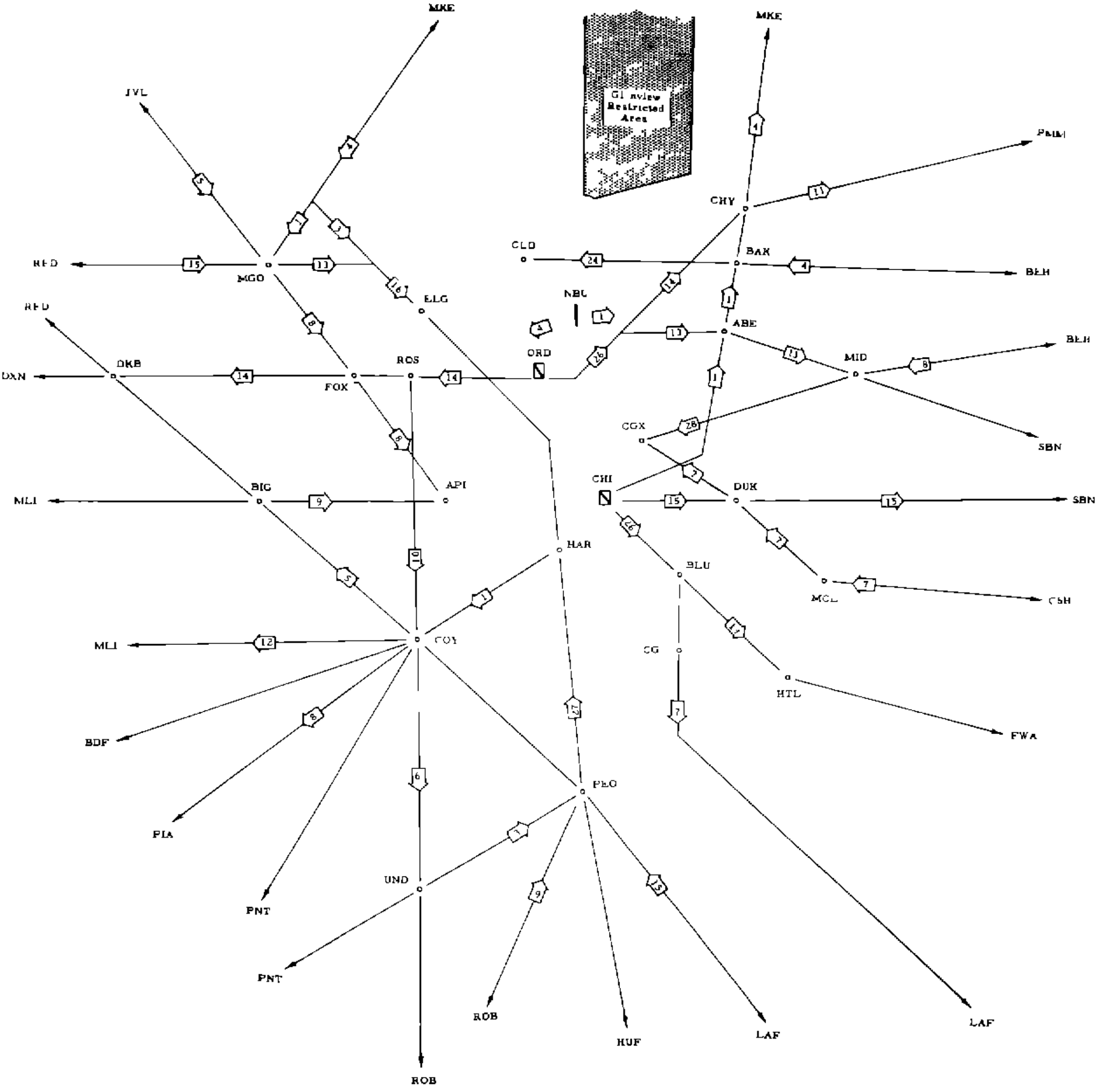


FIG 6 TRAFFIC FLOW - VOR SYSTEM NO. D (SAMPLE NO 2)

CAA TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS INDIANA

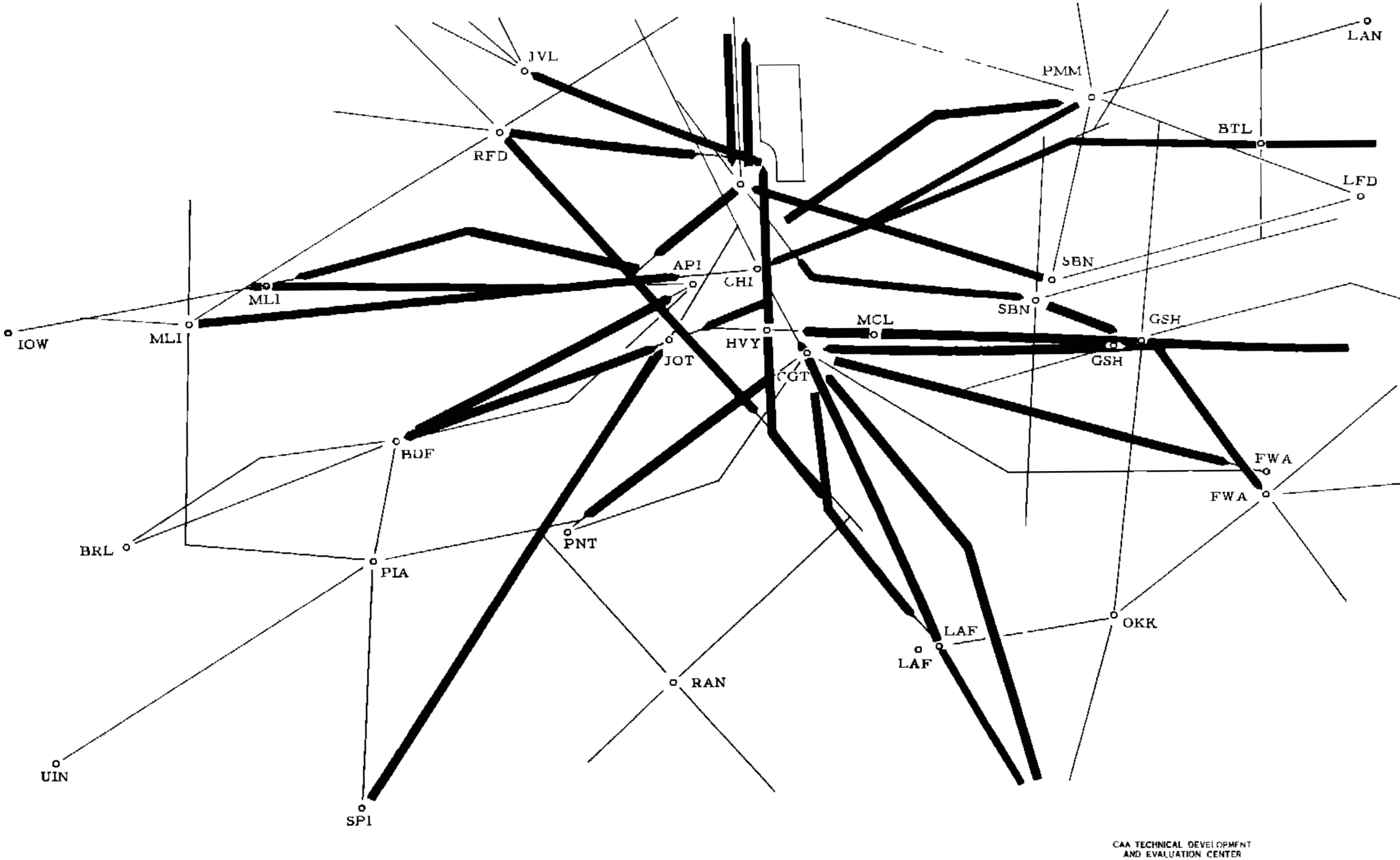
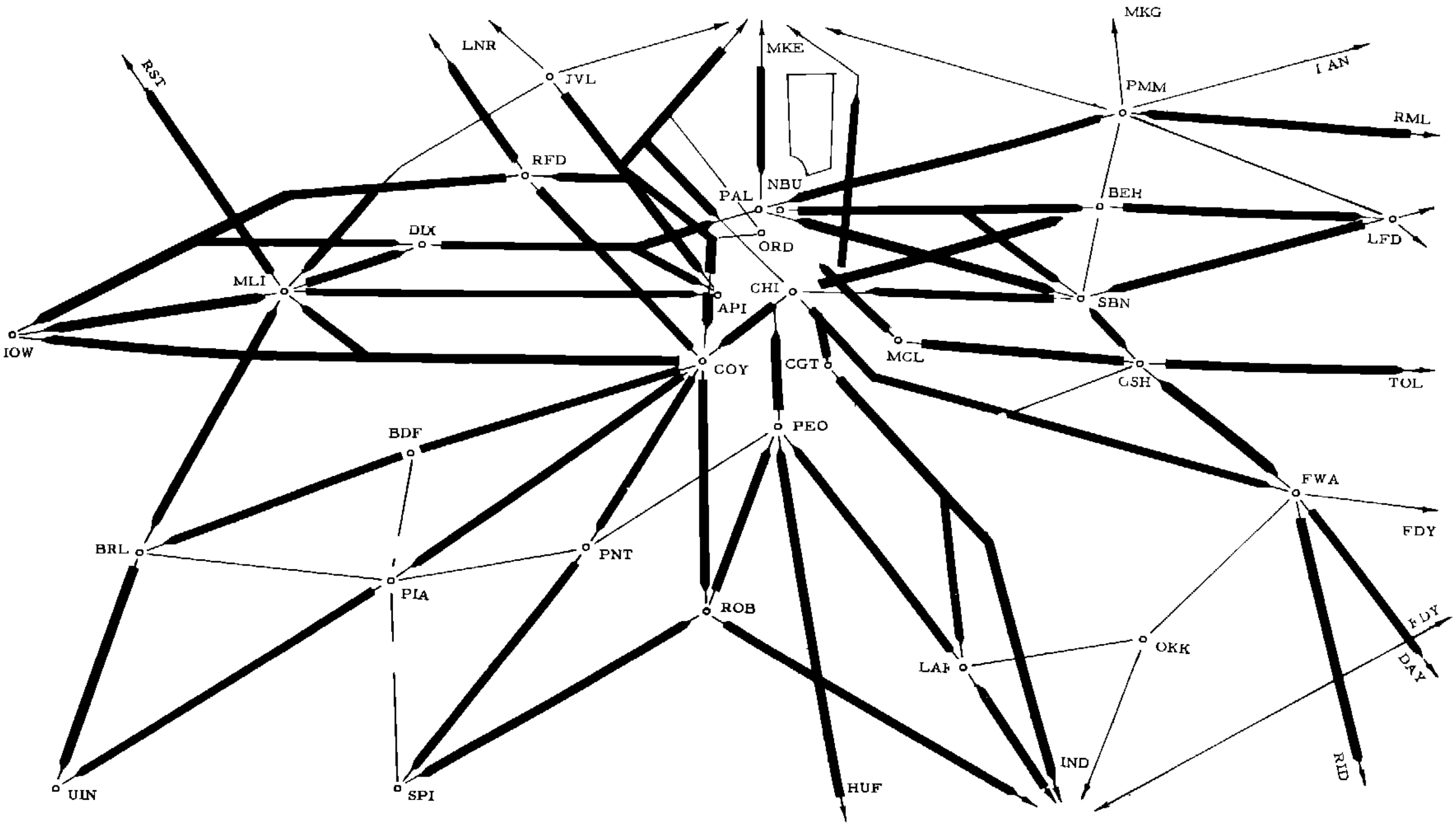


FIG 7 TRAFFIC FLOW -- PRESENT AIRWAY SYSTEM



FAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

FIG 8 ROUTE ARRANGEMENT, VOR SYSTEM A

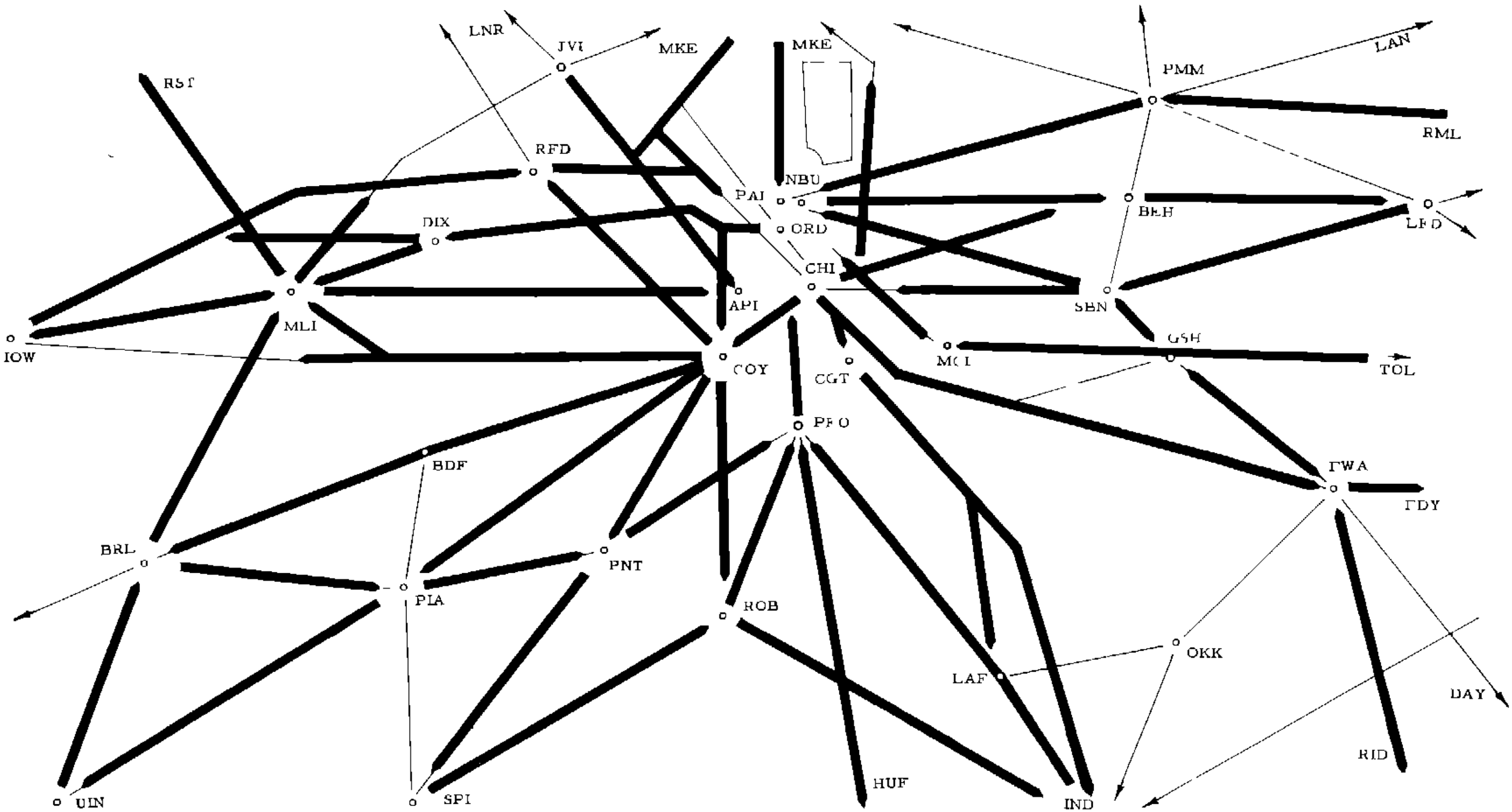


FIG 9 ROUTE ARRANGEMENT -- VOR SYSTEM B

CAA TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS INDIANA

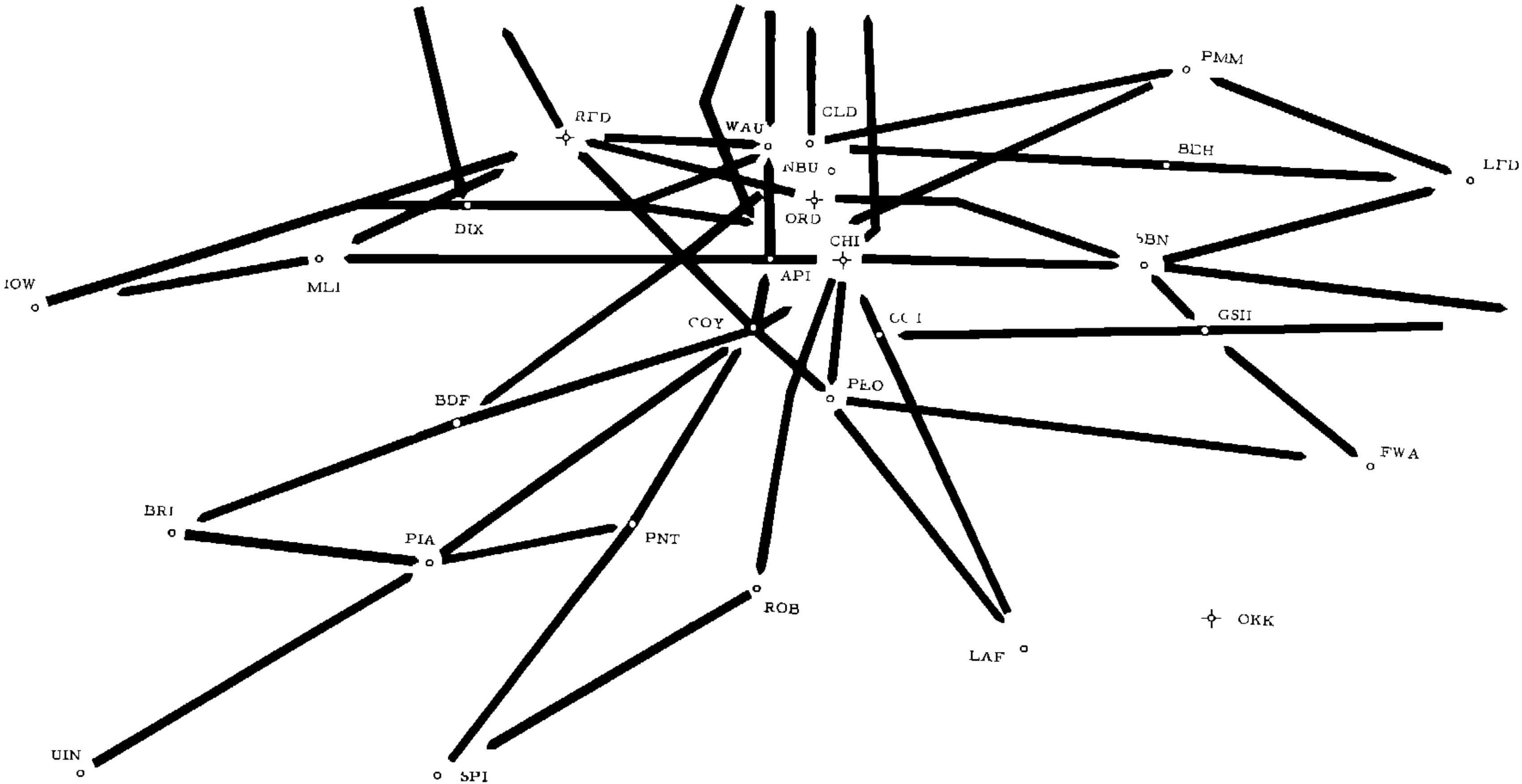
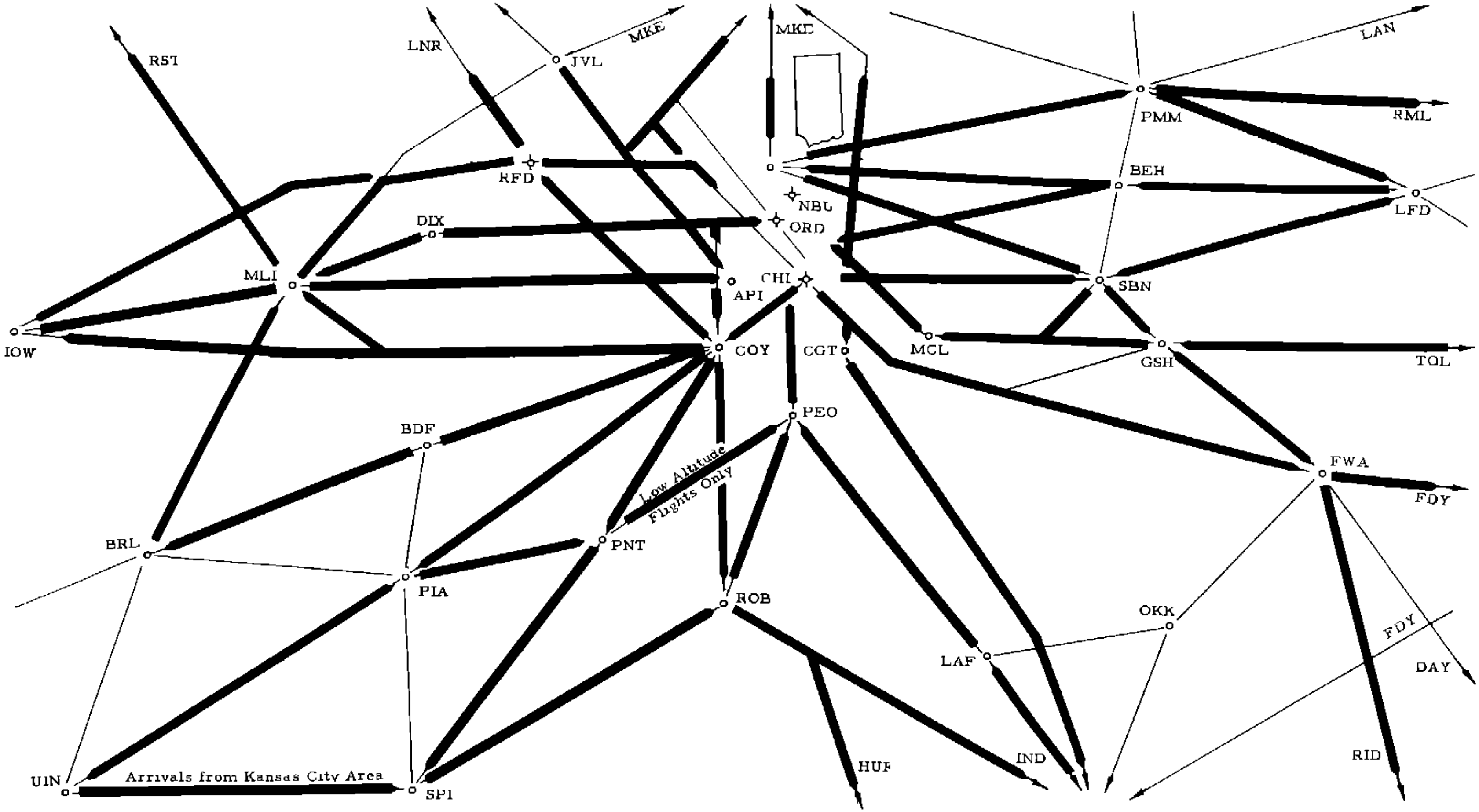


FIG 10 ROUTE ARRANGEMENT, VOR SYSTEM C

AA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA



FAA TECHNICAL DEVELOPMENT
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FIG 11 ROUTE ARRANGEMENT -- VOR SYSTEM D

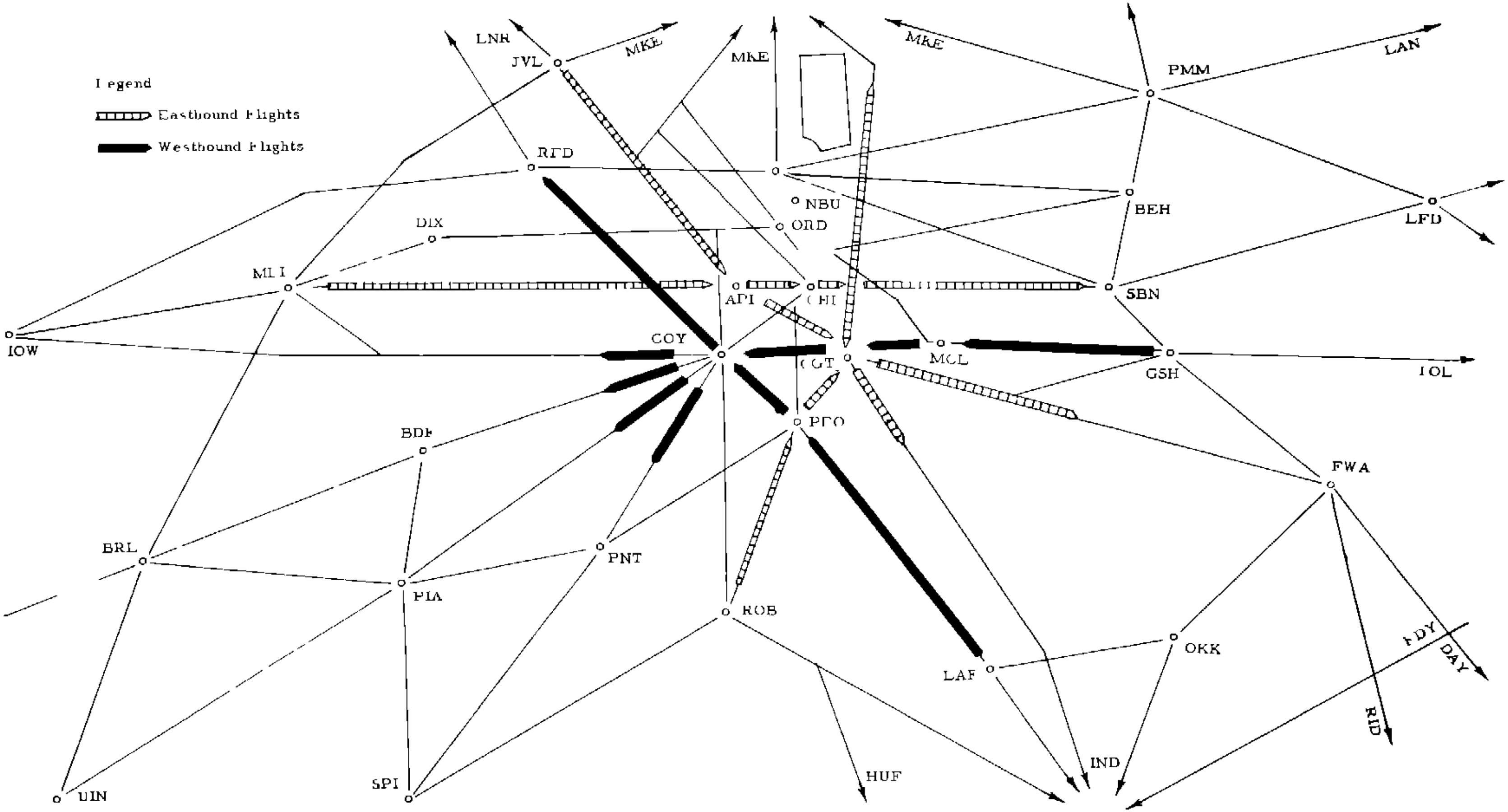


FIG 12 SUGGESTED PATTERN OF AIRWAYS FOR OVERFLIGHTS

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

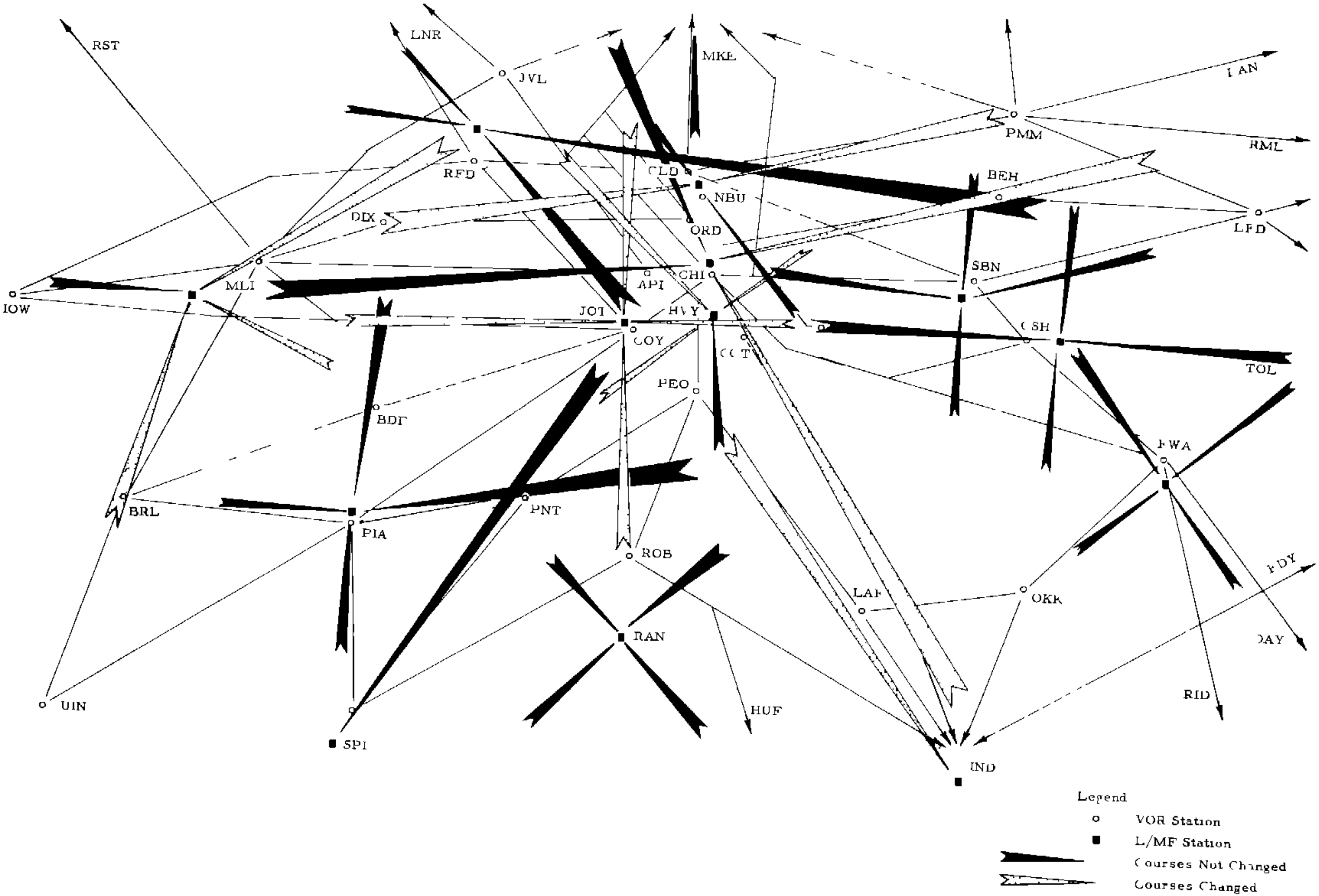
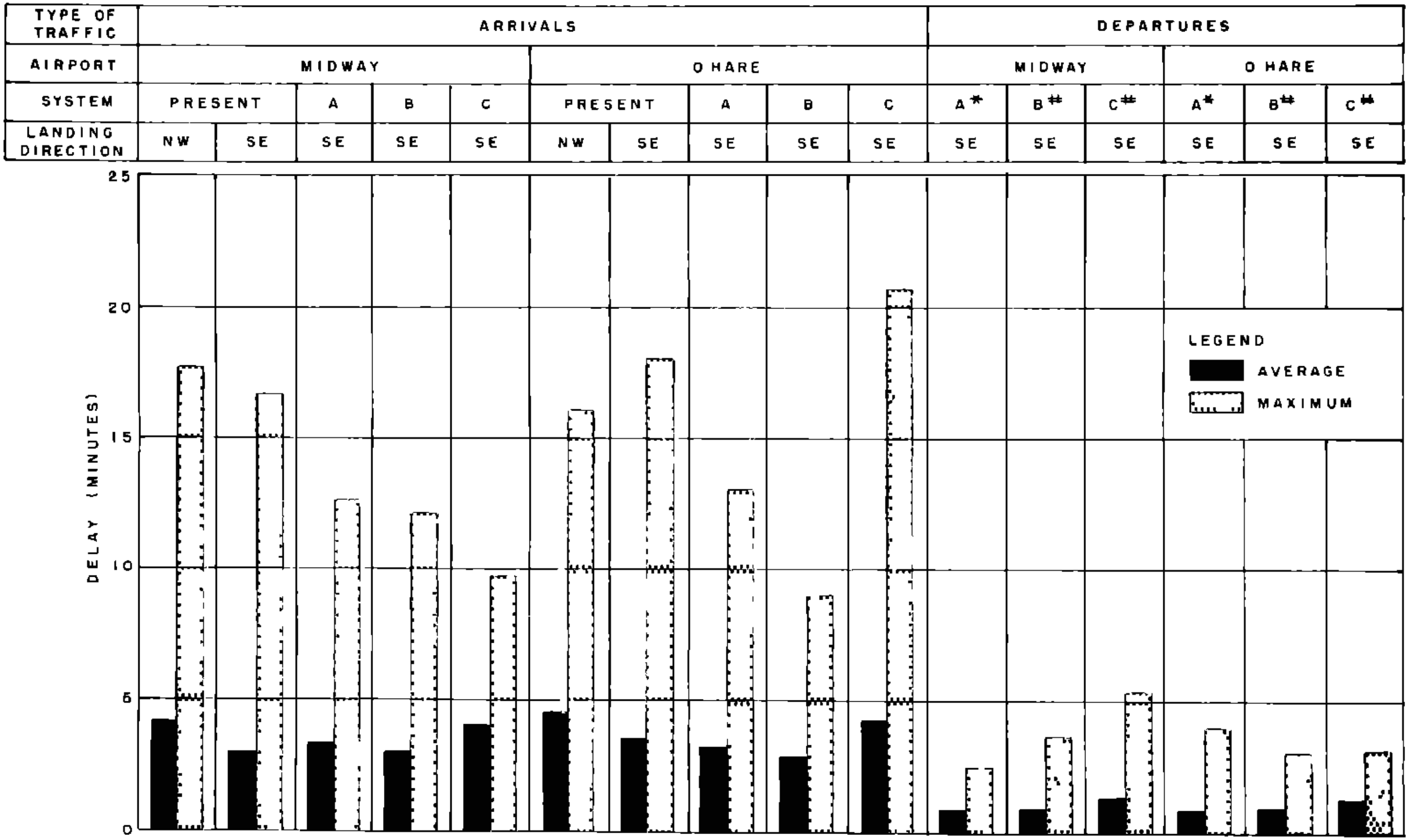


FIG. 13 RECOMMENDED REALIGNMENT OF L/MF RANGES COMPATIBLE WITH PROPOSED VOR ROUTES



* SHORT CLEARANCE ISSUED BY TOWER

\# SHORT CLEARANCE ISSUED BY ARTC

TOWER RADAR USED IN ALL TESTS

FIG 14 DELAYS, SAMPLE I

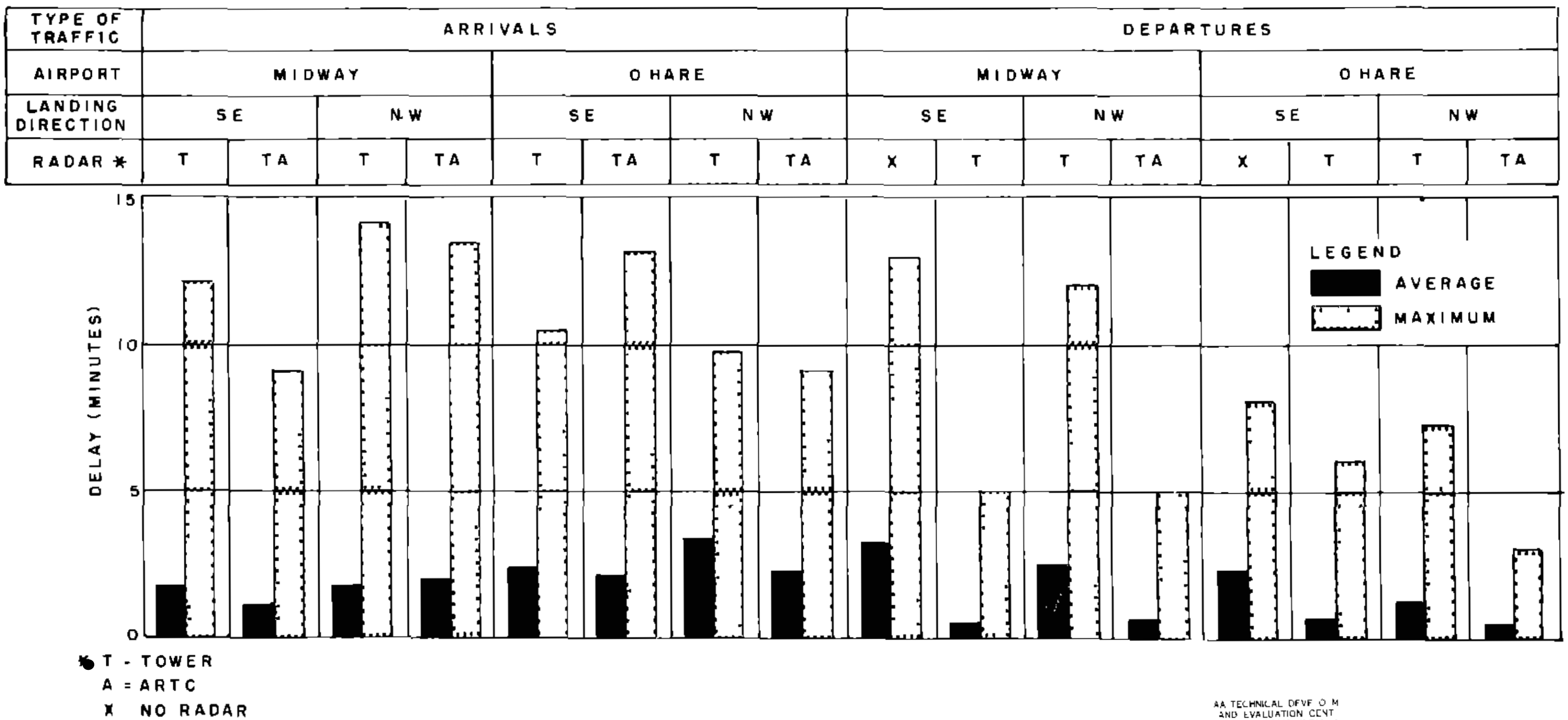


FIG 15 DELAYS—SAMPLE 2, SYSTEM D

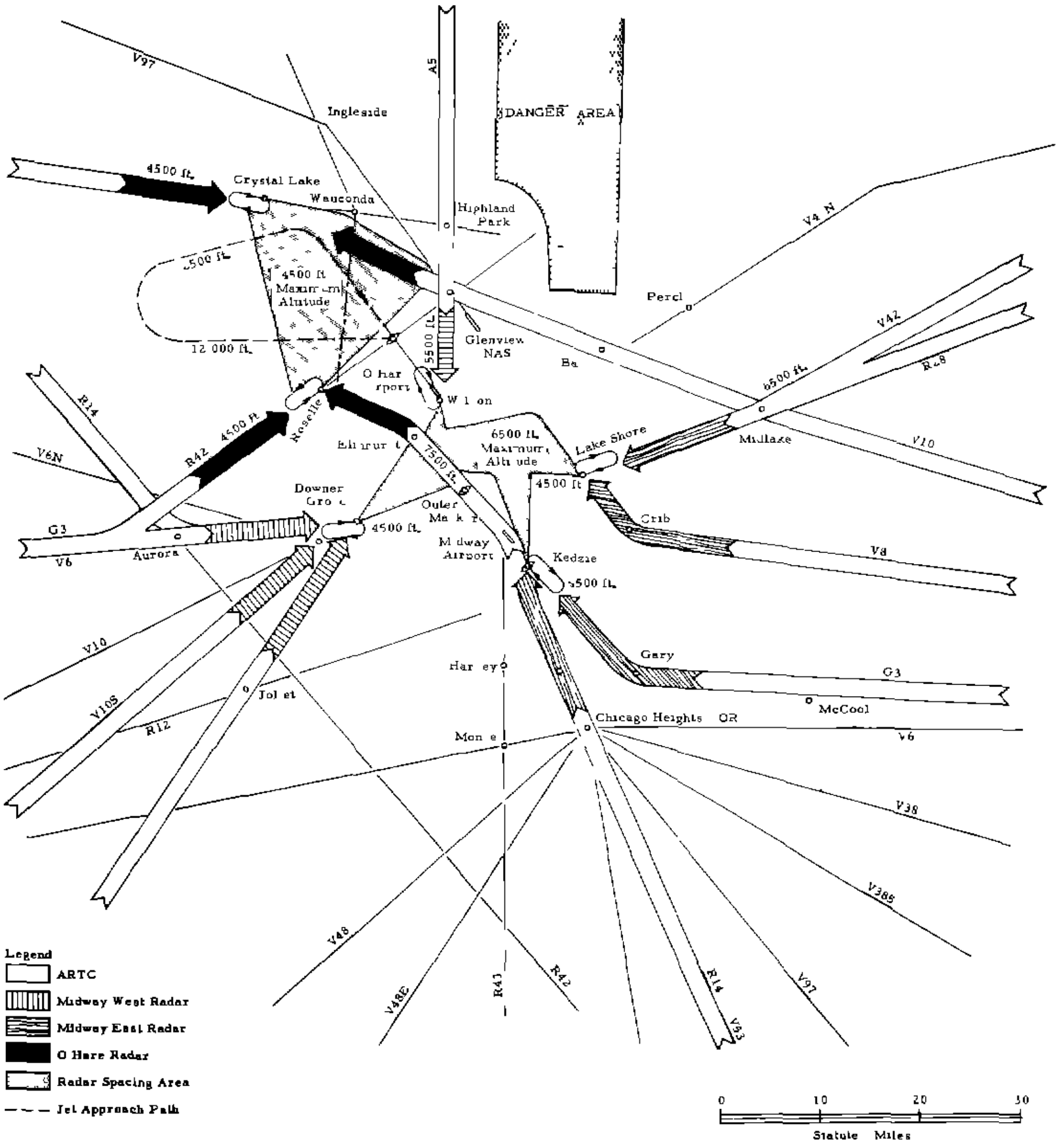


FIG 16 ARRIVAL ROUTES PRESENT SYSTEM (SOUTHEAST LANDINGS)

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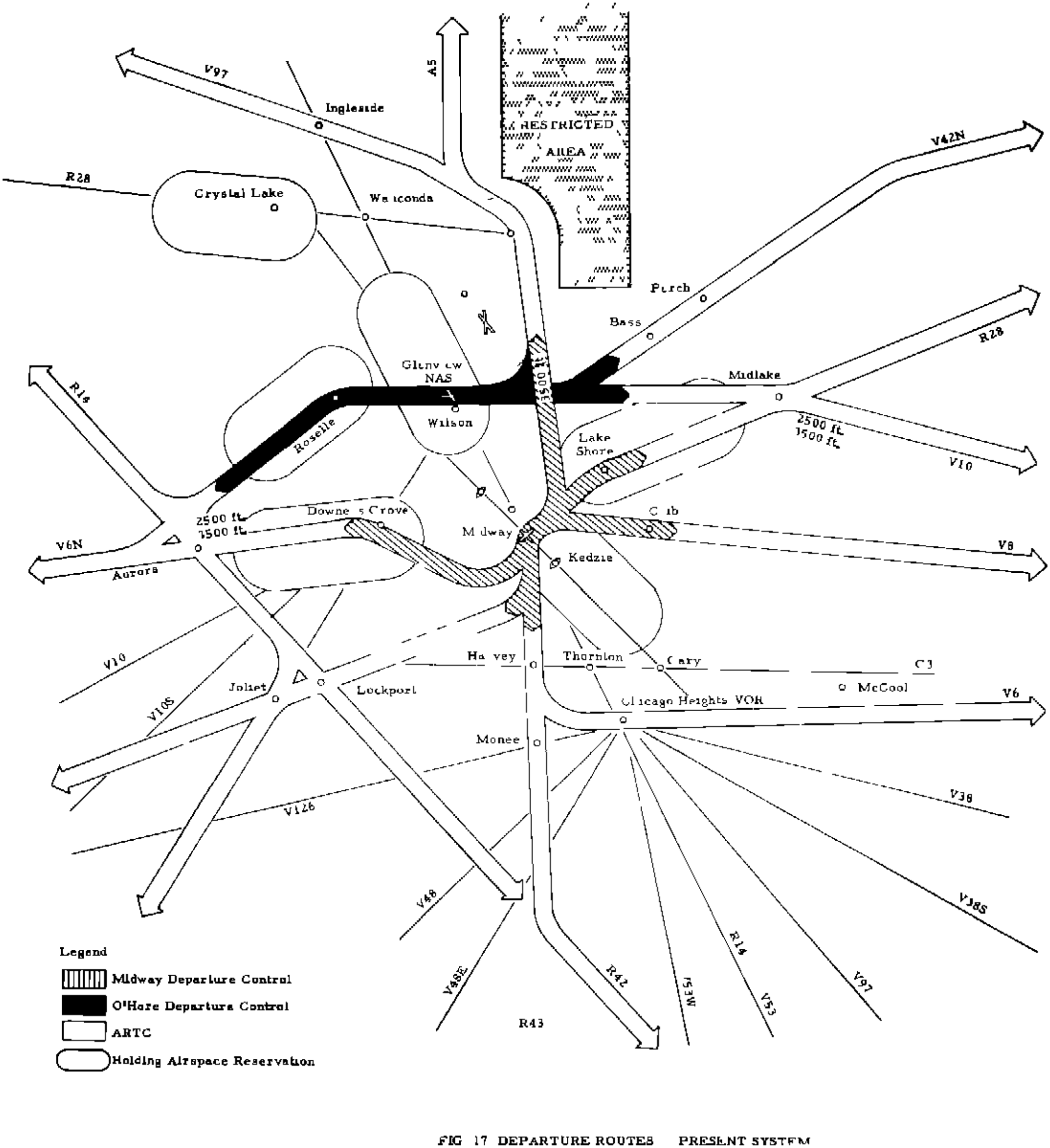


FIG 17 DEPARTURE ROUTES   PRESENT SYSTEM

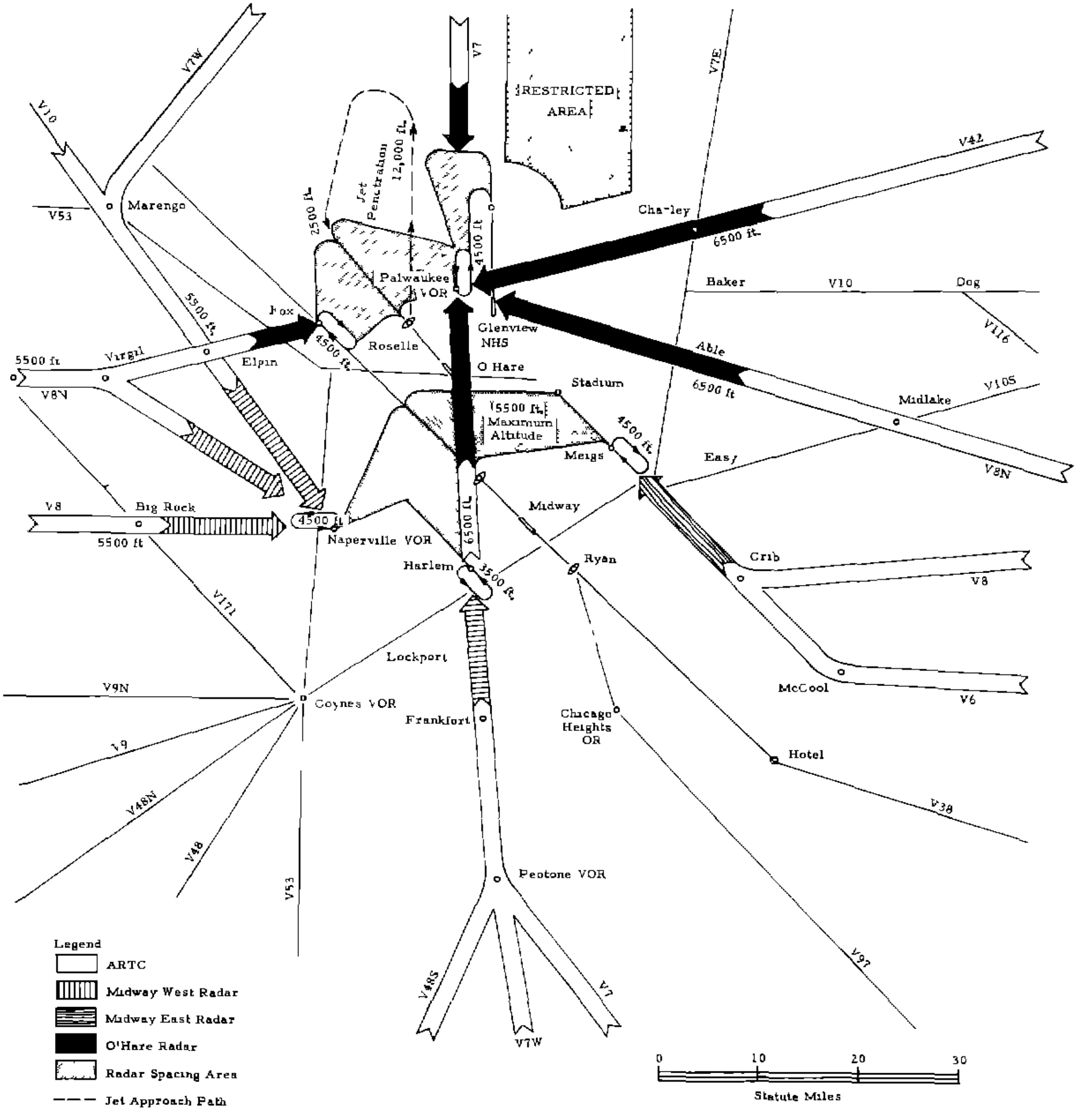


FIG 18 ARRIVAL ROUTES - VOR SYSTEM A

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

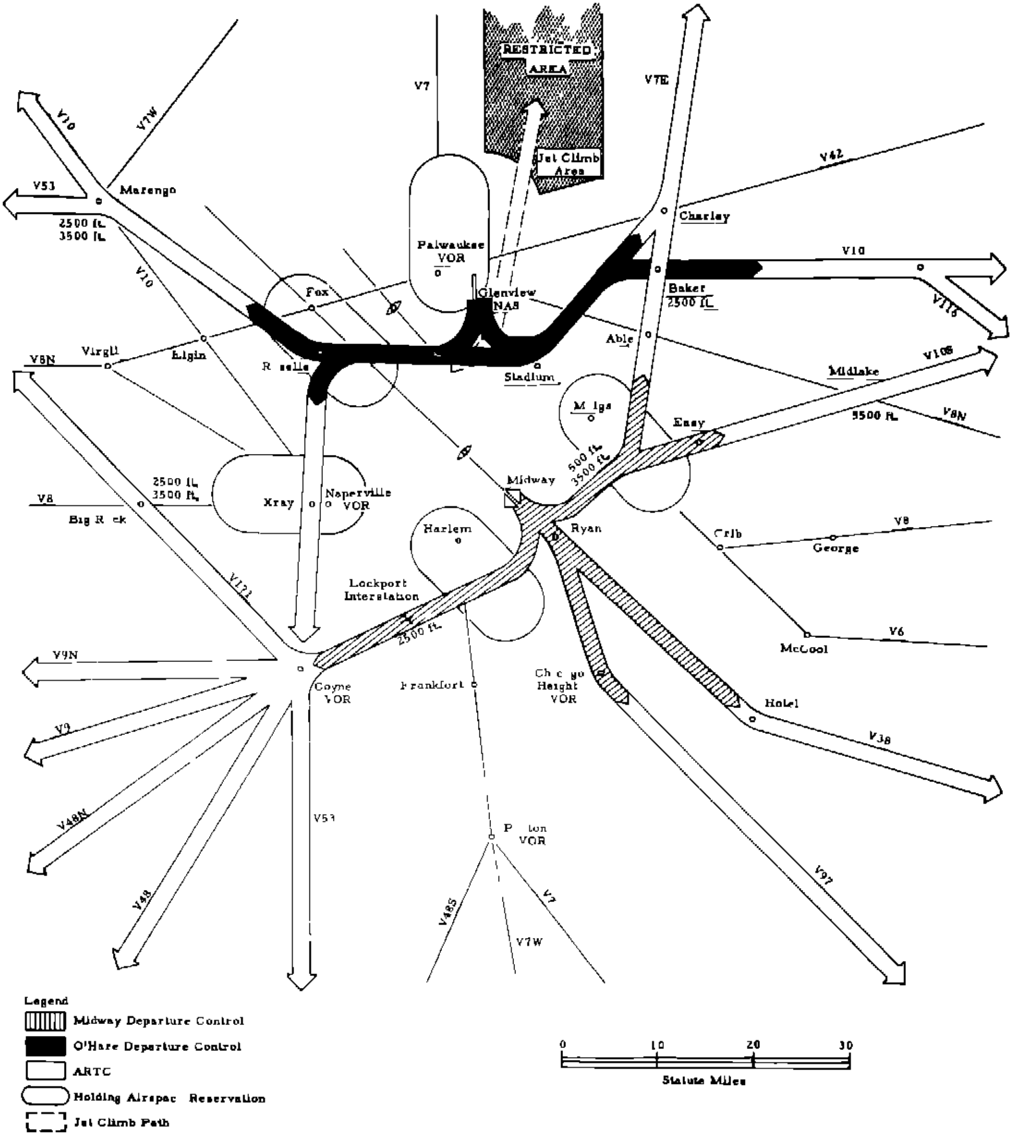


FIG. 19 DEPARTURE ROUTES -- VOR SYSTEM A

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

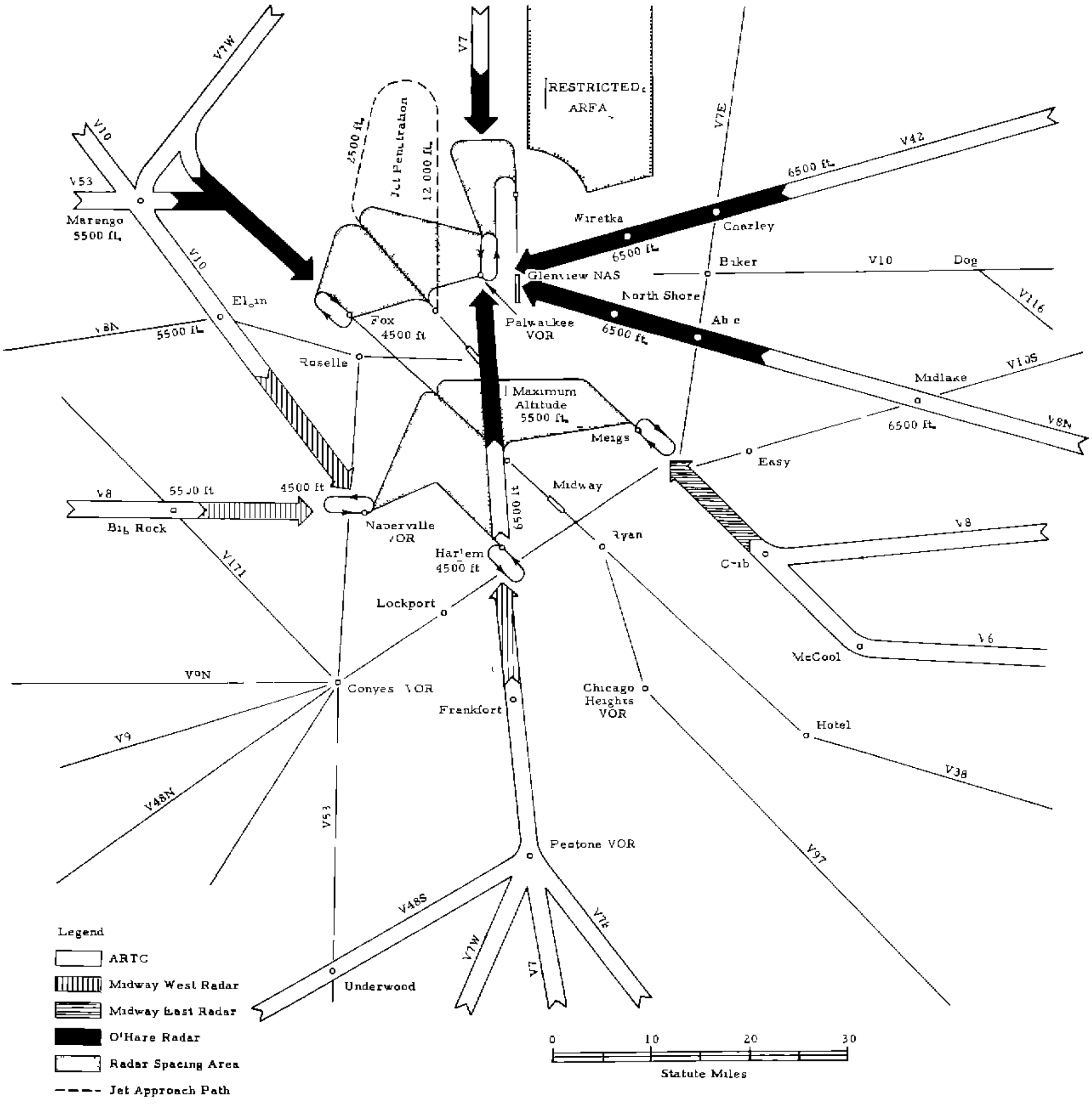


FIG 20 ARRIVAL ROUTES - VOR SYSTEM B

CAA TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS INDIANA

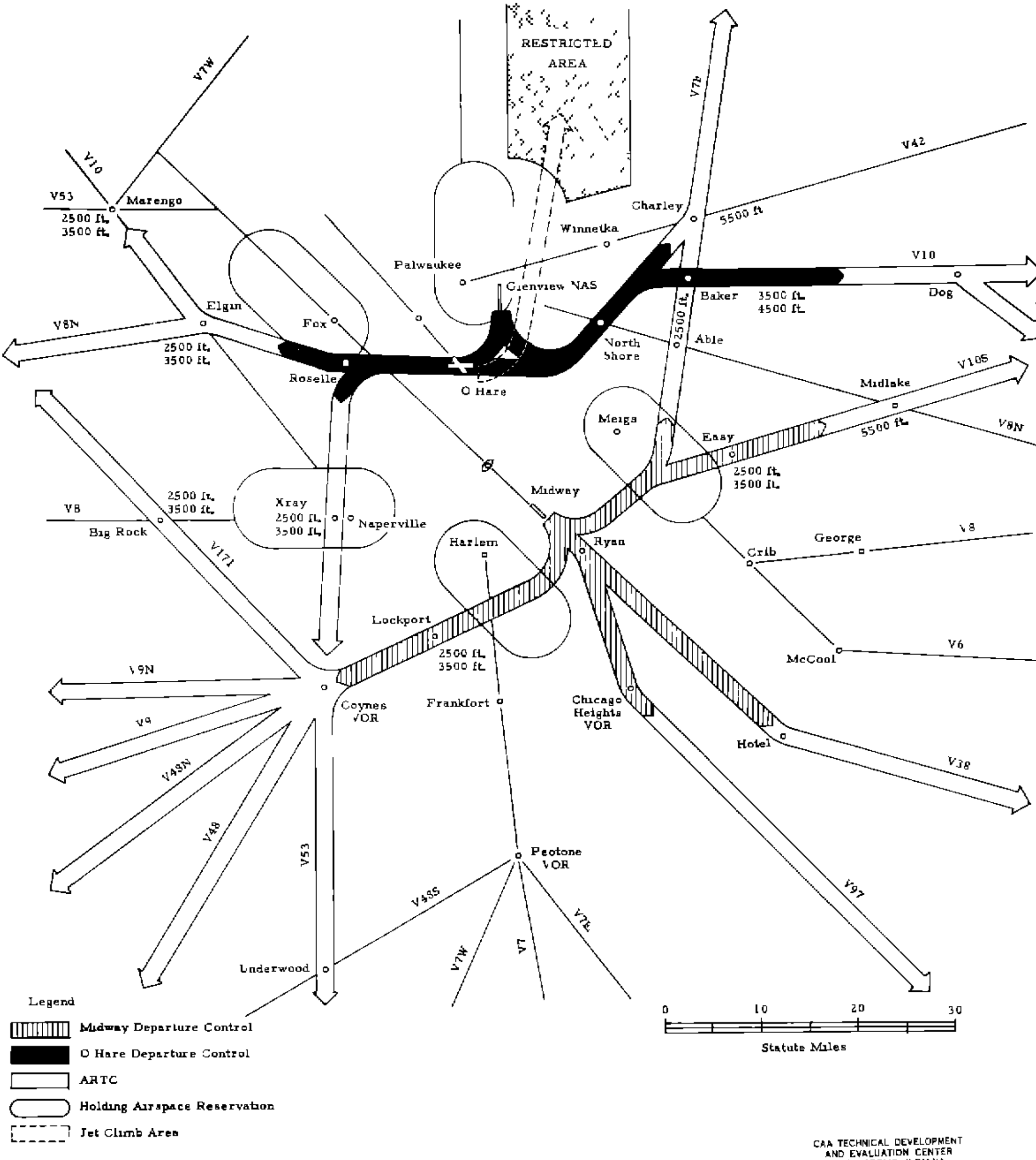


FIG 21 DEPARTURE ROUTES -- VOR SYSTEM B

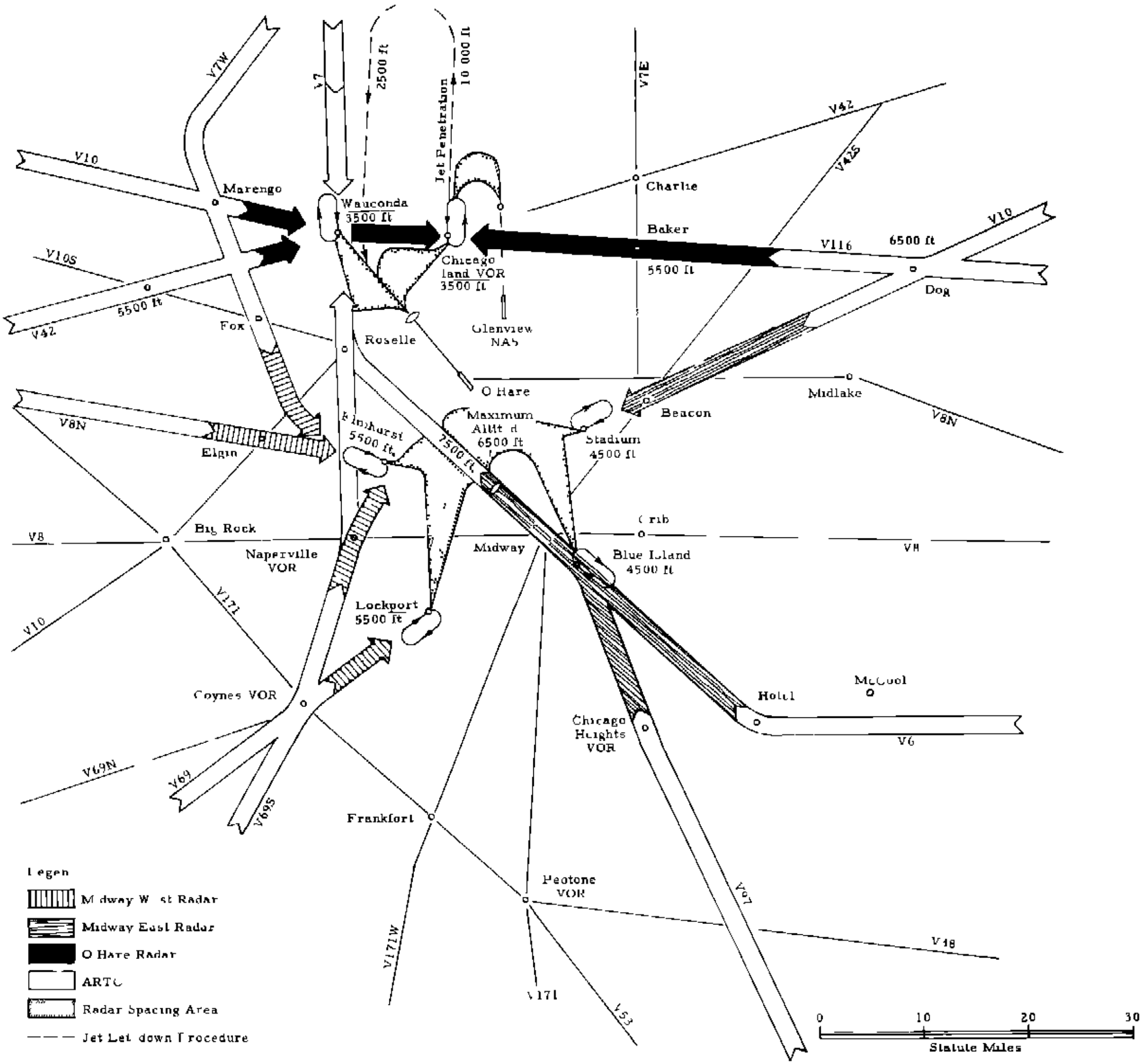


FIG ARRIVAL ROUTES VOR SYSTEM C

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

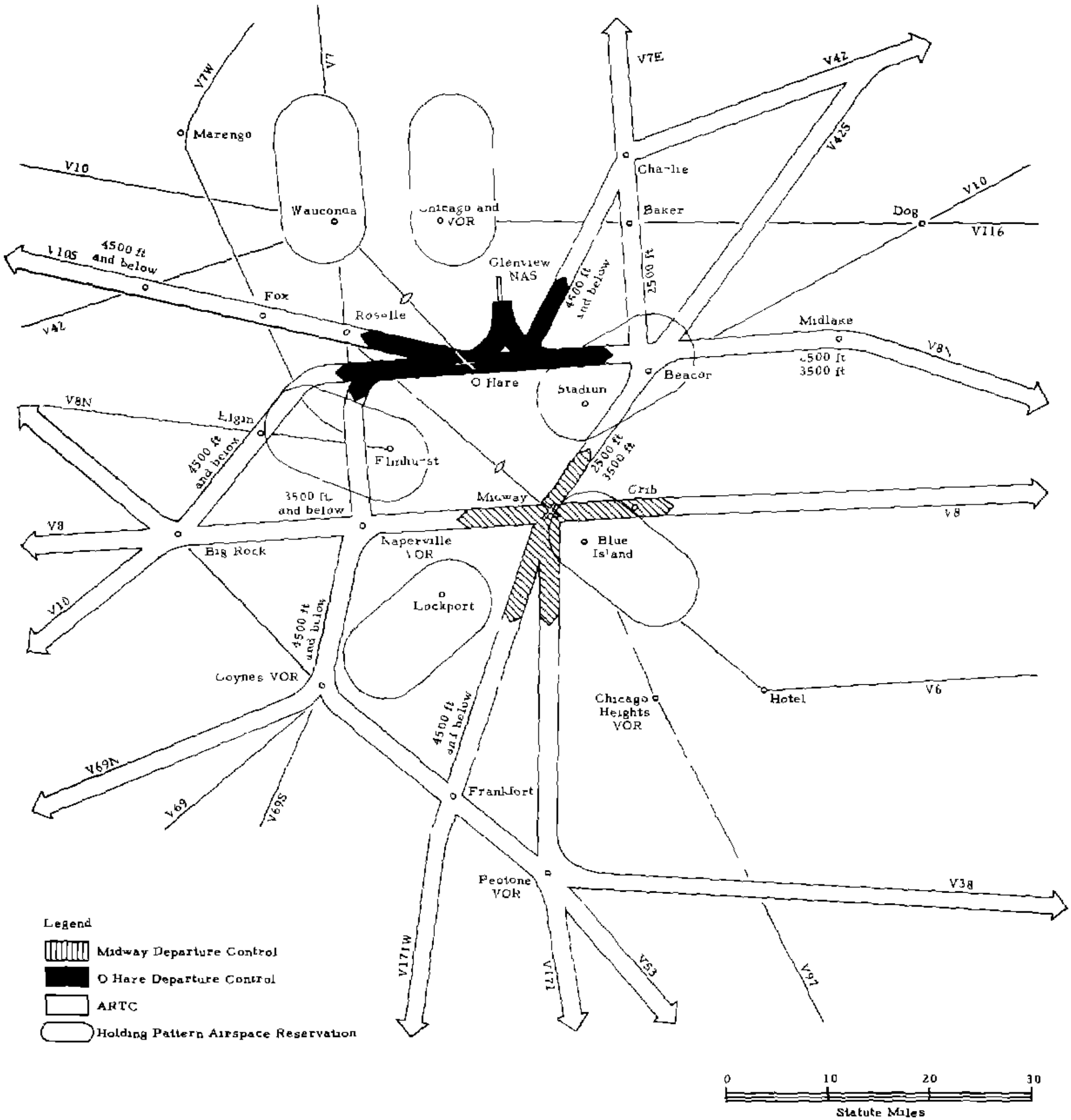


FIG 23 DEPARTURE ROUTES - VOR SYSTEM C

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

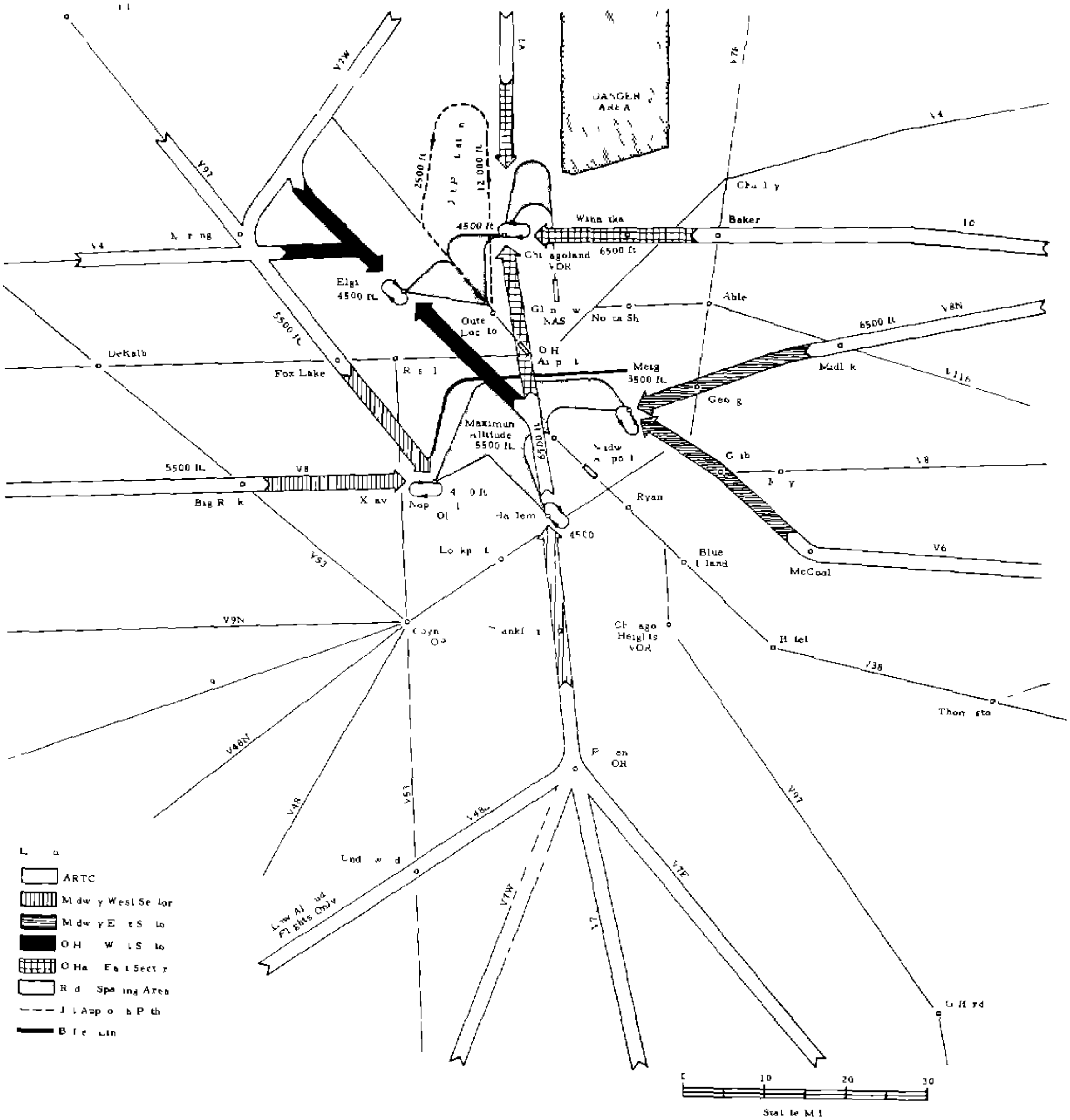


FIG 24 ARRIVAL ROUTES OR SYSTEM D (SOUTHEAST LANDINGS)

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

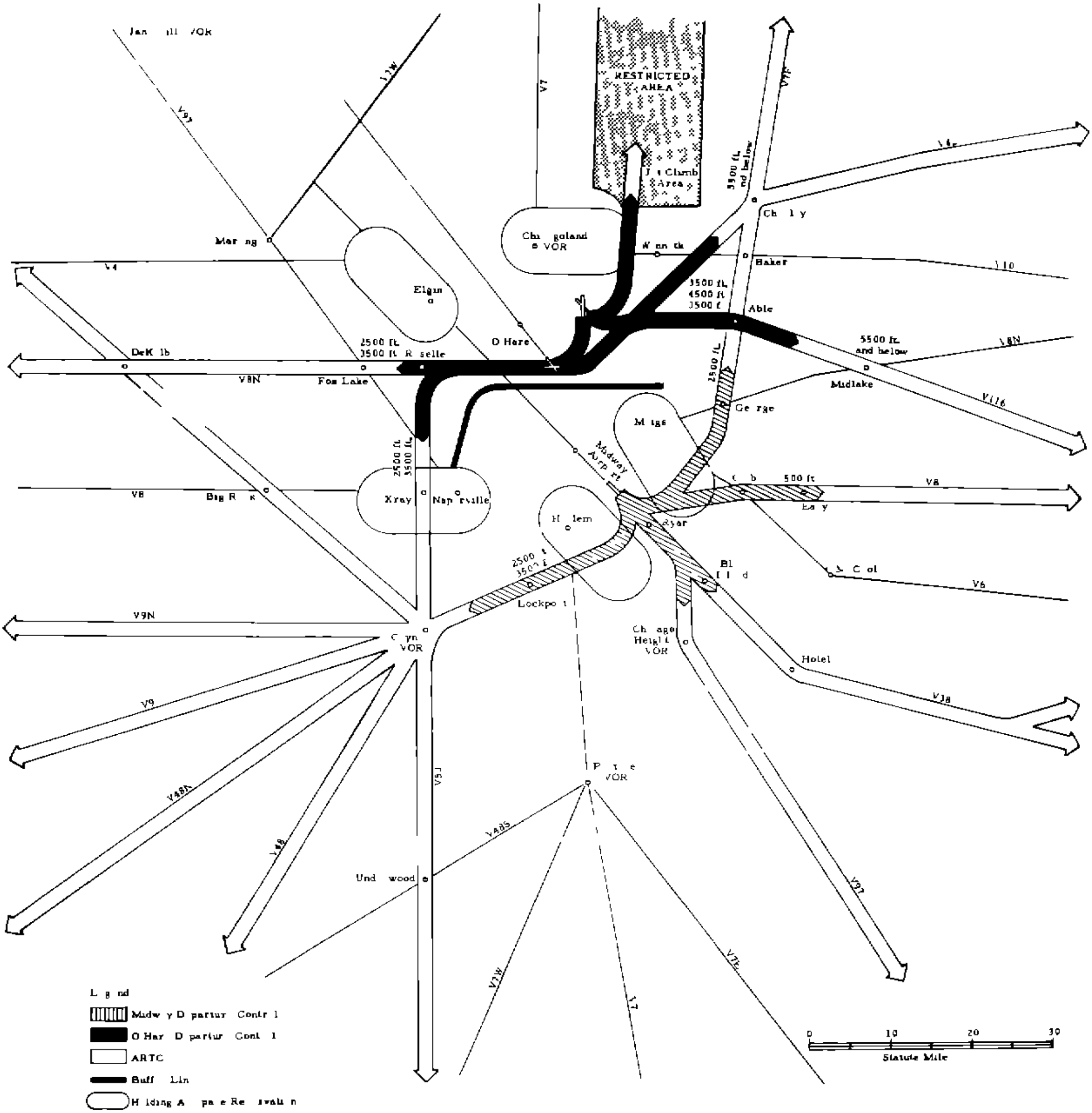
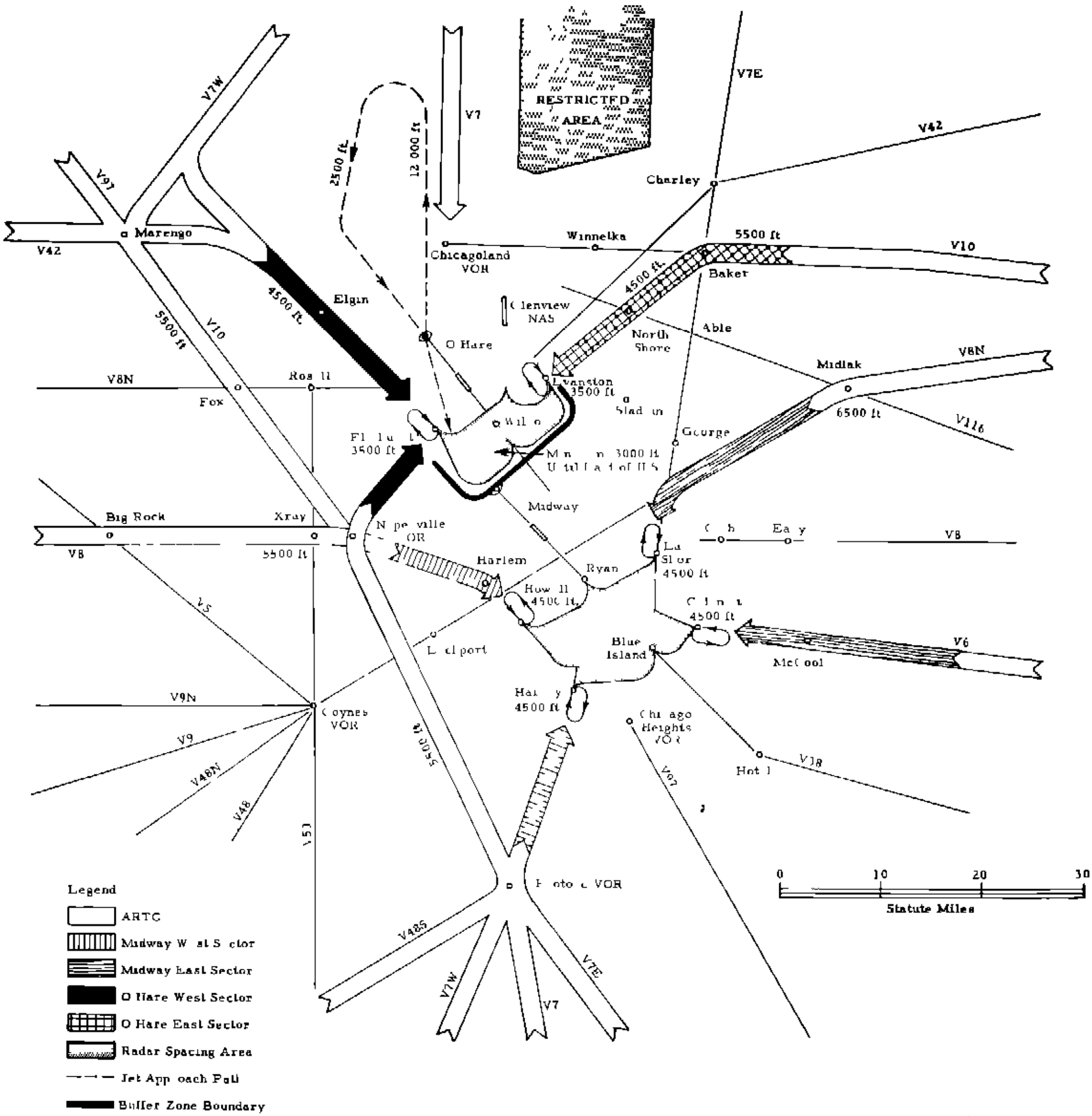


FIG 25 DEPARTURE ROUTES VOR SYSTEM D (SOUTHEAST TAKEOFFS)

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA



CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

FIG 26 ARRIVAL ROUTES VOR SYSTEM D (NORTHWEST LANDINGS)

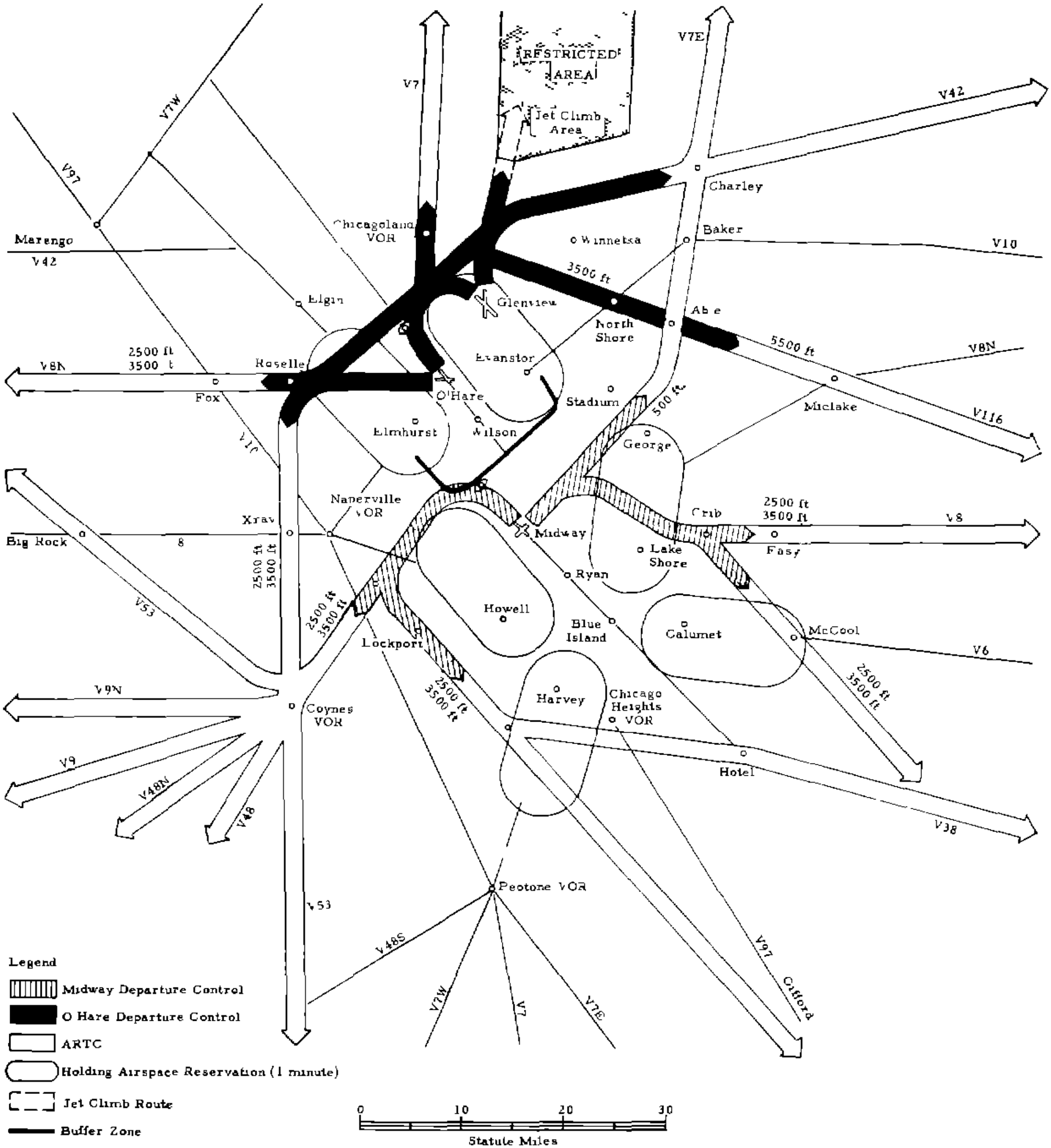


FIG 27 DEPARTURE ROUTES -- VOR SYSTEM D (NORTH TAKEOFFS)

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

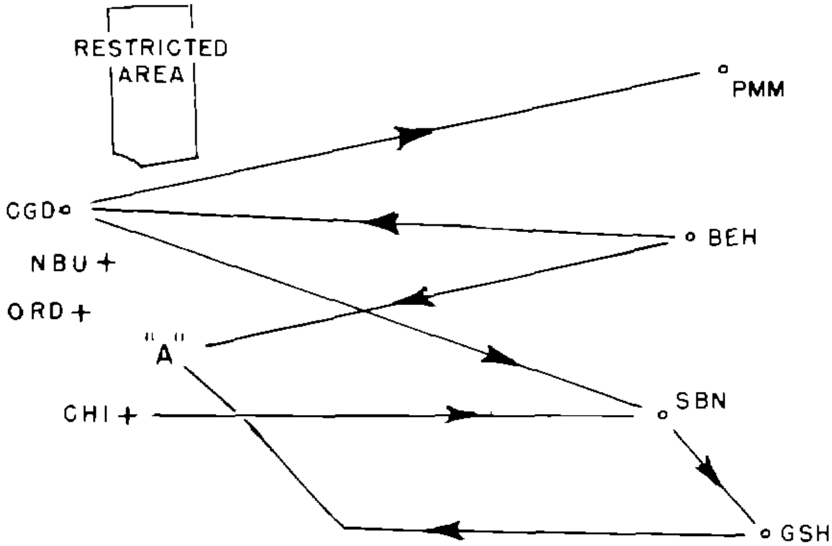


FIG 28 ROUTE ALIGNMENT
(PORTION OF RESTRICTED AREA REMOVED)

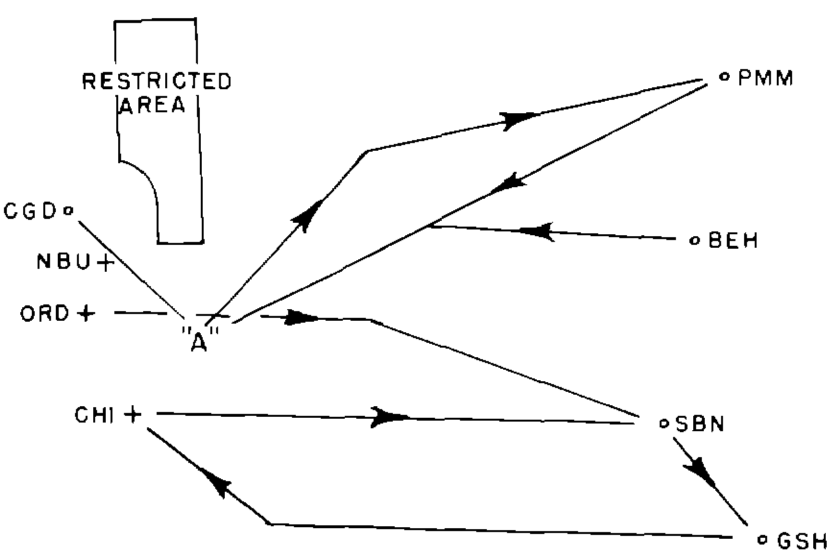


FIG 29 ROUTE ALIGNMENT
(ALL OF RESTRICTED AREA RETAINED)