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AIR TRAFFIC SIMULATION TESTS OF THREE PROPOSED SITES FOR THE WASHINGTON SUPPLEMENTAL AIRPORT

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SUMMARY

This report describes a simulation study of instrument flight rule operation at three proposed sites for a supplemental civil airport in the Washington, D. C. area. The air traffic flow characteristics of the Belmont Bay, Burke, and Chantilly sites were investigated, using traffic samples forecast for the 1960-1965 period. The purpose of this study was to determine which site would be most desirable from the standpoint of air traffic control. All tests were conducted through use of the dynamic air traffic simulator at the CAA Technical Development Center.

Evaluation criteria included: (1) over-all terminal-area traffic capacity, as indicated by airport acceptance rates and delay data under two opposite wind conditions, (2) ease of control, as reflected by communications measurements as well as the subjective opinions of the test controllers, and (3) comparative route mileages.

Results indicated that the Chantilly site consistently ranked highest in efficiency, as this configuration permitted a sustained high acceptance rate virtually independent of activity at Washington National Airport, regardless of wind conditions. Although results indicated that the Burke site would be usable, mutual interference between traffic patterns at Burke and National Airports reduced the over-all acceptance rate, particularly when wind conditions required takeoffs and landings to be made in a southerly direction. The Belmont Bay site proved to be least efficient, chiefly due to its awkward location in relation to Restricted Areas 37 and 38, as well as its proximity to the final approach course at Washington National Airport. These restrictions required the use of extremely circuitous flight paths, producing a high controller workload and a reduced acceptance rate under all wind conditions.

INTRODUCTION

The objective of this project was to analyze the air traffic flow characteristics of three proposed sites for the Washington Supplemental Airport in order to determine the functional advantages of each, and thus establish a firm basis for the selection of a suitable site.

The eventual need for a supplemental airport to handle increased civil traffic in the Washington D. C., area has been given serious consideration by the CAA ever since the Washington National Airport was started in 1939. After a study of several possible sites, the CAA acquired 1,050 acres of land near Burke, Virginia, for future airport development. In 1952, the CAA Technical Development Center (TDC) was requested to make a simulation study of the proposed Burke site for the purpose of determining the most suitable arrangement of navigation facilities, flight routes, and airport runways.

Results of this study[1] indicated that the operation of Burke Airport would tend to reduce the instrument flight rule (IFR) traffic capacity of Washington National Airport. Also, they indicated that the operation of Burke Airport could be improved somewhat by shifting the instrument landing system (ILS) runway alignment parallel to the ILS runway at Washington National Airport. This change was made on the engineering drawings but the project remained dormant due to a lack of development funds.

In 1954, TDC was requested to make a simulation study to determine the effects of converting Andrews Field for use as a supplemental civil airport. This study[2] indicated that, from the air traffic control standpoint, this solution would be satisfactory, assuming that the military traffic demand remained small.

Meanwhile, the existing Baltimore Friendship Airport was proposed for use as a supplemental Washington airport. In 1957, the Technical Development Center was requested to undertake a simulation study of this operation. This project was conducted concurrently with a simulation study to determine the effects of establishing a naval air station near Davidsonville, Maryland.

Results of the Baltimore study[3] indicated that the increased operations at Friendship Airport would require circuitous rerouting of the busy New York-Washington airway routes. Later, a CAA traffic forecast indicated that Friendship would be unsuitable for consideration as a supplemental airport for Washington because within a few years its capacity would be fully used for traffic generated by the Baltimore area.

[1] C. M. Anderson, F. S. McKnight, T. K. Vickers, and M. H. Yost, "Preliminary Study of Traffic Control Systems for the Washington Supplemental Airport Using Simulation Techniques," Technical Development Report No. 187, November 1952.

[2] C. M. Anderson and T. K. Vickers, "Dynamic Simulation Tests of Several Proposed Dual-Airport Traffic Control Systems for Washington Terminal Area," Technical Development Report No. 237, May 1954.

[3] C. M. Anderson, T. E. Armour, A. B. Johnson, and D. S. Schlots, "Dynamic Simulation Tests of Balitmore Friendship Airport at Increased Traffic Densities," Technical Development Report No. 316, July 1957.

Results of the Davidsonville study[4] pointed up the critical shortage of usable airspace in the area, due partly to the large allocations of airspace for military and naval restricted areas. The simulation tests also indicated that a moderate amount of IFR activity at Davidsonville would have a critical effect on Andrews Field operations. As a result of these tests, the Davidsonville project was abandoned and arrangements were started for the joint use of Andrews Field by the Navy and Air Force. This prospect, together with increased Air Force flight activity, made Andrews Field unsuitable for consideration as a possible supplemental airport site, and thus narrowed the selection to three main possibilities, Belmont Bay, Burke, and Chantilly.

The impending operation of large commercial jet transports, which would require runways longer than those available at Washington National Airport, spurred the need for a final selection of a suitable site. During the summer of 1957, the Congress appropriated $12 million to begin the development of a supplemental airport, and General E. R. Quesada, Special Assistant to the President, was assigned the task of preparing a formal recommendation to the President regarding the choice of a site. To assist in gathering the necessary facts for a decision, a consulting firm was engaged to study the engineering and economic aspects, and the Technical Development Center was requested to study the air traffic aspects of the problem.

Maps of the three alternate airport layouts were secured from the Office of Airports, and a number of additional control personnel were detailed to the TDC staff for the duration of the tests. Actual simulation runs were started on October 1, 1957. Twenty-four simulation runs, including 1,715 individual flights, were completed during the test period.

TEST ASSUMPTIONS

Radar and Communications Coverage.

It was assumed that dependable primary or secondary radar coverage would be available within a radius of 70 nautical miles of the Washington National Airport, and that direct air/ground air communication would be possible with all aircraft operating under instrument flight rules within this area.

Control of Civil Jet Aircraft.

It was assumed that civil jet operations would be handled at the supplemental airport, but not at Washington National. It also was assumed that such aircraft would be able to hold for short periods at low altitudes, if necessary, in a manner similar to propeller (prop) aircraft.

[4] C. M. Anderson, T. E. Armour, A. B. Johnson, D. S. Schlots, and T. K. Vickers, "Simulation Tests of IFR Operations at the Proposed Davidsonville Naval Air Station," Technical Development Report No. 315, June 1957.

Jet arrivals were cleared from altitudes of 20,000 mean sea level (MSL) and above by the air route controller after radar contact was established, usually between 50 and 20 miles from the terminal area. Pilots were requested to reduce speed, in order to enter the terminal area at a speed which would permit the aircraft to remain within the confines of the TSO holding airspace area if any holding was necessary. Holding altitudes varied between 5,000 and 10,000 MSL, depending on traffic congestion; in most cases the holding delays were quite short. A turning rate of 1 1/2° per second was used by jets at all altitudes.

Traffic Samples.

Two basic traffic samples were used in the simulation study. Sample I, which was used in the air route studies, had an input of 100 arrivals and 100 departures within a period of 2 hours. Based on both present traffic and estimates of future traffic, this sample was used as the basis for simulation runs Nos. 1 through 15.

Sample II was a high-density arrival sample used in the airport capacity tests. It comprised 50 arrivals within a 1 1/2 -hour period. Table I shows the distribution of aircraft, by routes and speed categories, in both samples. Table II lists the flight characteristics assumed for the various categories of aircraft types used in these tests.

Use of Andrews Field.

The time alloted for this program and the lack of simulator target capacity did not permit a concurrent study of Andrews Field problems; however, all the supplemental airport sites involved in this study were west of the Washington National Airport ILS localizer course and clear of the Andrews Field area. In setting up routes for the various systems studied, care was taken to avoid encroaching on the area presently blocked for Andrews approach control operations. In these tests, it was assumed that a single side stack for Andrews approach control was established in the vicinity of Croom, and that all Andrews approaches were made to Runway 36.

Use of Restricted Areas.

For the purpose of these tests, it was assumed that the portions of two restricted areas which presently are available for flight operations most of the time still would be available after the supplemental airport is established. These portions include: (1) the north end of Restricted Area No. 38 lying north of a line five statute miles south of, and parallel to, a line connecting the Quantico Range and the Charlotte Hall homing facility, (2) the south end of Restricted Area No. 54, including and lying south of, Red Airway 17.

Navigation Aids.

It was assumed that sufficient very high frequency (VHF) navigation aids would be installed tossupply the route structure necessary for the operation of either system.

EVALUATION CRITERIA

Traffic Capacity.

The most important functional index of airport efficiency is its capacity, or acceptance rate, in operations per hour. Unlike previous simulation programs, one aim of this program was to set up flow patterns which would permit each airport to maintain maximum capacity under two approximately opposite wind directions. This concept was adopted because it was realized that schedule reliability will become increasingly important when jet speeds and jet operational costs are considered; therefore, it will become even more necessary that airport capacities remain consistent regardless of the direction of the prevailing wind. For this reason, considerable study was given to the use of a second operating direction for each airport, and the ability of either airport to shift operating direction independently of the other.

As the over-all capacity of a traffic system depends considerably on the number of independent flight paths which can function simultaneously, another aim in setting up the route systems for these tests was to minimize the amount of interference between airports by keeping the routes to each airport as independent of the routes of the other airport as possible. This in turn tended to keep the combined terminal-area acceptance rate at a maximum.

Delays.

For repeated runs of the same high-density traffic sample, aircraft delay data form a sort of inverse index of traffic capacity in that small decreases in acceptance rate can cause large increases in aircraft delays. This principle is shown graphically in Fig. 1.

Controller Workload.

Previous tests have shown that the human factor is one of the most critical elements in the operation of the present air traffic control system.[5] Therefore, for reasons of safety, efficiency, and economy, it is desirable that the controller workload be kept as low as possible.

Controller workload includes the basic functions of data collection, display, and analysis. From these come the making of decisions in accordance with applicable rules and strategy, the formulation of [illegible] instructions or clearances, and the communication of these instructions to the aircraft. This cycle is a continuous one.

At the present time, the communications workload is the only portion of the entire load that can be measured accurately. However, it

[5] C. M. Anderson and T. K. Vickers, "Application of Simulation Techniques in the Study of Terminal Area Air Traffic Control Problems," Technical Development Report No. 192, November 1953.

forms a rough comparative index of controller workload, as systems which include a large number of potential conflictions between flight paths, implying a high degree of control, usually tend to require a large number of position reports and control instructions and thus produce a greater amount of communications activity.

Pending the development of a quantitative method of measuring the other factors involved in the total human control workload, it has been found useful to employ subjective analysis, by the controllers themselves, to determine the relative workloads of various systems. Usually this is done by means of special questionnaires which are filled out by control personnel at the end of a specific series of tests.

Route Mileage.

From the flight operations standpoint, it would be desirable, theoretically, at least, for all flight routes to be as direct, and therefore as short, as possible. Of course, some differences in route mileages would be inherent when different terminal sites are considered. However, large differences can occur when certain systems require circuitous routings around military restricted areas, high terrain, or nearby airport operating areas.

TEST PROCEDURES

Air Route Control.

Three radar sectors of the Washington Air Route Traffic Control (ARTC) Center were simulated, using three flight progress boards and a single superimposed Panoramic Radar Display (SPANRAD). This layout is shown in Fig. 2. SPANRAD is a new radar tracking unit which employs TV techniques to superimpose a picture of a manually generated tracking display on a bright display of the radar target data. The manually generated portion employs pointed cardboard target markers approximately 1 1/4 inches by 3/4-inch on which aircraft identity, type, and altitude data are posted. Figure 3 shows a closeup of the SPANRAD unit.

Three experienced radar controllers from the Washington ARTC Center were detailed to TDC for the tests. They handled radar control operations, using direct communications with the various aircraft. Each controller was teamed with an assistant controller who handled the data-collection and display functions using the flight progress board and the interphone system. The assistant controller also prepared the target markers for the radar controller.

The area under study was divided geographically into three sectors, with the exact boundaries varying somewhat, depending on the systems and flight operations being tested. Because of a basic limitation of the simulator, which permitted only 18 aircraft to be operated simultaneously, it was not possible to handle all arrival, departure, and en route traffic operations simultaneously. In some cases, only arrivals were run. In other tests, only the departures in a given direction were operated. In any case, full allowance was made for the airspace which would be in used by the other aircraft.

Arrivals appeared in the system at Gordonsville, Front Royal, Westminster, Herndon, Tappahannock, and Brooke. They were controlled through ARTC territory and handed off to approach control at the appropriate transfer point. Prior to takeoff, departures were given short-range clearances based on the use of ANC separation up to the time that radar separation could be established by the Center. Normal exit fixes for the departures were Baltimore, Westminster, Martinsburg, Gordonsville, and Penola.

Terminal-Area Control.

Two terminal-area IFR rooms were simulated. The layout used for Washington National Airport is shown at the extreme right of Fig. 2. The layout simulating the IFR Room of the Washington supplemental airport is shown in Fig. 4. For twin-stack approach control operations, two controllers and one assistant controller were used at each airport. For the departure tests, one controller and one assistant were used at each airport. In every case, each controller used an individual scope with a small flight progress board.

To maintain optimum acceptance rates and also to standardize approach operations, each approach controller utilized the separation table shown in Fig. 5. This table was computed to make allowance for the following factors:

1. The three-mile radar separation minimum.

2. Normal variations in approach speed between aircraft of the same speed category.

3. The speed differential between successive aircraft of different speed categories.

Curved reference lines spaced at radii of 3, 5, and 7 miles from the approach gates were marked on the radar maps to serve as guides in securing the specified separation between aircraft. These arcs extended exactly 20° on each side of the localizer course to assist the controller in knowing when he could start an aircraft on an ILS interception heading 20° from the localizer course.

In the approach tests, a supervisor at each IFR room monitored all approach separations and noted the test results.

A list of location designators used on route maps is presented in Table III.

SYSTEM TESTS

Chantilly.

The airway structure used for north operations is shown in Fig. 5, and for south operations in Fig. 6. Approach patterns for both directions of landing are shown in Fig. 7. One feature which was scrutinized closely was the procedure of routing Washington arrivals from the west, at 6,000 MSL and above, across the extreme south end of the Chantilly approach vector area. However, it was found that this procedure worked very well and produced no appreciable confusion as far as the Chantilly approach controllers were concerned.

The feeding system of this layout was quite flexible in that it permitted cross feeding of arrivals from one stack to the other. This procedure tended to equalize the workload between approach controllers and also permitted better utilization of available altitudes and communications channels.

The route layout permitted independent reversal of traffic flow (north or south operations) by either airport. As the Chantilly site was farther away from Washington National Airport than either Burke or Belmont Bay, and in addition, farther away from any restricted area, the Chantilly approach vectoring areas were less restricted than those of the other two supplemental airport sites. Although not far enough away from Washington to permit completely independent flight routes, the Chantilly layout produced less inter-airport interference than the other two sites.

The most undesirable feature of the Chantilly system was the circuitous route required for Washington National westbound departures when southerly airport operations were in progress. The alternative to this procedure would be to clear these aircraft off Washington National Airport with a right turn to proceed west via Victor Airway 501. This procedure would require a high degree of coordination with the Chantilly tower and in most cases, would necessitate a long "tunnel" procedure at low altitude until reaching Warrenton. As it was, the routing shown in Fig. 6 usually permitted the departure to begin immediate climb to cruising altitude. In some cases, a more direct route, monitored by air route radar, could be assigned after the departure was clear of all other traffic in the vicinity of Baltimore.

South-southwest of Washington National Airport, the clear airspace between Restricted Areas 37 and 38 is only 14 miles wide, too narrow for the establishment of dual standard-width parallel airways. However, the importance of this gateway led to the establishment of the "Ramona" (Radar Monitored Airway) concept which proved to be a satisfactory solution to the problem. Two parallel airways, shown as Victor 3 and Victor 508 in Figs. 6 and 7, were established five miles apart, using radials from the Brooke very high frequency omnirange (VOR) and the proposed Hyde VOR. Pilots could be cleared by either designated route using VOR navigation. Radar monitoring was established by the Center to see that aircraft stayed in their own traffic lane until reaching a point where ANC separation could be applied. The advantage of the Ramona concept over the old procedure of vectoring aircraft off the airway to a parallel course was that the new procedure relieved the controller of the direct responsibility for navigating the aircraft. This responsibility remained with the pilot. The controller's function in this procedure was simply to maintain separation between aircraft. This procedure tended to reduce communications, since in most cases, no vectoring instructions were necessary when the aircraft remained in their assigned lanes.

Burke.

The map layout furnished by the Office of Airports showed two parallel north-south runways at Burke, supplemented by an east-west runway near the south end of the airport site. This configuration is shown in Fig. 8, which also shows the route layout used for north landing operations in this system.

The presence of the Washington Monument and the prohibited areas over the city of Washington preclude the use of back-course ILS approaches to the south at Washington National Airport. Instead, approaches have to be conducted toward the southeast over Georgetown to Runway 15. This configuration places the south approach path to Burke too close to the southeast approach course at Washington National to permit twin-feed approach systems to be established at both airports. One possibility would be to install a twin-fix system at Burke and a single-fix system at Washington. Comparative tests of single and twin-fix approaches to Runway 15 at Washington showed that the acceptance rate with the single-fix system dropped from 31 to 27 operations per hour, while arrival delays increased as shown in Fig. 10.

To avoid this reduction in terminal-area capacity, the southerly approach path at Burke was realigned to approximately 150 magnetic, paralleling that at Washington. This configuration, which is shown in Figs. 11 and 12, permitted twin-fix operations at both airports.

In this system, Washington arrivals from the west were routed via Victor Airway 144 across the Burke airport area. To keep the Burke holding fixes clear of this airway required that they be placed a considerable distance away from the approach gates, necessitating a rather awkward vectoring procedure. This configuration also precluded easy crossfeeding operations to equalize the Burke stack loadings.

The proximity of Restricted Area 37 to the Hoadley holding fix had a restrictive effect on radar vectoring operations at Burke, particularly in the spacing of jet aircraft. The most undesirable features of this system involved congestion in the area between Restricted Areas 37 and 38. In order to establish twin-fix approach patterns at both airports for north operations, it was necessary to locate one of the Burke feeding fixes at Potomac Heights. This was far from an ideal setup as far as Burke was concerned, and was even worse because it required Washington arrivals from the south to overfly the Potomac Heights holding stack before letting down for approach. This route congestion also required the Washington National southbound departure route to go around the east side of Restricted Area 38, which not only added additional mileage but would interfere somewhat with IFR operations in and out of Andrews Field.

A difficult control problem was caused by the crossover of two main arrival routes, Victor 144 and Victor 251, over the Burke Airport.

Belmont Bay.

This system proved to be even more congested than that for Burke, due to the proximity of Belmont Bay to the Washington ILS course and to Restricted Areas 37 and 38. The original south approach path to Belmont Bay had to be realigned toward the southeast for the same reason that was encountered in the Burke system. Routes for north operations are shown in Fig. 13, and for south operations in Fig. 14. Approach patterns are detailed in Fig. 15.

The approach patterns for Belmont Bay were quite awkward to operate, due to the odd shape of the airspace available for this purpose. Crossfeeding operations were not possible between Dumphries and Quantico. An "over-the-shoulder" procedure had to be used for north approaches from the Dumphries pattern. The very slow turning rate of the jet aircraft made the approach spacing function very difficult to handle, due to the lack of flexibility possible in path-stretching operations. Jet aircraft occasionally overshot into the active portion of Restricted Area 38. The very long final approach from the Quantico pattern made spacing operations even more difficult.

Like the Burke system, the Belmont Bay system had poor routings to and from Washington National Airport from the south. A difficult control problem was caused by the intersection of the Victor 144 and Victor 251 arrival routes at Herndon.

MEASUREMENTS

Acceptance Rates.

Airport acceptance rates were measured under the saturated conditions produced by Sample II. Results for north landings were:

Chantilly - 31 approaches per hour

Burke - 28 approaches per hour

Belmont Bay - 28 approaches per hour

Delays.

Figure 16 shows the average delays encountered with Sample II and also shows how these delays built up during the course of the problem.

Communications.

Results of communications measurements, using Sample I, are shown in Fig. 17. It will be noted that operation of the Chantilly system required less communication workload than either of the other two systems.

Controller Workload.

After the simulation tests were completed, the three air route controllers reviewed each configuration of facilities tested, and rated the difficulty of control which had been experienced in handling each major route in each of the three systems. A summary of the ratings is shown in Table IV. Each entry in Table IV represents the consensus of the three controllers. Although some differences existed in the ratings of the individual controllers, all three rated Chantilly, Burke, and Belmont Bay in increasing order of difficulty, as shown by the totals at the right of Table IV.

Route Mileages.

Table V lists the mileages for all major routes of the three systems. These are comparative figures to and from common route points. It will be noted that the Chantilly system shows the lowest total mileage in both north and south operations. This is due mainly to the circuitous routes required in the Burke and Belmont Bay systems to get around the restricted areas.

During a one-hour period with 50 operations at each of the two airports (Washington National and the second airport), assuming the same traffic distribution as that used in Sample I, mileage flown in the Chantilly system would be about 510 miles less than in the Burke system and about 780 miles less than in the Belmont Bay system.

CONCLUSIONS

1. The Chantilly site showed consistent superiority over Burke and Belmont Bay in each of the criteria used in this evaluation.

2. There is not enough airspace available at any of the three proposed supplemental airport sites to permit a standard jet penetration.

3. If jet transports are able to turn at the rate of 1 1/2° per second only, it will be necessary that they enter the holding patterns at reduced speeds if they are to remain within the confines of the holding airspace as defined by TSO-N-20-A.

4. These tests indicate that under normal conditions when holding delays will be relatively short, it will be desirable to descend jet transports en route so that they can enter the holding patterns at the lowest available altitudes.

RECOMMENDATIONS

1. From the air traffic control standpoint, the Chantilly site is recommended as superior to the Belmont Bay and Burke sites.

2. The Belmont Bay site is not recommended under any circumstances.

3. Although the Burke site could be considered usable, it cannot be recommended unless the layout is changed to permit southeast instead of south operations. Even then it would require a higher control workload than Chantilly, because of its greater interference with operations at Washington National Airport. In addition, its initial capacity would be lower than Chantilly.

4. Since limitations in time and simulation capacities did not permit a study of the Andrews Field area in this simulation program, it is recommended that, after the supplemental airport location has been determined, another simulation study be made to determine the optimum methods of handling traffic in the Andrews area.

TABLE I

SUMMARY OF TRAFFIC SAMPLES

Sample I - 200 Aircraft in 2 Hours
(Used in Air Route Studies)

	Airport	WSA	DCA
Arrivals from	NE&N	11	19
	W	22	16
	SW&W	17	15
	TOTAL	50	50
Departures to	NE&N	9	16
	W	26	14
	SW&W	18	17
	TOTAL	53	47

Distribution by Routes

Airport	WSA	DCA
Slow	6	8
Medium	25	49
Fast	59	40
Jet	13	0
TOTAL	103	97

Distribution by Aircraft Types

Sample II - 50 Aircraft Per Airport in 1 1/2 Hours
(Used in Airport Capacity Tests)

	Airport	WSA	DCA
Arrivals from	NE&N	15	15
	W	17	17
	SW&S	18	18
	TOTAL	50	50

Distribution by Routes

Airport	WSA	DCA
Slow	3	3
Medium	13	13
Fast	19	34
Jet	15	0
TOTAL	50	50

Distribution by Aircraft Types

LEGEND

WSA - Washington Supplemental Airport
DCA - Washington National Airport

TABLE II

SUMMARY OF AIRCRAFT CHARACTERISTICS

Type	Speed (Knots) Cruise	Intermediate	Approach	Vertical Rates (Feet Per Minute) Descent Normal	Descent Maximum	Climb Normal	Climb Maximum
Civil Jets*	450	240	156	**	4000	1000	2500
DC-7	300	220	140	1000	2000	1000	1500
Super-Constellation	285	220	140	1000	2000	1000	1500
DC-6/Constellation	270	180	140	1000	2000	800	1200
B-26	220	150	130	1000	2000	900	1500
Martin 404/Convair	210	150	125	800	1500	800	1200
DC-4	180	150	120	500	900	500	1000
C-46	160	140	115	500	900	500	800
DC-3	140	120	110	500	800	500	800
Twin Beech	120	110	100	500	800	500	800

*Douglas DC-8
Boeing 707
Convair 880

**4000 fpm when above 10,000 MSL
2000 fpm when below 10,000 MSL

TABLE III

LOCATION DESIGNATORS USED ON ROUTE MAPS

ARL Arlington
ADW Andrews
ALX Alexandria
ASH Ashburn
ATW Ashton

BAL Baltimore
BET Bethesda
BKE Brooke
BRY Bryton
BUC Buckner

CAH Charlotte Hall
CAS Casanova
CES Chesterton
COP Coles Point
CRM Croom

DAW Dawsonville
DUM Dumfries

EMI Westminster

FAX Fairfax
FAL Falls Church
FDR Frederick
FIS Fishing Creek
FRR Front Royal
FTS Flint Stone

GVE Gordonsville

HAY Haymarket
HNT Huntingtown
HOD Hoadley
HRN Herndon
HYD Hyde

IDH Indian Head
ING Ingleside

JEF Jefferson

KEY Keymar

LEE Lee

MRB Martinsburg

NOK Nokesville
NRV Norris
NYG Quantico

PEN Penola
PLN Plains
PTD Port Deposit

QRY Quarry

REM Remington
RVD Riverdale

STV Standardsville

TPP Tappahannock

VIE Vienna

WAR Warrenton

TABLE IV

AIR ROUTE
CONTROLLER WORKLOAD SURVEY

System	Route Direction	Arrivals to DCA	Arrivals to WSA	Departures from DCA	Departures from WSA	Total VD	Total D
Chantilly	NE						
	NW						
	W	D					
	SW			D		0	2
Burke	NE		D				
	NW						
	W	D					
	SW	D		VD		1	3
Belmont Bay	NE		VD		VD		
	NW						
	W	D		D	D		
	SW	D		VD		3	4

Legend

DCA - Washington National Airport
WSA - Washington Supplemental Airport
D - Difficult
VD - Very difficult

TABLE V

ROUTE MILEAGE CHART

Terminal	Operation	Direction	Common Fix	North Operations: Chantilly	North Operations: Burke	North Operations: Belmont Bay	South Operations: Chantilly	South Operations: Burke	South Operations: Belmont Bay
Washington Supplemental Airport	Arrivals from	NE	Westminster	55	62	86	47	50	70
Washington Supplemental Airport	Arrivals from	W	Petersburg	90	104	111	86	100	103
Washington Supplemental Airport	Arrivals from	SW	Gordonsville	69	66	50	81	70	73
Washington Supplemental Airport	Departures to	NE	Woodstown	125	130	147	151	184	173
Washington Supplemental Airport	Departures to	W	Martinsburg	31	45	53	46	97	90
Washington Supplemental Airport	Departures to	SW	Gordonsville	75	68	68	76	68	57
Washington National Airport	Arrivals from	NE	Westminster	53	53	53	41	43	43
Washington National Airport	Arrivals from	W	Petersburg	105	118	110	117	112	105
Washington National Airport	Arrivals from	SW	Gordonsville	76	82	82	89	93	100
Washington National Airport	Departures to	NE	Chestertown	45	45	45	47	47	47
Washington National Airport	Departures to	W	Martinsburg	56	56	49	92	92	92
Washington National Airport	Departures to	SW	Gordonsville	98	105	120	98	63	124
			System Totals	878	934	974	971	1019	1077

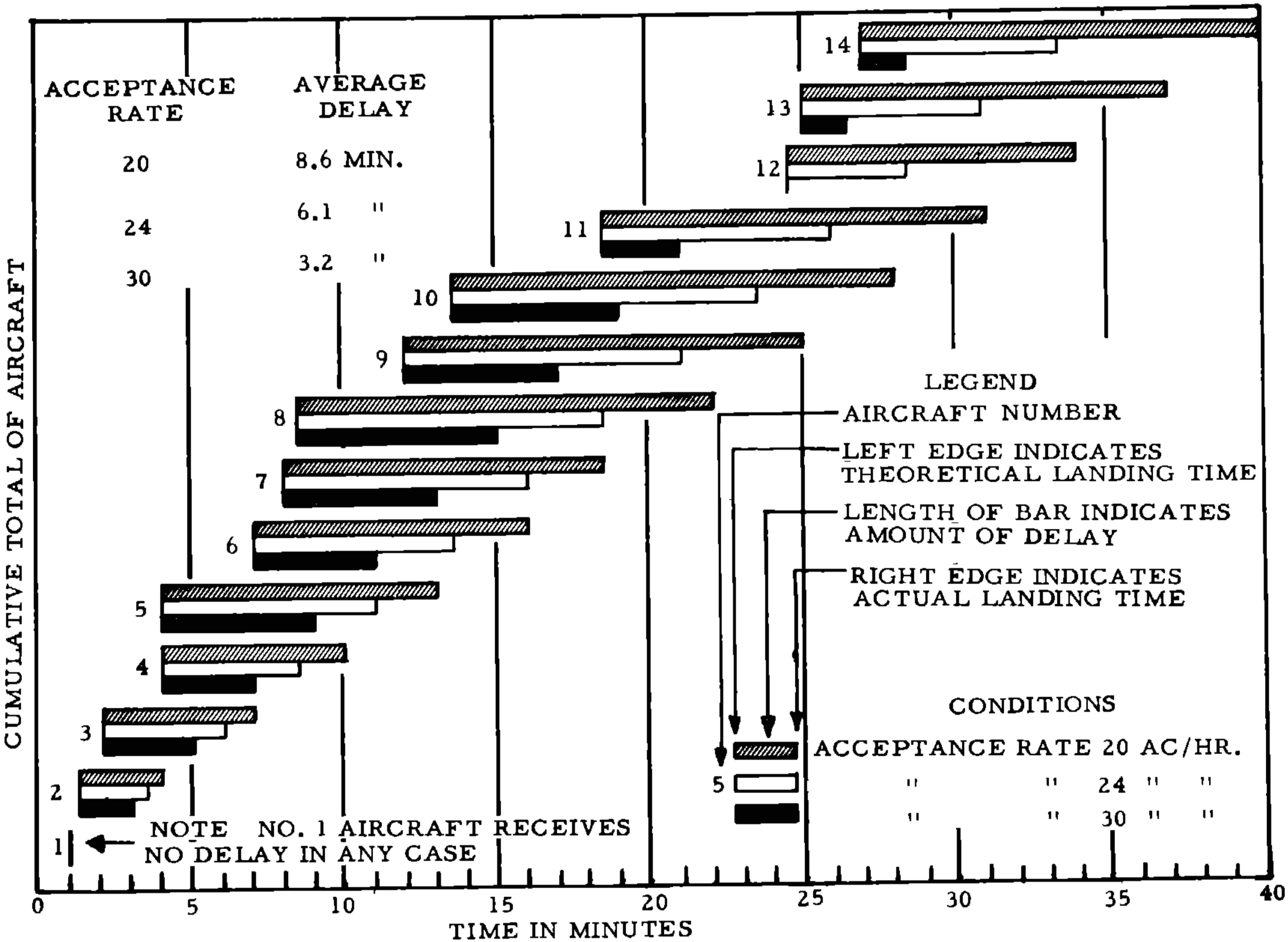


FIG. 1 EFFECT OF ACCEPTANCE RATE ON DELAY OF A TYPICAL SEQUENCE OF ARRIVING AIRCRAFT

FIG 2 CONTROL ROOM LAYOUT SIMULATING WASHINGTON ARTC CENTER (LEFT) AND IFR ROOM AT WASHINGTON NATIONAL AIRPORT (RIGHT)

FIG. 3 SPANRAD (SUPERIMPOSED PANORAMIC RADAR DISPLAY)

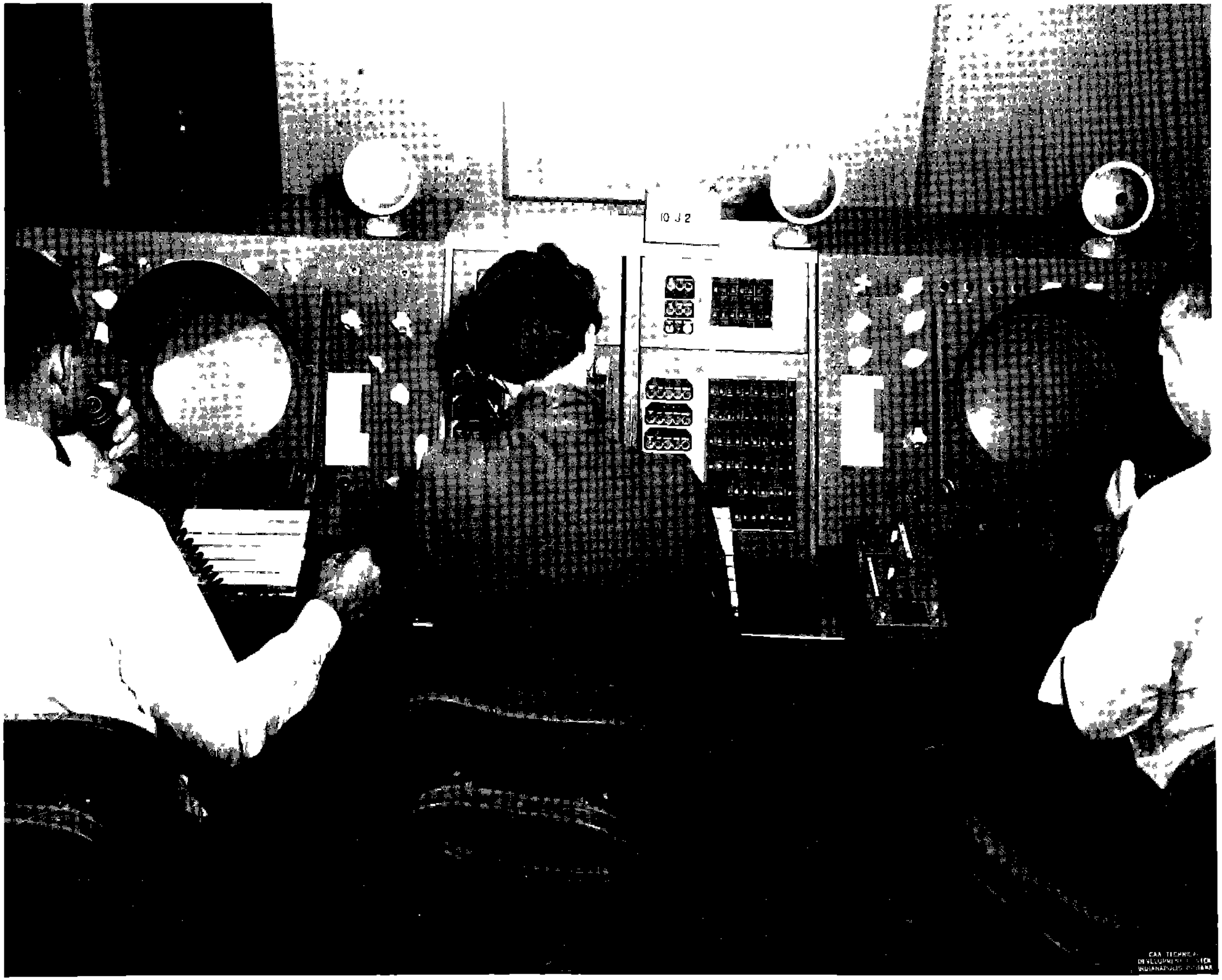
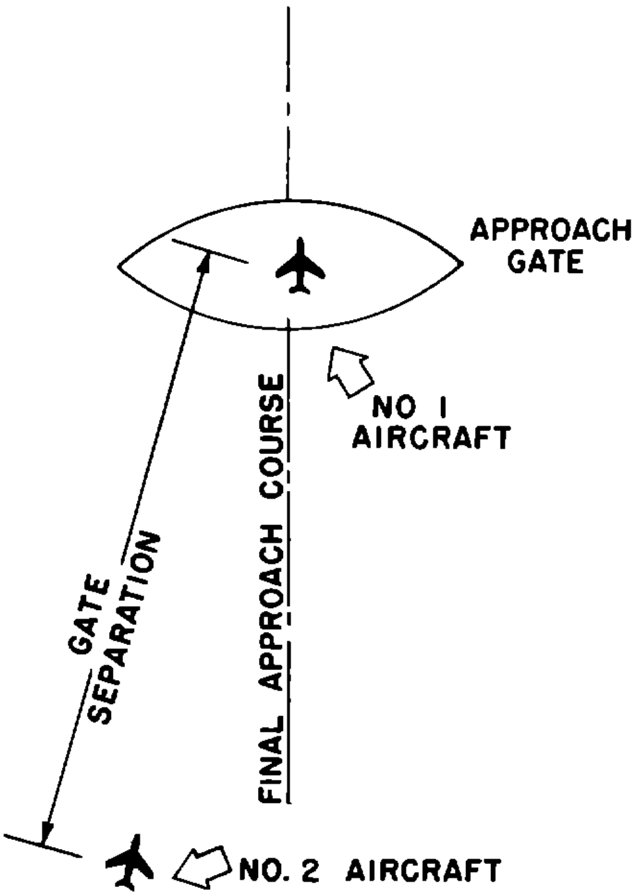


FIG 4 CONTROL ROOM LAYOUT SIMULATING IFR ROOM AT WASHINGTON SUPPLEMENTAL AIRPORT



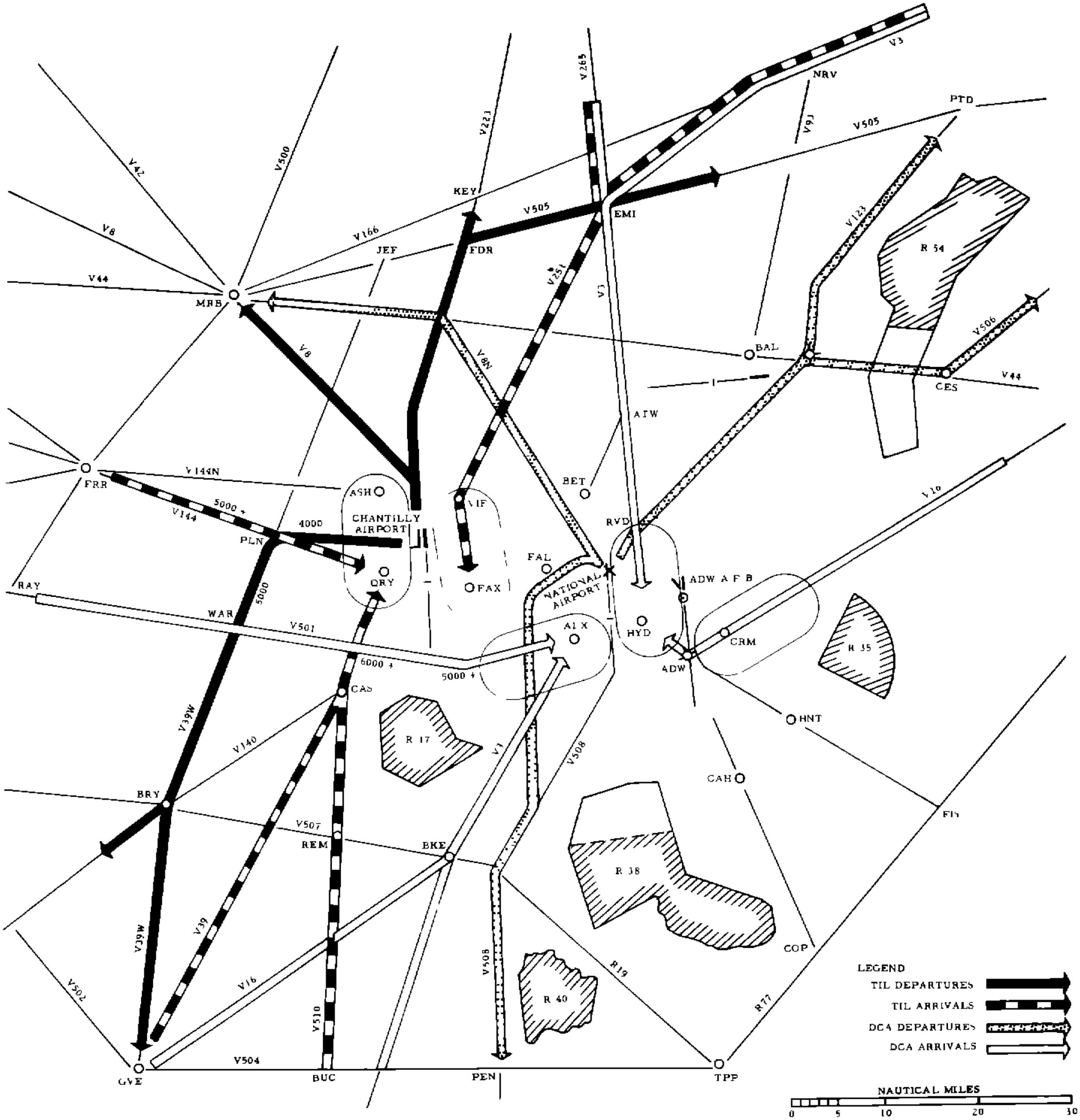
OPTIMUM
AIRCRAFT SPACING

WASHINGTON ILS
ZERO WIND CONDITION

AIRCRAFT SEQUENCE		GATE SEPARATION (MILES)
NO I	NO 2	
S	M	5 I
S	F	5 5
S	J	6.6
M	S	3 I
M	F	4.5
M	J	5 8
F	S	3 0
F	M	3.5
F	J	5.2
J	S M F	3 0
SAME TYPE		4 0

AIRCRAFT CATEGORY		APPROX APPROACH SPEED	
		M P H	KT
S	SLOW	I20	I04
M	MEDIUM	I40	I22
F	FAST	I50	I30
J	JET	I80	I56

FIG 5 SPACING TABLE USED IN APPROACH CONTROL OPERATIONS



CHANTILLY SYSTEM

FIG 6 ARRIVAL AND DEPARTURE ROUTES
NORTH OPERATIONS

CAA TEC N A
DEV LO MENT CEN ER
N I NAPCLIS IND A

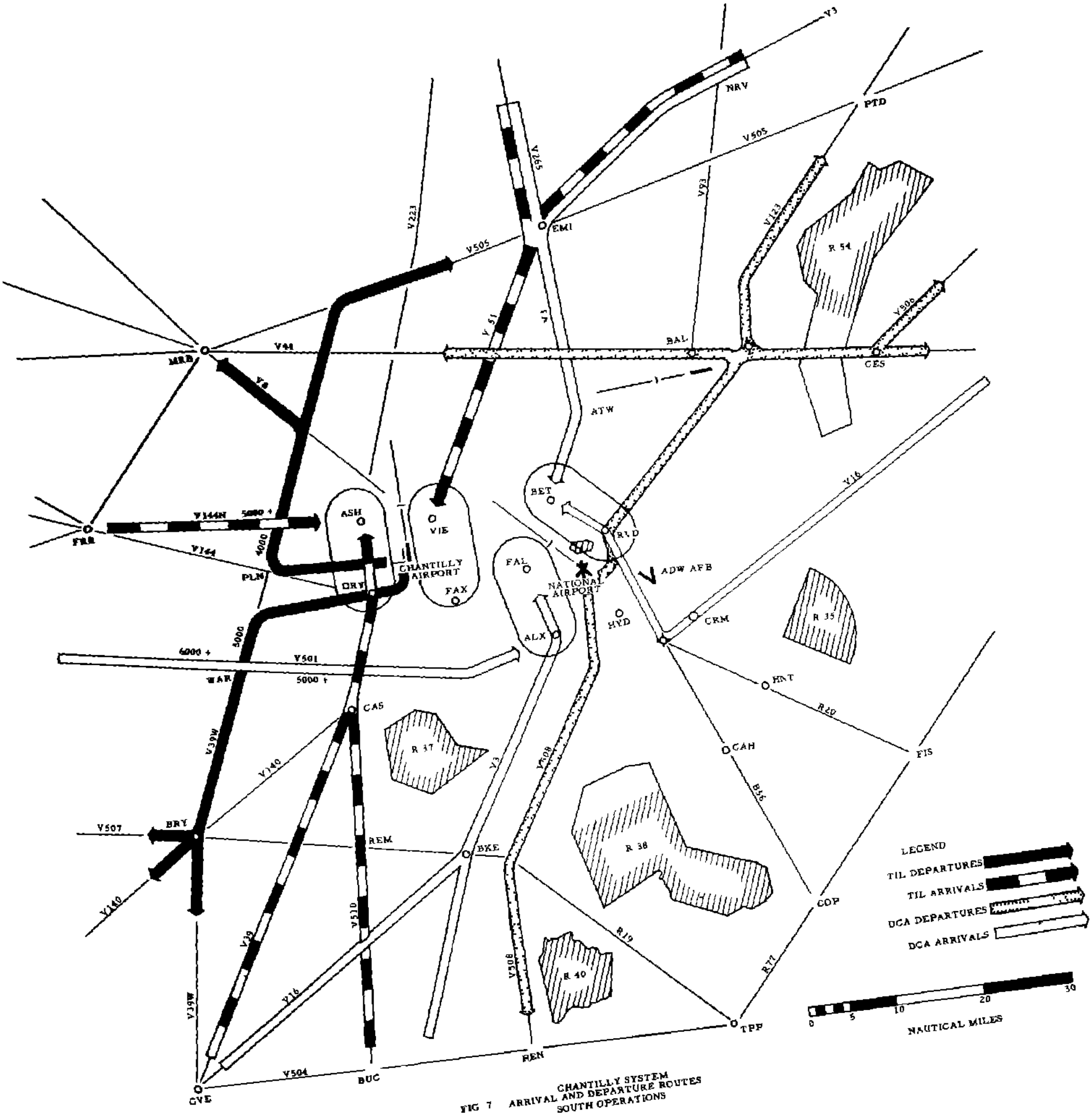


FIG 7 CHANTILLY SYSTEM ARRIVAL AND DEPARTURE ROUTES SOUTH OPERATIONS

CAA TECHNICAL DEVELOPMENT CENTER INDIANAPOLIS INDIANA

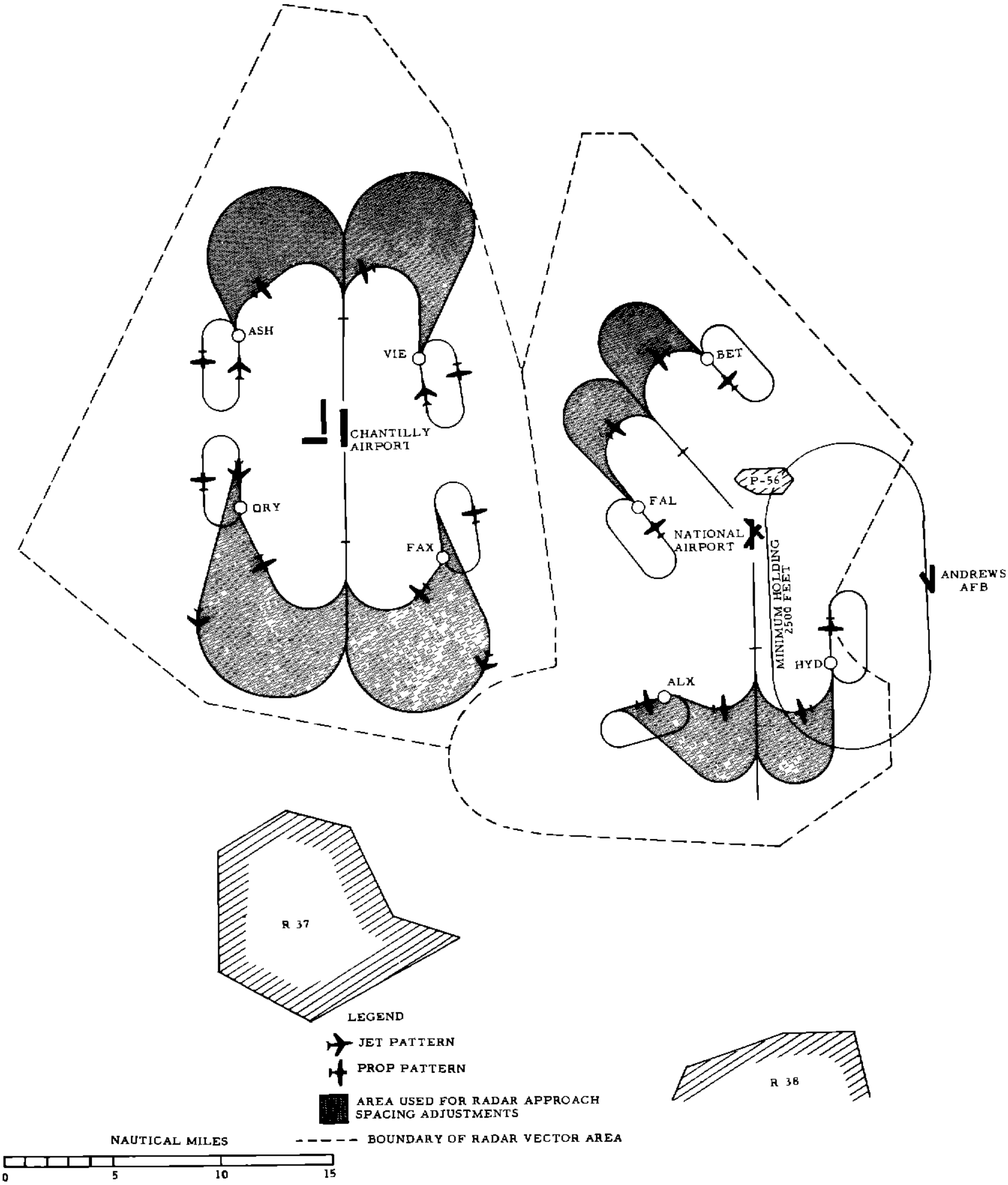


FIG 8 RADAR VECTOR AREAS
CHANTILLY SYSTEM
NORTH AND SOUTH OPERATIONS

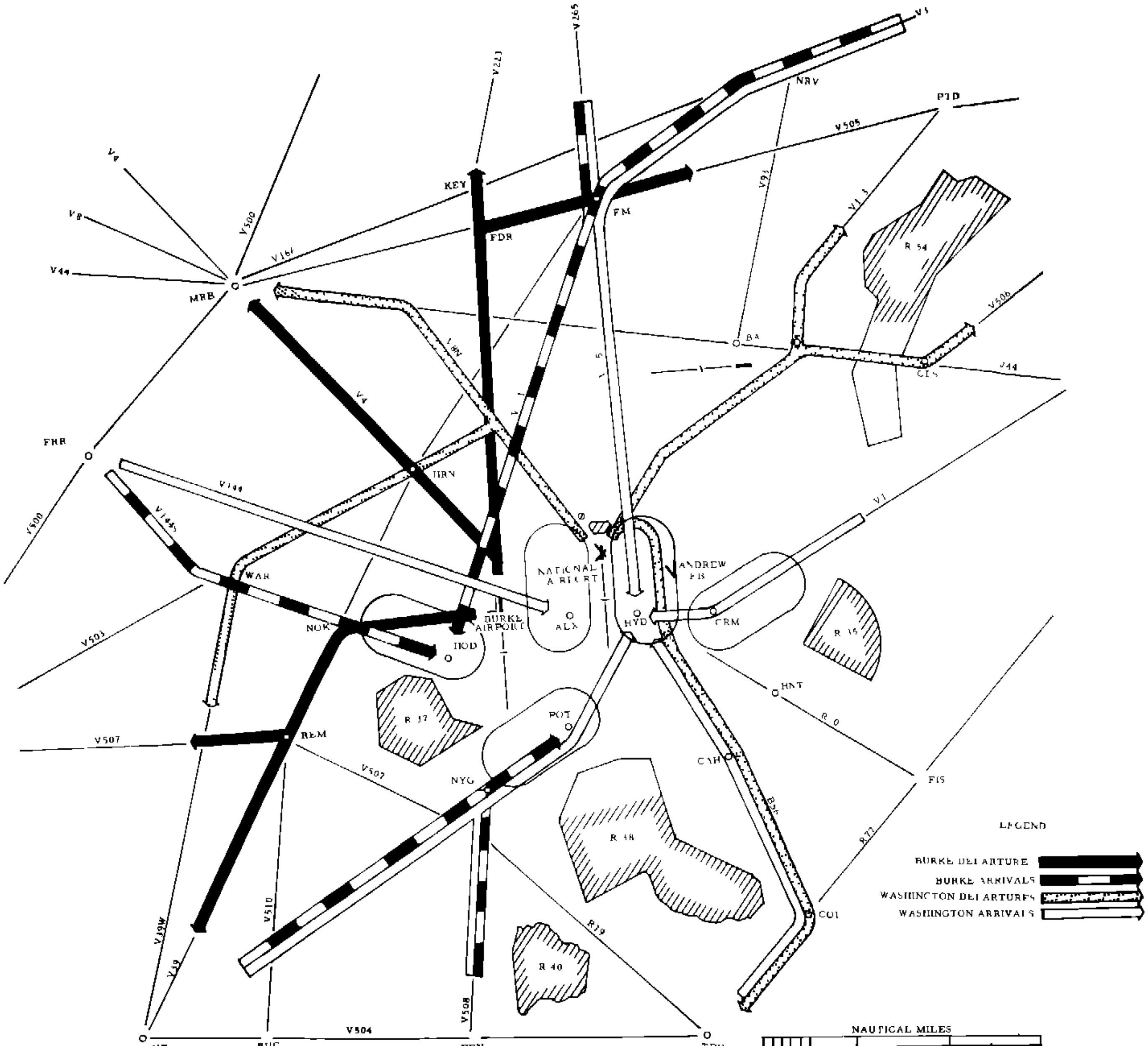


FIG 9 BURKE SYSTEM ARRIVAL AND DEPARTURE ROUTES NORTH OPERATIONS

CAA TECHNICAL DEVELOPMENT CENTER INDIANAPOLIS INDIANA

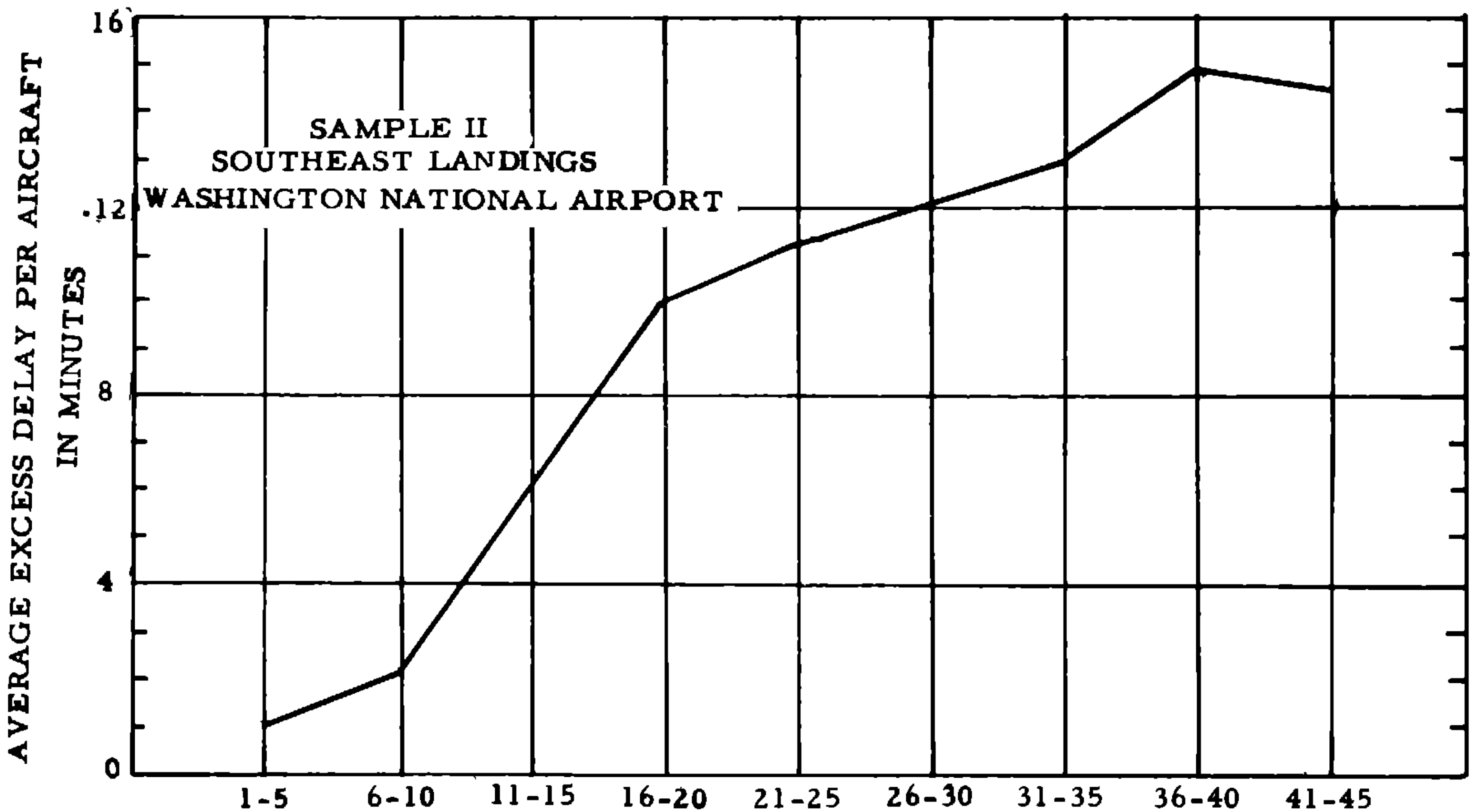


FIG. 10 DELAYS FROM SINGLE-FIX APPROACH SYSTEM IN EXCESS OF DELAYS OF TWIN-FIX SYSTEM

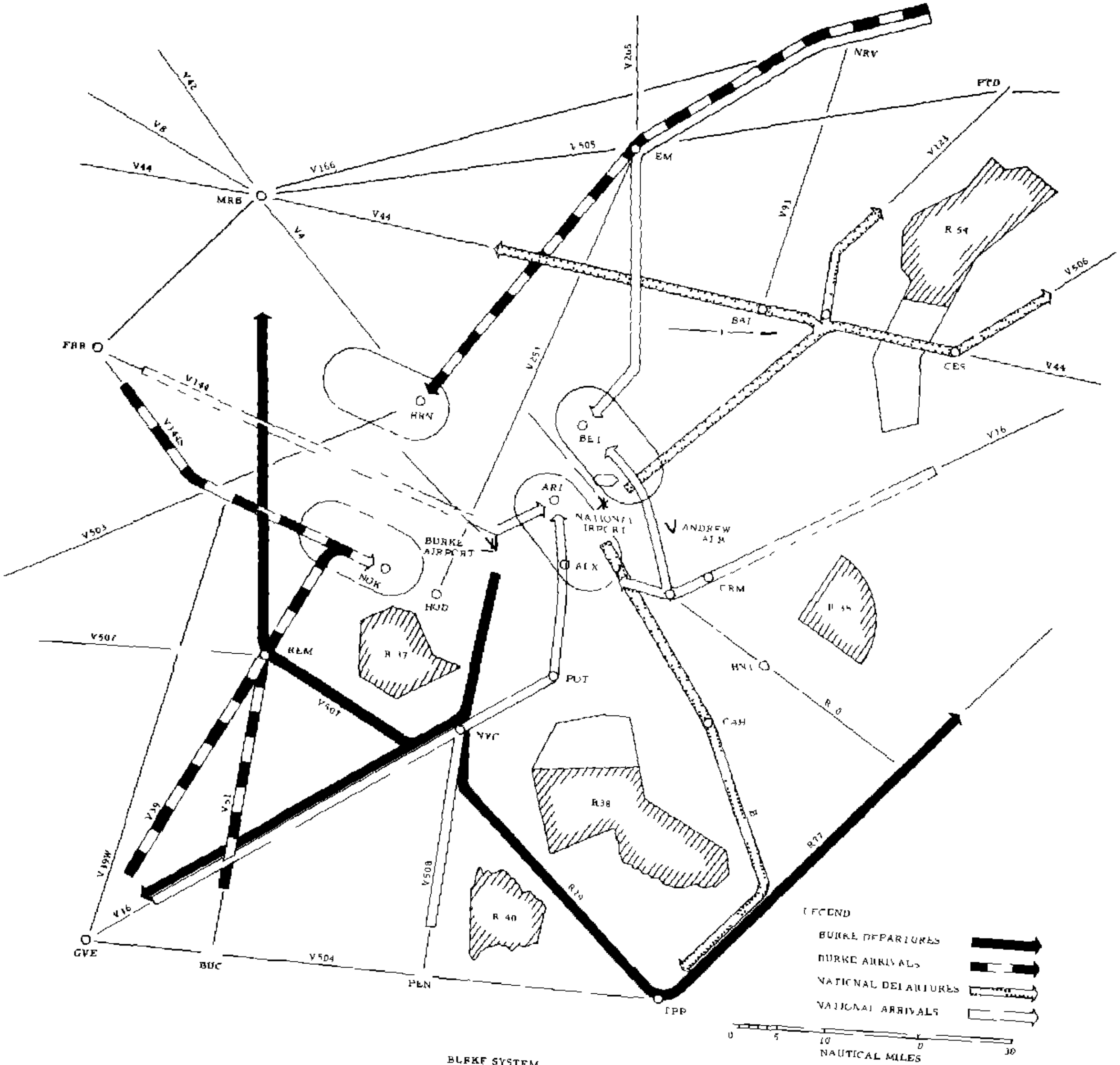


FIG 11 BURKE SYSTEM
ARRIVAL AND DEPARTURE ROUTES
SOUTHEAST OPERATIONS

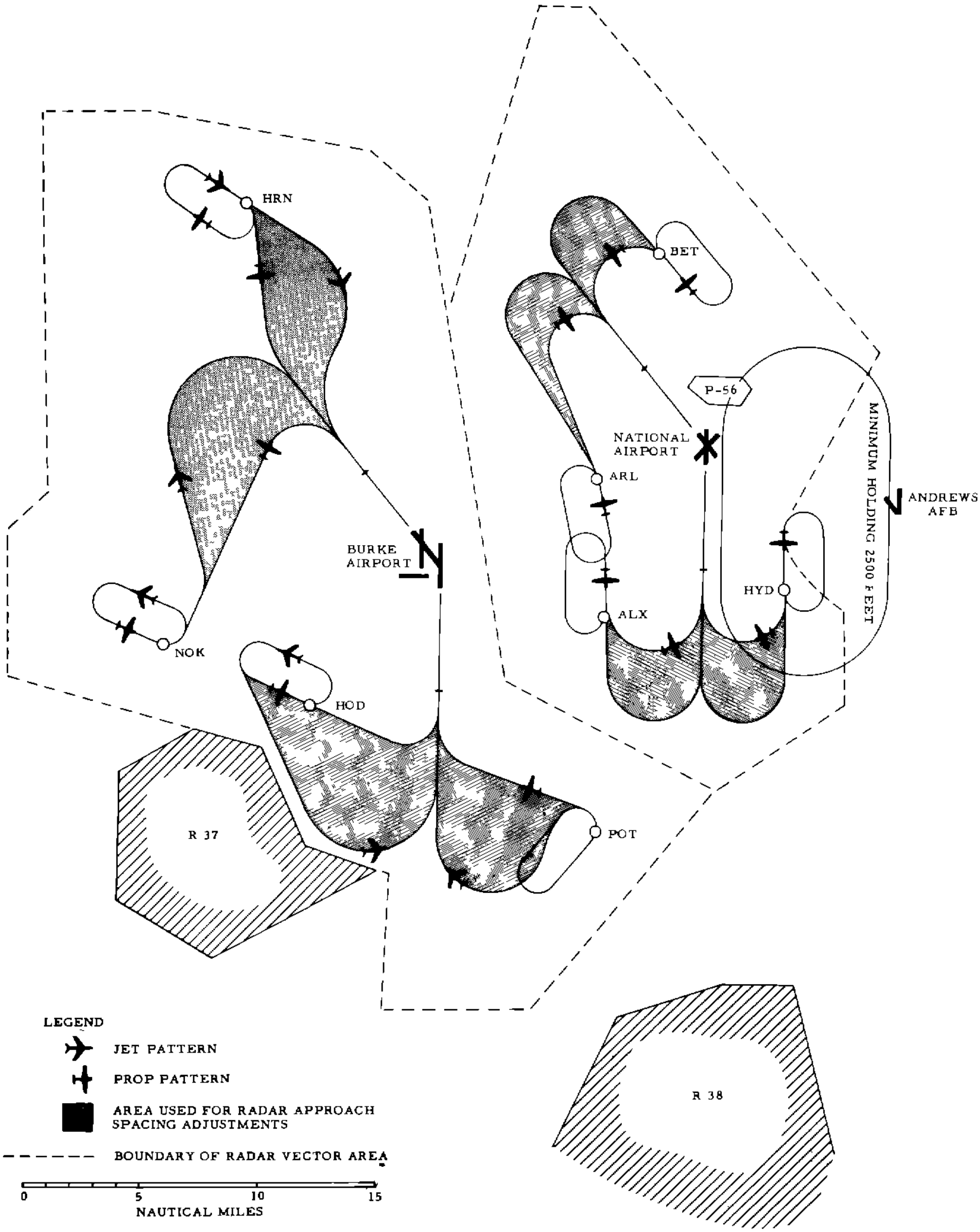


FIG 12 APPROACH CONTROL RADAR VECTOR AREAS
BURKE SYSTEM
NORTH AND SOUTHEAST OPERATIONS

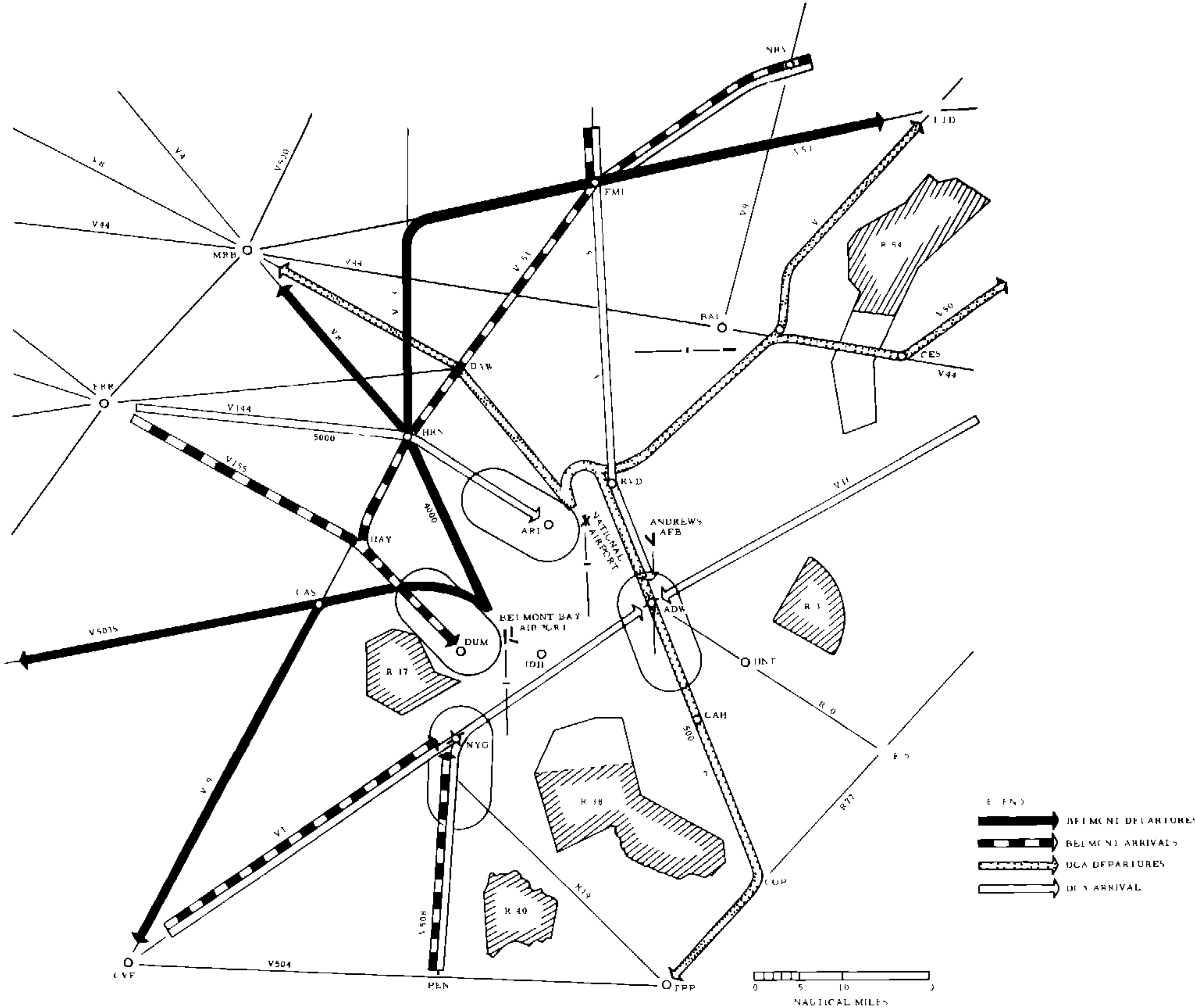


FIG 11 BELMONT BAY SYSTEM NORTH OPERATIONS

CAA TECHNICAL
DEVELOPMENT CENTER
INDIANAPOLIS INDIANA

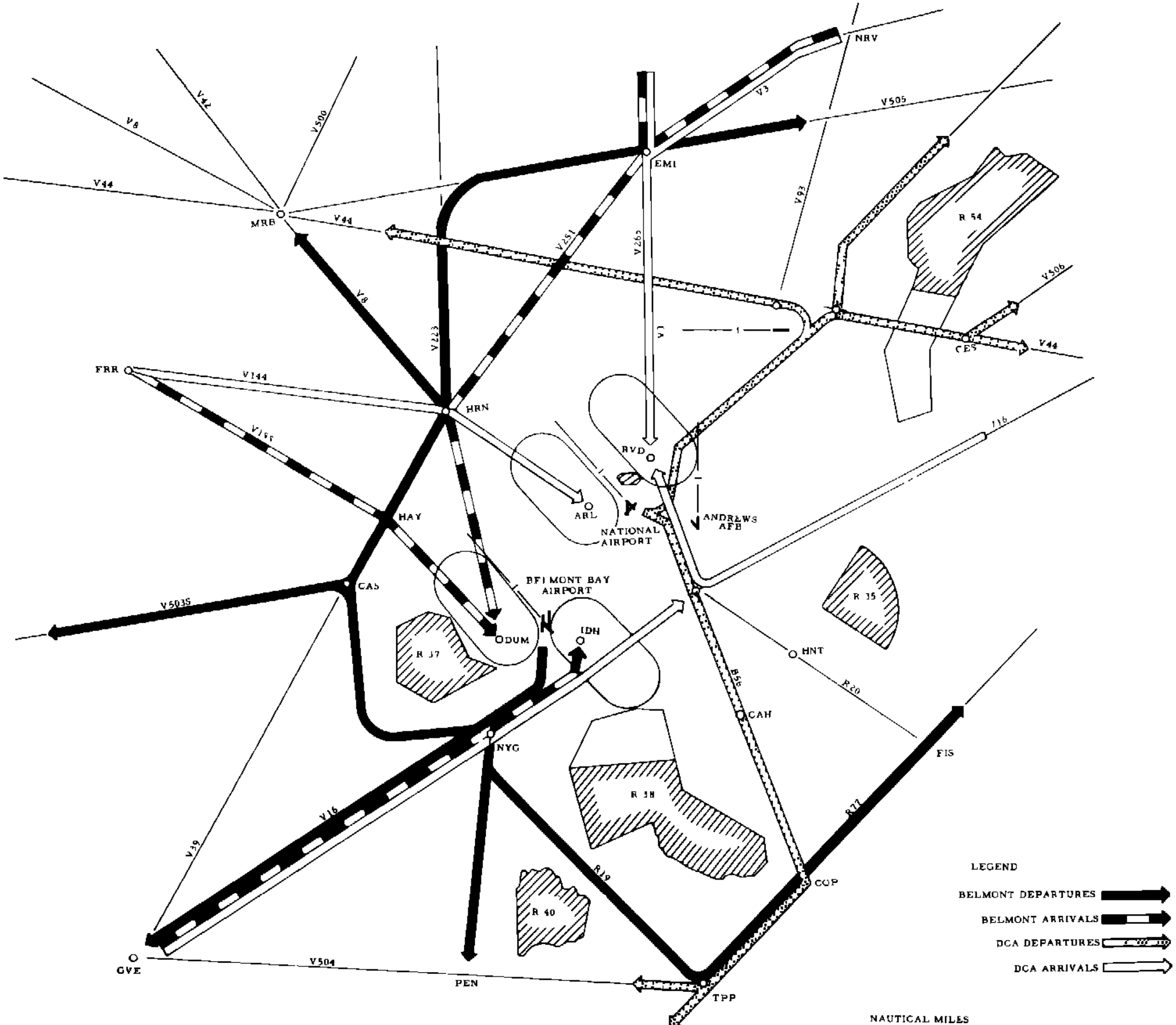


FIG 14 BELMONT BAY SYSTEM SOUTHEAST OPERATIONS

CAA TECHNICAL DEVELOPMENT CENTER INDIANAPOLIS INDIANA

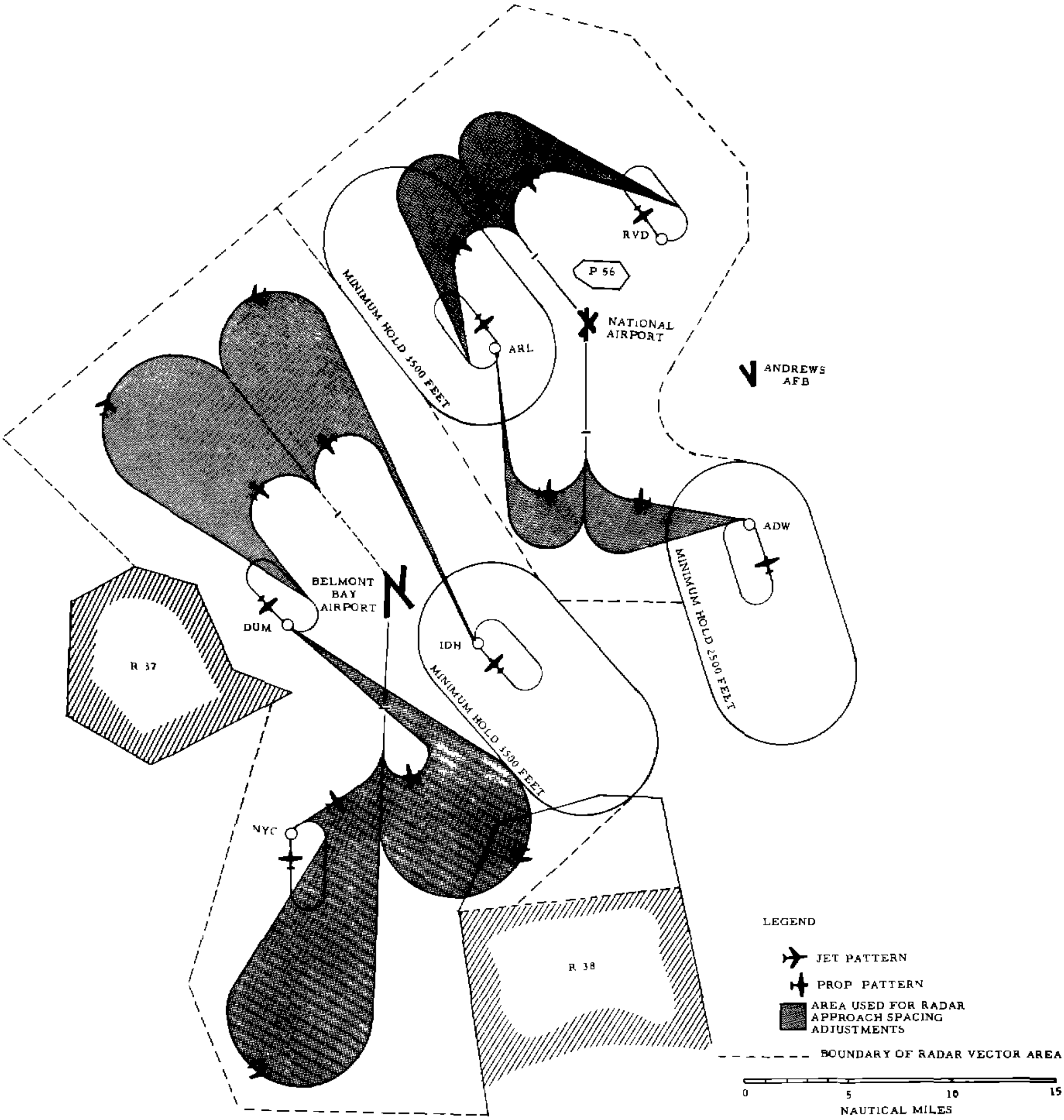
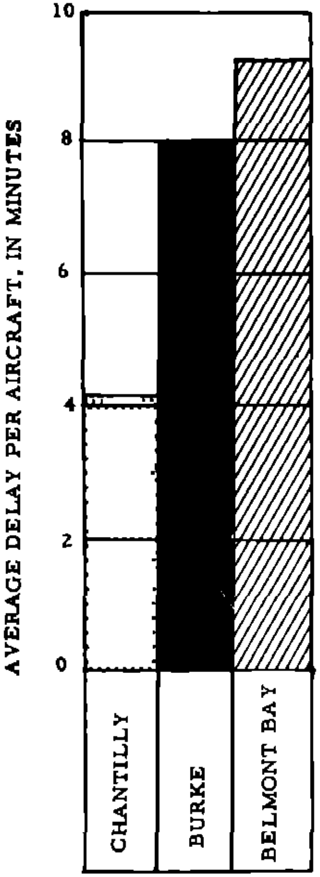
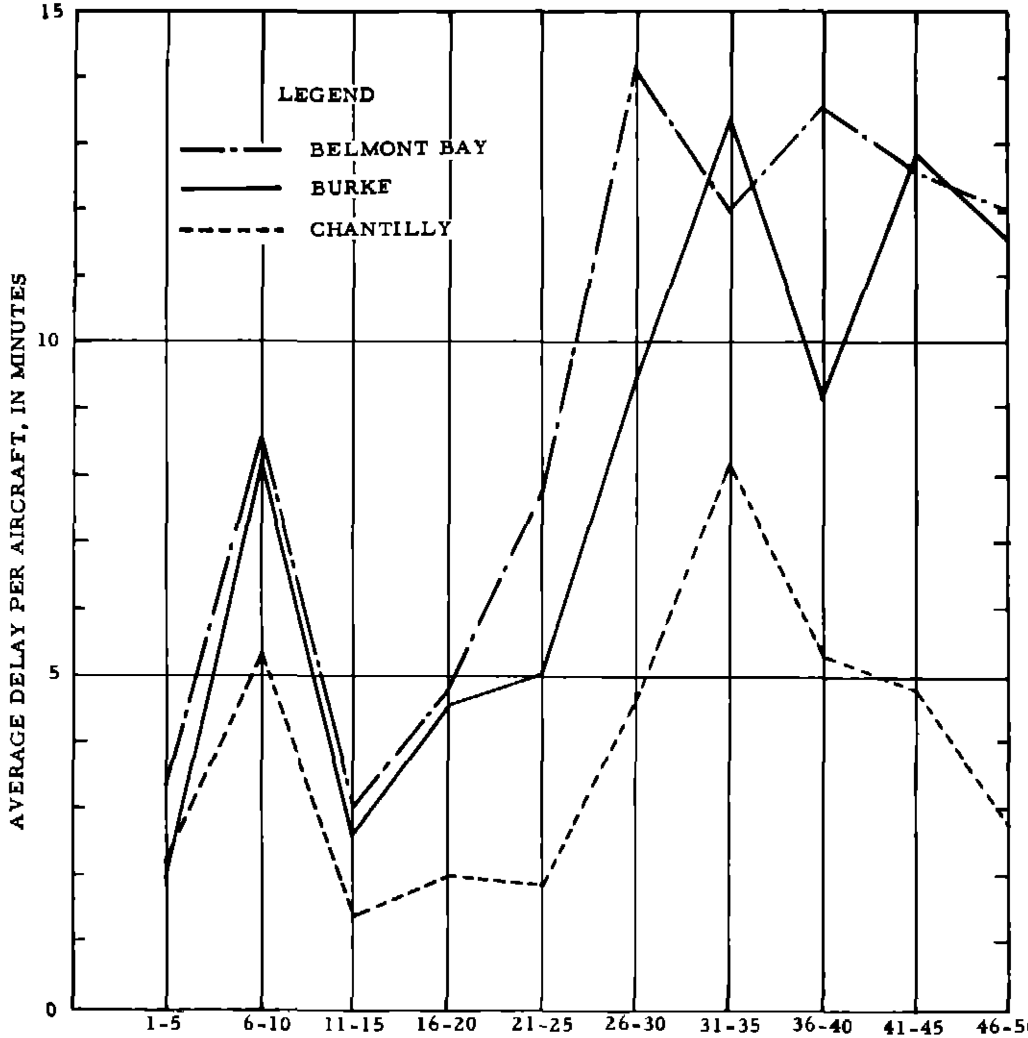


FIG 15 APPROACH CONTROL RADAR VECTOR AREAS
BELMONT BAY SYSTEM
NORTH AND SOUTHEAST OPERATIONS

SAMPLE II
NORTH LANDINGS



AVERAGE DELAY
FOR ALL AIRCRAFT



AIRCRAFT IN GROUPS OF FIVE

BUILDUP OF AIRCRAFT DELAYS

FIG 16 AIRCRAFT DELAY MEASUREMENTS

CAA TECHNICAL
DEVELOPMENT CENTER
INDIANAPOLIS INDIANA

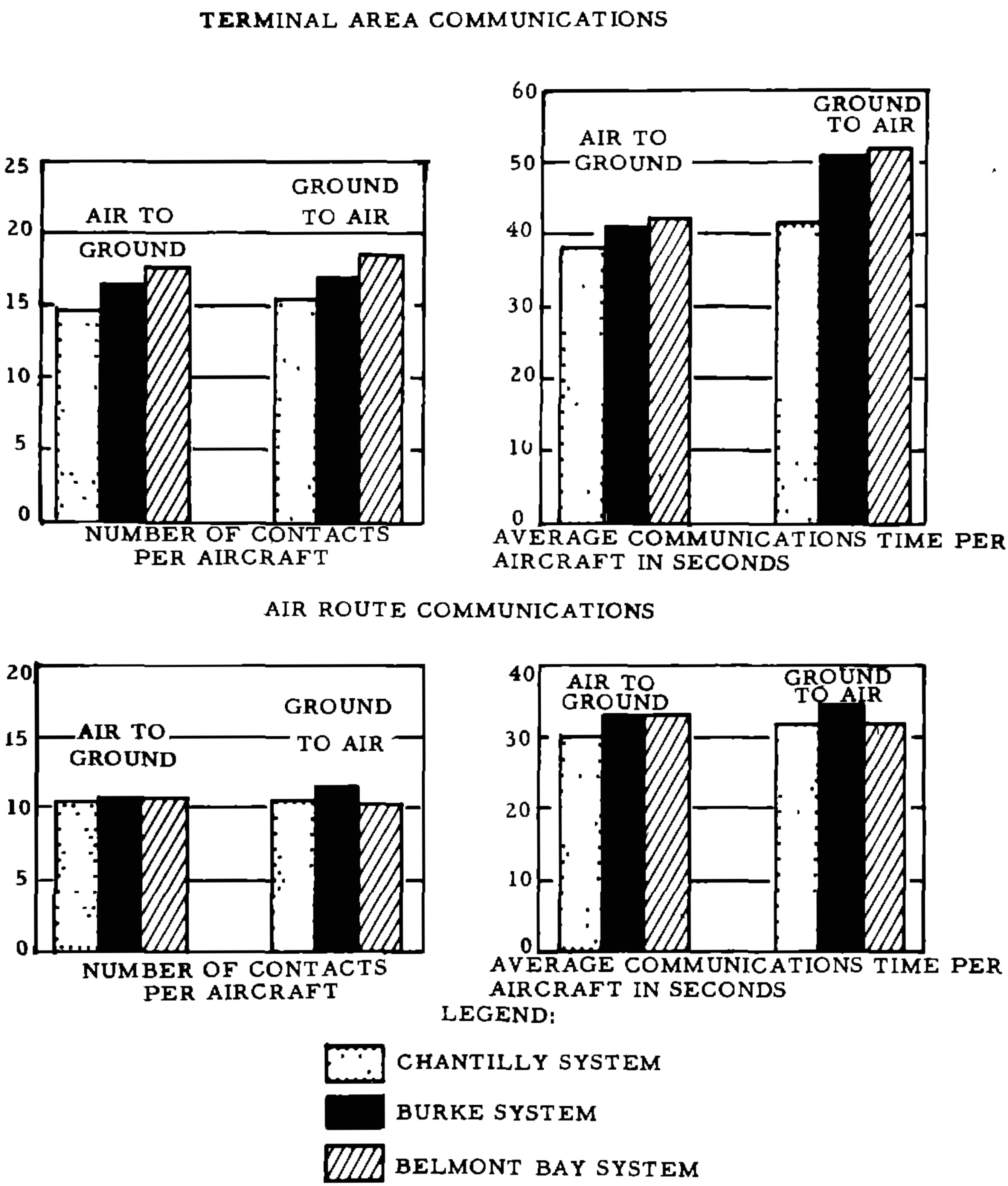


FIG. 17 COMMUNICATIONS MEASUREMENTS
SAMPLE I