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PRELIMINARY STUDY OF TRAFFIC CONTROL SYSTEMS FOR THE PROPOSED WASHINGTON SUPPLEMENTAL AIRPORT USING SIMULATION TECHNIQUES

FOR LIMITED DISTRIBUTION

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SUMMARY

This report describes the results of an air traffic control study by simulation methods to determine the relative merit of several possible traffic patterns and airport layouts for a Washington supplemental airport site at Burke, Virginia.

A preliminary analysis of four different configurations of navigational aids and instrument runway alignments was made to determine a system that would provide the most efficient flow of traffic in and out of the proposed Burke Airport with the least restriction on Washington National and Andrews AFB air traffic. It was considered desirable that the system include a suitable approach procedure for jet type aircraft.

In making these studies, it was necessary to consider the restrictions on air traffic caused by the nearby Quantico and Dahlgren danger areas.

The results of the simulation studies indicate that the Dumfries System, as described in this report, offers the best en route and terminal area navigational features of any of the four systems tested.

INTRODUCTION

In order to assist in the initial planning for the proposed Washington supplemental airport at Burke, Virginia, the Office of Federal Airways, through the Air Navigation Development Board, requested that the Technical Development and Evaluation Center conduct a preliminary study of possible air traffic patterns and airport layouts. This study, which was necessarily of a cursory nature, was intended primarily to determine the most suitable arrangement of navigational facilities and instrument runways for the proposed airport.

The proposed Washington supplemental airport site at Burke, Virginia, presents several diverse problems. The most formidable restriction to efficient traffic flow is the Quantico danger area, which is located 11 miles southwest of the Burke site. This Marine gunnery and rocket range, which covers an area of over 100 square miles, limits considerably the air space available for maneuvering aircraft into the final approach path at Burke Airport.

The Dahlgren danger area, located 24 miles south-southeast of Burke, does not restrict traffic flow in the immediate airport vicinity. However, it does complicate the arrival routes to the three major airports in the terminal area.

The proximity of the Burke site to the Washington National Airport will tend to restrict the flow of traffic into the latter field by obviating the use of a west sector holding fix for feeding traffic into the Washington National Airport. This restriction may not be too serious if Burke becomes the principal airport in the Washington terminal area, since it is likely that Washington National Airport would then lose much of its present commercial traffic.

EVALUATION METHODS

The study of four possible traffic control systems for Burke Airport was conducted through the use of the dynamic traffic control simulator. A brief description of this equipment is given in another report.[1]

In order to obtain comparative measurements on the operating characteristics of various systems, it was necessary to develop a representative traffic problem for the simulation tests. This problem was assembled through use of techniques developed by the Franklin Institute. Table I shows the schedule of arriving aircraft used in all simulation runs. The basic input to the problem consisted of 40 aircraft. Four general speed categories were included, with a distribution as follows:

3 Jets

10 Fast (DC-6 or Constellation)

21 Medium (Convair or Martin)

6 Slow (DC-3 or Twin Beech)

Table II shows the speed program and descent rates of the aircraft used in the standard problem.

Traffic Control Systems

All approach control systems tested for Burke Airport were twin-stack systems, with one holding fix located on either side of the final approach path. All facility layouts were based on the use of VOR facilities to define arrival and departure routes. Holding patterns were

[1] Technical Development Report No. 185, titled "Evaluation of Traffic Control Systems for the Norfolk Terminal Area Using Simulation Techniques."

aligned with specified VOR radials, and the holding fixes themselves were assumed to be either LVOR facilities or compass locators.

In conducting the simulation tests, it was assumed that the terminal area had complete radar coverage. Also it was assumed that radar vector procedures would be utilized in clearing aircraft from the holding fixes to the approach gate and in spacing aircraft properly on the final approach course.

Division of Control

Burke arrivals from the southwest, west, and northwest normally were cleared by ARTC to the west sector holding fix. Arrivals from the south, southeast, east, and northeast were cleared to the east sector holding fix. Aircraft arriving from the north could be cleared to either fix. Control of aircraft was transferred to the appropriate sector radar controller at designated transfer points which are indicated in Figs. 1, 3, 5, and 7.

All jet aircraft destined for the Burke Airport were cleared by ARTC to the Riverside VOR or to the nearby Brooke fan marker. Upon arrival at Riverside or Brooke, the control of jet aircraft was transferred to the east sector radar controller.

Detailed coordination was performed between the sector radar controllers whenever a jet aircraft was cleared for approach. This coordination was necessary in order to decide when to clear the approach path of conventional propeller-diven aircraft and to set up the approach sequence to follow the jet aircraft.

Delay Measurements

The basic problem input data listed in Table I furnished the theoretical time at which each inbound aircraft should be over the outer marker or approach gate, assuming that no other traffic was involved. Through use of an Esterline-Angus recorder, the simulator pilots recorded the actual arrival time of their aircraft over the approach gate. The theoretical arrival time was compared with the actual arrival time to determine the relative delay to each inbound aircraft.

Communications Measurements

Communications for each sector included complete control instructions, current weather information, and pilot reports and acknowledgements. In each system the total amount of communications time necessary to bring the aircraft to the approach gate was recorded by electric clocks. The number of separate communications contacts was recorded through the use of electric counting devices.

Significance of Measurements:

Comparison of previous tests with results attained in actual operations indicates that the speed and course errors in the simulation equipment produce deviations roughly equivalent to the deviations of actual aircraft in terminal area operations.

One consideration in setting up these simulation tests was to obtain a maximum amount of significant information about the flow characteristics of the various systems in a minimum number of working hours. Since potential bottlenecks are not as apparent in light traffic conditions, the traffic problem used in this program had a relatively high flow rate.

Although every effort was made to keep the simulation tests as realistic as possible, it was not practical to reproduce in the laboratory all the complications and distractions which might exist under actual operating conditions. Therefore, in studying the results of these simulation tests, it should be realized that the actual quantitative data may not be duplicated in actual practice. However, since the same traffic sample was used in all systems tested, the results are indicative of the relative performance of each system and should be regarded as qualitative only.

SYSTEMS TESTS AND RESULTS

Brentsville System

An airport layout and arrangement of navigational fixes furnished by the Office of Federal Airways wss simulated in the first test. A map, showing control jurisdiction, arrival routes, holding patterns, and the jet letdown procedure, is shown in Fig. 1. The departure routes and holding pattern air space reservations are shown in Fig. 2. The results of the test runs made using this system are shown in Figs. 9, 10, 11, and 12.

Observations:

1. Maneuvering Air Space. Because of the proximity of the Quantico danger area, the maneuvering air space between Brentsville and the outer marker was extremely limited. This restricted the amount of path stretching that could be accomplished by the west sector controller and made it difficult for him to obtain precise spacing of aircraft at the approach gate.

The holding fixes were 12 miles away from the outer marker in this system. Because of this great distance, it was necessary that the sector controllers have several aircraft off the holding fixes in order to keep the approach gate full of aircraft at minimum spacing.

The east sector holding pattern air space reservation at Indian Head extended into the Dahlgren danger area. The safety and legality of such an arrangement appears questionable.

2. Coordination Work Load. Since very little flexibility was possible in adjusting the flight path of aircraft en route from Brentsville to the

outer marker, coordination between sector controllers was necessary each time an aircraft left the Brentsville holding fix in order to reserve space on the final approach course. The coordination work load was increased each time a jet aircraft started an approach because the controllers had to clear the approach path of other aircraft and decide which sector controller would clear an aircraft to follow the jet aircraft.

3. Jet Aircraft Approach Procedure. In this system, the jet approach course intersected the final approach course near the outer marker. This was objectionable because of the possibility of overshooting the final approach course at a point close to the outer marker. It was also necessary that the jet pilot change from VOR frequency to ILS frequency during a critical portion of the approach.

Lake Jackson System

In the Lake Jackson System the holding fixes were located only 6-1/2 miles from the outer marker. The Riverside VOR was moved slightly east of its previous location, in order to permit jet aircraft to intercept the ILS course farther away from the outer marker. A map, showing the arrival routes, areas of control jurisdiction, holding patterns, and the jet letdown procedure, is shown in Fig. 3. The departure routes and holding pattern air space reservations are shown in Fig. 4. The results of the test runs made using this system are shown in Figs. 9, 10, 11, and 12.

Observations:

1. Maneuvering Air Space. This system provided the west sector controller with the most maneuvering air space of any of the four systems tested. As the holding fixes were only 6-1/2 miles from the outer marker, the approach gate could be kept full of aircraft at minimum spacing with less aircraft under simultaneous radar vector control.

2. Coordination Work Load. The coordination work load was lighter in this system than it was in the Brentsville system. With more maneuvering air space and with fewer aircraft under radar vector control at one time, it was much easier to fit jet approaches into the normal landing sequence.

3. Jet Aircraft Approach Procedure. The jet approach course passed very close to the east tip of the Quantico danger area. Precise navigation was required to remain clear of the danger area. In this system, jet aircraft intercepted the final approach course at a point about 12 miles south of the outer marker. This gave the pilot a little more time to get established on the final approach before crossing the outer marker. It still was necessary for him to change from VOR to ILS frequency in order to complete an approach. In the event that the pilot overshot the turn on to the final approach, it is conceivable that the aircraft might enter the west sector holding area.

4. Other. The Indian Head holding pattern air space was clear of the Dahlgren danger area in this system. The departure route mileage was shortened somewhat for aircraft departing the area to the southwest.

Hoadley System

In the Hoadley System the runway alignment was changed from north-northeast to north. A fan marker was located at Brooke, Virginia, permitting a straight-in jet approach procedure on the ILS course. The east and west sector holding patterns were located 4-1/2 miles away from the outer marker, and were parallel to the final approach course. The arrival routes, areas of control jurisdiction, holding patterns and the jet letdown procedure are shown in Fig. 6. The results of the test runs made using this system are shown in Figs. 9, 10, 11, and 12.

Observations:

1. Maneuvering Air Space. The holding fix location in this system provided ample air space for path stretching. The location of the fixes with respect to the outer marker required fewer aircraft away from the holding fixes to keep the approach path full.

2. Coordination Work Load. In this system the coordination work load was lighter than in the first two systems tested. The jet approach was straight in and did not require as much radar assistance. The fact that fewer aircraft were maneuvering in the immediate area of the approach path lessened the amount of coordination necessary for the jet approach clearance. The location of the holding fixes with respect to the final approach course permitted each controller to determine more readily what control action was being taken in the opposite sector, thus reducing the coordination work load.

3. Jet Aircraft Approach Procedure. Jet aircraft commenced a straight-in ILS approach from the Brooke fan marker. This jet approach procedure caused a minimum amount of interference with approaches of conventional type aircraft.

4. Other. The Hoadley System arrangement of holding fixes encompassed the least total air space of any of the four systems. In this system the distance from the east edge of the Andrews holding pattern air space reservation to the west edge of the west sector holding pattern air space reservation was 36 miles as compared to 52 miles in the Brentsville system.

Dumfries System

The Dumfries System was based on the use of VHF omniranges at Riverside and Herndon. The Riverside VOR was located on the ILS localizer course. The Herndon VOR was located on the extended centerline of the alternate north-south runway, in order to provide means for making instrument approaches to the south when wind conditions made north landings inadvisable.

The Dumfries System was designed specifically to provide these features:

1. More flexibility for ARTC with alternate clearance limits for aircraft approaching from the south as well as the north.

2. A straight-in ILS jet approach procedure without the need of an additional fan marker.

3. A navigation aid for approaches to a south landing.

4. More direct arrival routes to the three airports in the area.

A map of this system, with holding patterns, arrival routes, areas of control jurisdiction, and the jet letdown procedure, is shown in Fig. 7. The departure routes and holding pattern air space reservations are shown in Fig. 8.

The results of the test runs made using this system are shown in Figs. 9, 10, 11, and 12. It will be noted that this system had the lowest delays, lowest communications times, and lowest radar navigation work load of any system tested.

Observations:

1. Maneuvering Air Space. The northerly final approach path adopted for the Hoadley System was retained. Holding patterns were aligned on Riverside VOR radials with the markers placed a distance of five miles away from the outer marker. To avoid convergence of down-wind courses after aircraft left the holding fixes, the controllers could, when necessary, instruct the pilots to leave the fix on a heading of 180 degrees. The maneuvering air space in this system was found to be ample for path stretching.

2. Coordination Work Load. The coordination work load between sector controllers using this system was essentially the same as in the Hoadley System.

3. Jet Aircraft Approach Procedure. An improved jet approach procedure was provided in this system by locating the Riverside omnirange on the ILS localizer course. This provided the jet pilot with an alternate method of obtaining approach guidance to the runway in case of ILS equipment failure.

4. Arrival Routes. This system provided additional flexibility for ARTC in that aircraft arriving from the north could be diverted at the Vienna VOR to either holding fix. Likewise, aircraft arriving from the south could be diverted at the Riverside VOR to either holding fix. This tended to equalize the number of aircraft at the holding stacks and thus equalize the work load for the two sector controllers.

This system permitted aircraft not equipped with ILS to hold at either sector holding fix and make an approach and landing at Burke, using the Riverside VOR exclusively as a navigation aid.

Effect on Traffic Operations at Washington National Airport

Reference to Figs. 2, 4, 6, and 8 will show that operation of any system at Burke Airport will preclude the use of any west sector holding fix for Washington National Airport. Thus, the activation of Burke Airport will probably reduce the Washington National Airport approach control system from a twin-stack to a single-stack operation.

To determine the effect of this change on traffic operations at Washington National Airport, comparative simulation tests were made as follows:

1. The present twin-stack system for Washington National Airport was tested with present arrival routes, using Springfield and Andrews as holding fixes.

2. A single-stack system was tested with the arrival routes illustrated in Fig. 7 and with the primary stack located at the Washington outer marker. Secondary stacks at Riverside and Andrews were utilized when necessary.

Tests indicated that the change back to the single-stack system would reduce the acceptance rate of the Washington National Airport. Air/ground communications which averaged 1 minute, 21 seconds per aircraft in the twin-stack system increased to 1 minute, 41 seconds in the single-stack system. This, together with the combination of the two previous radar control sectors into one sector, increased the communications channel loading from 30 per cent in the twin-stack system to 64 per cent in the single-stack system. This loading was handled satisfactorily under the somewhat idealized conditions of the laboratory tests. However, it would probably not be possible to handle an operation requiring this amount of communications during a long period under the noise and stress of actual operating conditions.

CONCLUSIONS

1. Because of the location of the Quantico danger area, a straight-in jet letdown is not possible with the north-northeast instrument runway alignment originally proposed for Burke Airport.

2. Simulation tests indicate that the Dumfries System used in coordination with a north-south layout of instrument runways at Burke Airport would permit the most efficient flow of traffic in and out of the three airports in the Washington terminal area. This system provides the following advantages for Burke Airport traffic:

a. Straight-in jet approach for north landings.

b. Alternate VOR or ILS approaches for north landings.

c. VOR approach for south landings.

d. Low controller work load.

e. Flexible ARTC routings to equalize holding stacks.

3. Activation of Burke Airport will interfere with the west holding stack presently adopted for Washington National Airport and will probably require that the Washington National Airport approach system revert to a one-stack operation with a primary stack at the outer marker. Simulation tests indicate that this change would reduce the acceptance rate of the Washington National Airport somewhat and would greatly increase the communications work load of the approach control position.

RECOMMENDATIONS

1. It is recommended that a north-south alignment of instrument runways be adopted for Burke Airport and that the Dumfries System of navigation facilities be considered.

2. If planning and construction have already reached a stage where the airport is definitely committed to a north-northeast instrument runway layout, the Lake Jackson System of navigational facilities is recommended for consideration.

TABLE I - SCHEDULED INPUT

No.	Ident.	Type	From	Estimated Time Over Outer Marker
1	70	F	Shadyside	1:11:05
2	40	M	Front Royal	1:12:45
3	68	F	Woodford	1:15:05
4	25	M	Shadyside	1:20:40
5	30	S	Gordonsville	1:20:50
6	49	M	Lisbon	1:21:35
7	94	F	Shadyside	1:22:35
8	80	S	Front Royal	1:22:45
9	06	M	Gordonsville	1:25:25
10	77	F	Shadyside	1:27:25
11	29	M	Front Royal	1:29:10
12	60	F	Woodford	1:30:00
13	09	M	Lisbon	1:30:50
14	11	J	Lisbon	1:44:10
15	23	M	Front Royal	1:38:10
16	99	F	Gordonsville	1:39:40
17	01	M	Martinsburg	1:41:30
18	15	J	Woodford	1:45:40
19	27	M	Shadyside	1:41:05
20	37	S	Front Royal	1:41:55
21	45	M	Gordonsville	1:42:45
22	87	S	Gordonsville	1:46:00
23	04	M	Gordonsville	1:45:55
24	21	M	Shadyside	1:49:00
25	47	M	Shadyside	1:49:10
26	33	S	Front Royal	1:47:45
27	07	M	Lisbon	1:50:30
28	07	F	Gordonsville	1:52:40
29	03	M	Lisbon	1:50:25
30	19	J	Lisbon	2:08:25
31	22	M	Woodford	2:00:30
32	93	F	Front Royal	2:07:20
33	44	M	Lisbon	2:07:30
34	67	F	Martinsburg	2:07:40
35	41	M	Shadyside	2:06:35
36	79	F	Martinsburg	2:08:40
37	42	M	Gordonsville	2:17:30
38	02	M	Lisbon	2:16:35
39	89	S	Shadyside	2:18:50
40	28	M	Lisbon	2:22:05

TABLE II - SPEED AND DESCENT PROGRAM

Type	Speeds (MPH)			Descent
	Cruise	Intermediate	Approach	Rate-FPM
Jet	400	300	180	3000
Fast	290	220	150	1000
Medium	240	190	140	500
Slow	180	150	120	500

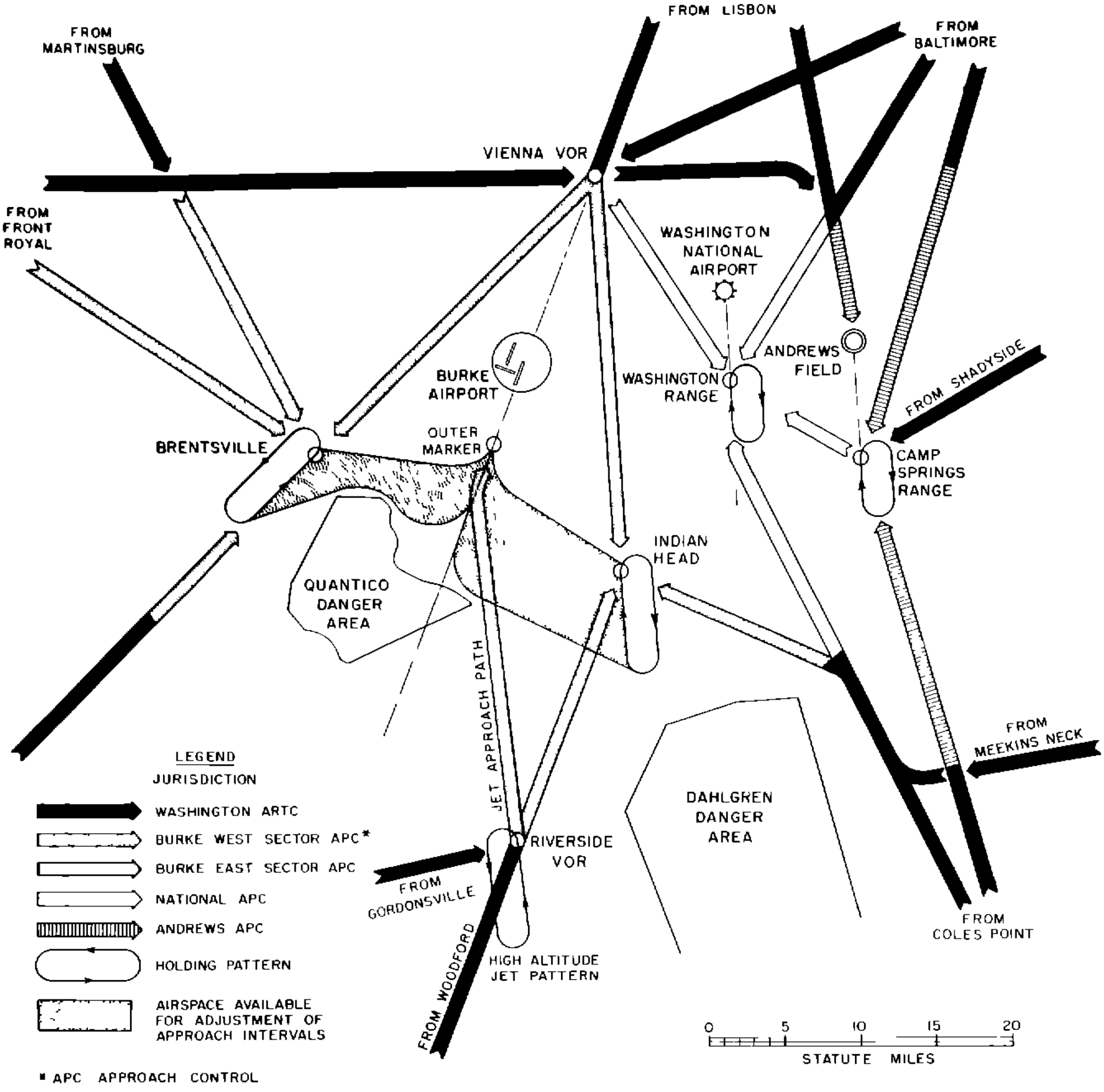


FIG I BRENTSVILLE SYSTEM SHOWING ARRIVAL ROUTES AND HOLDING PATTERNS

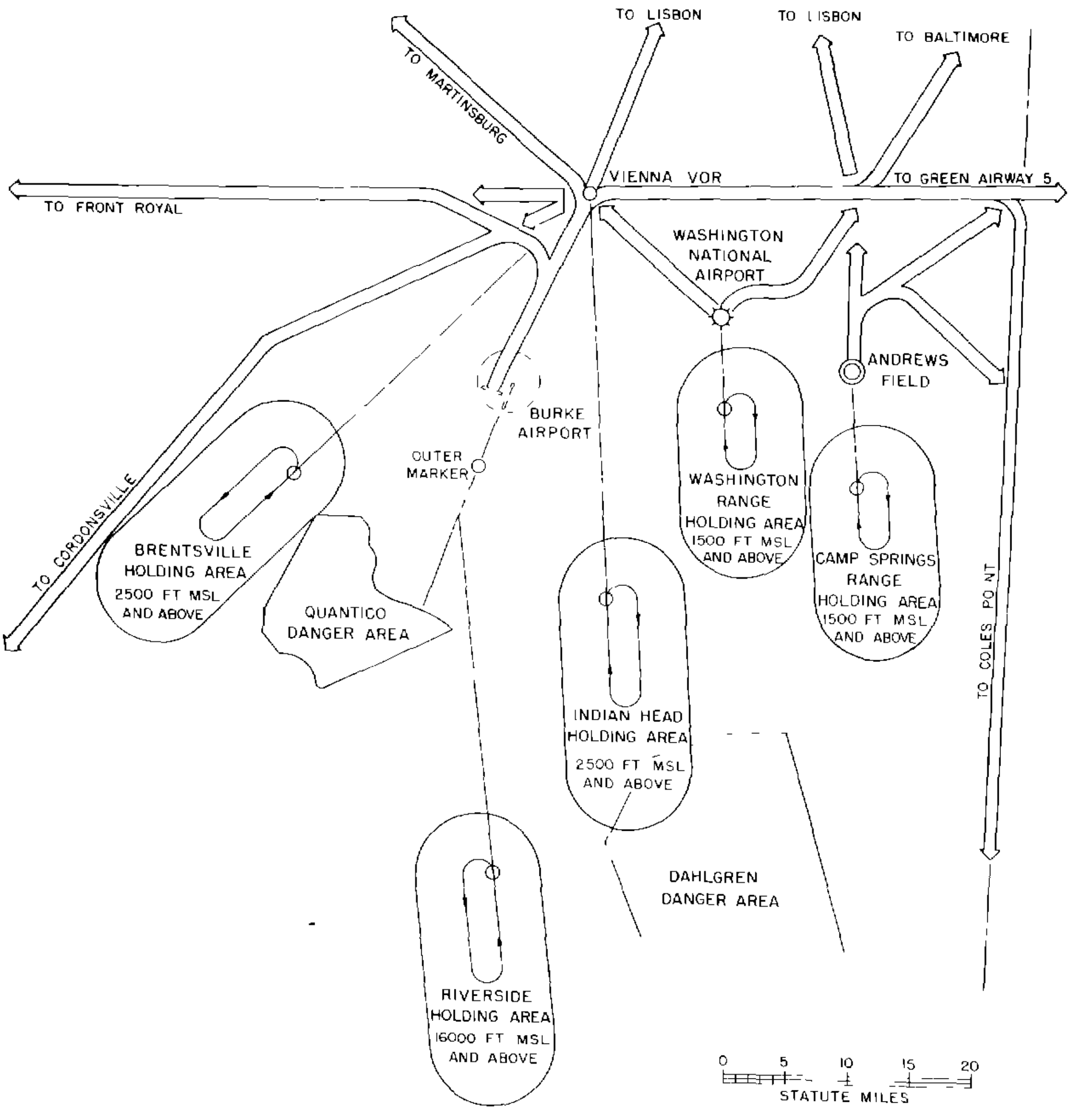


FIG 2 BRENTSVILLE SYSTEM SHOWING DEPARTURE ROUTES AND HOLDING AIRSPACE RESERVATIONS

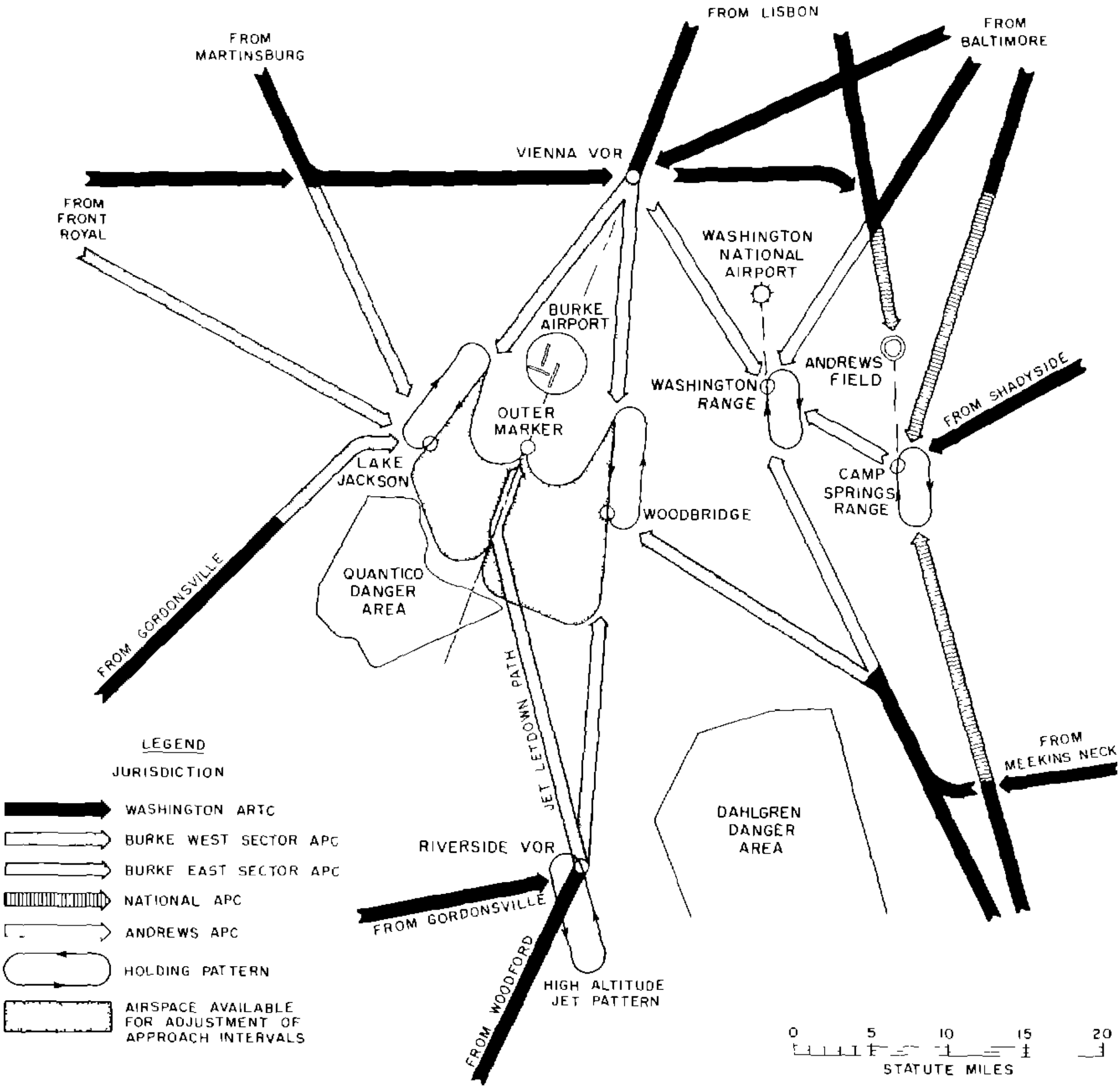


FIG 3 LAKE JACKSON SYSTEM SHOWING ARRIVAL ROUTES AND HOLDING PATTERNS

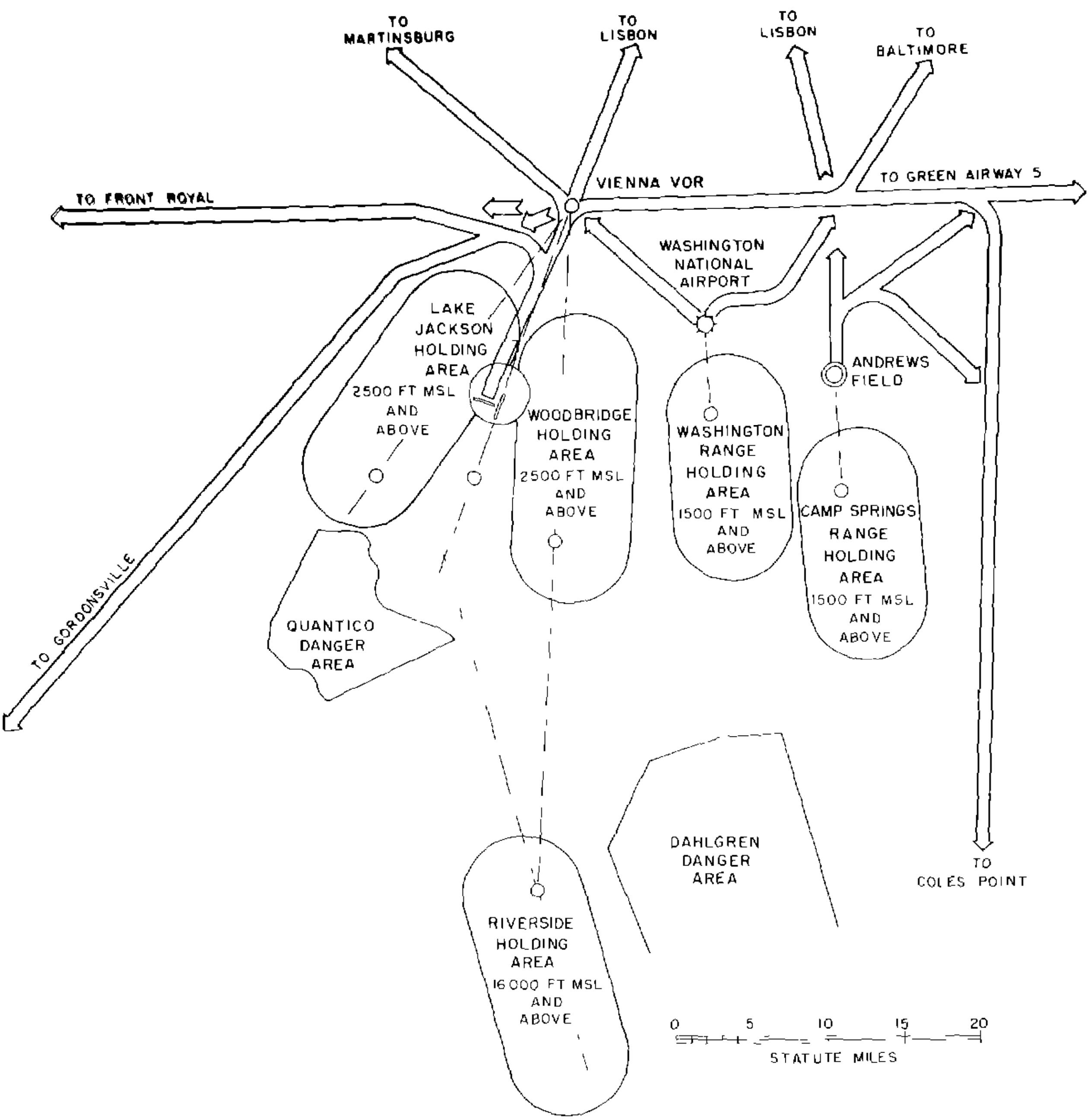


FIG 4 LAKE JACKSON SYSTEM SHOWING DEPARTURE ROUTES AND HOLDING AIRSPACE RESERVATIONS

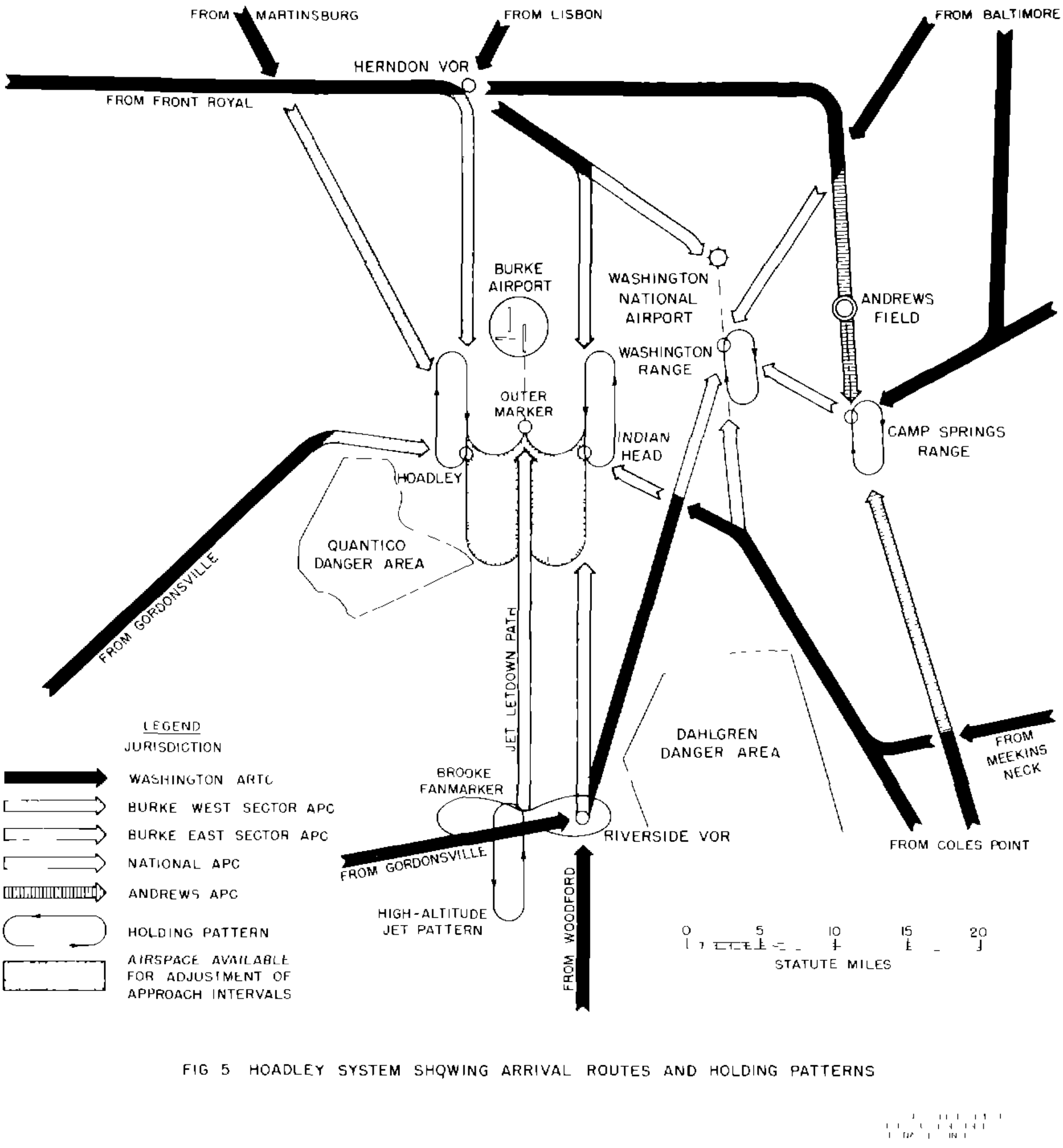


FIG 5 HOADLEY SYSTEM SHOWING ARRIVAL ROUTES AND HOLDING PATTERNS

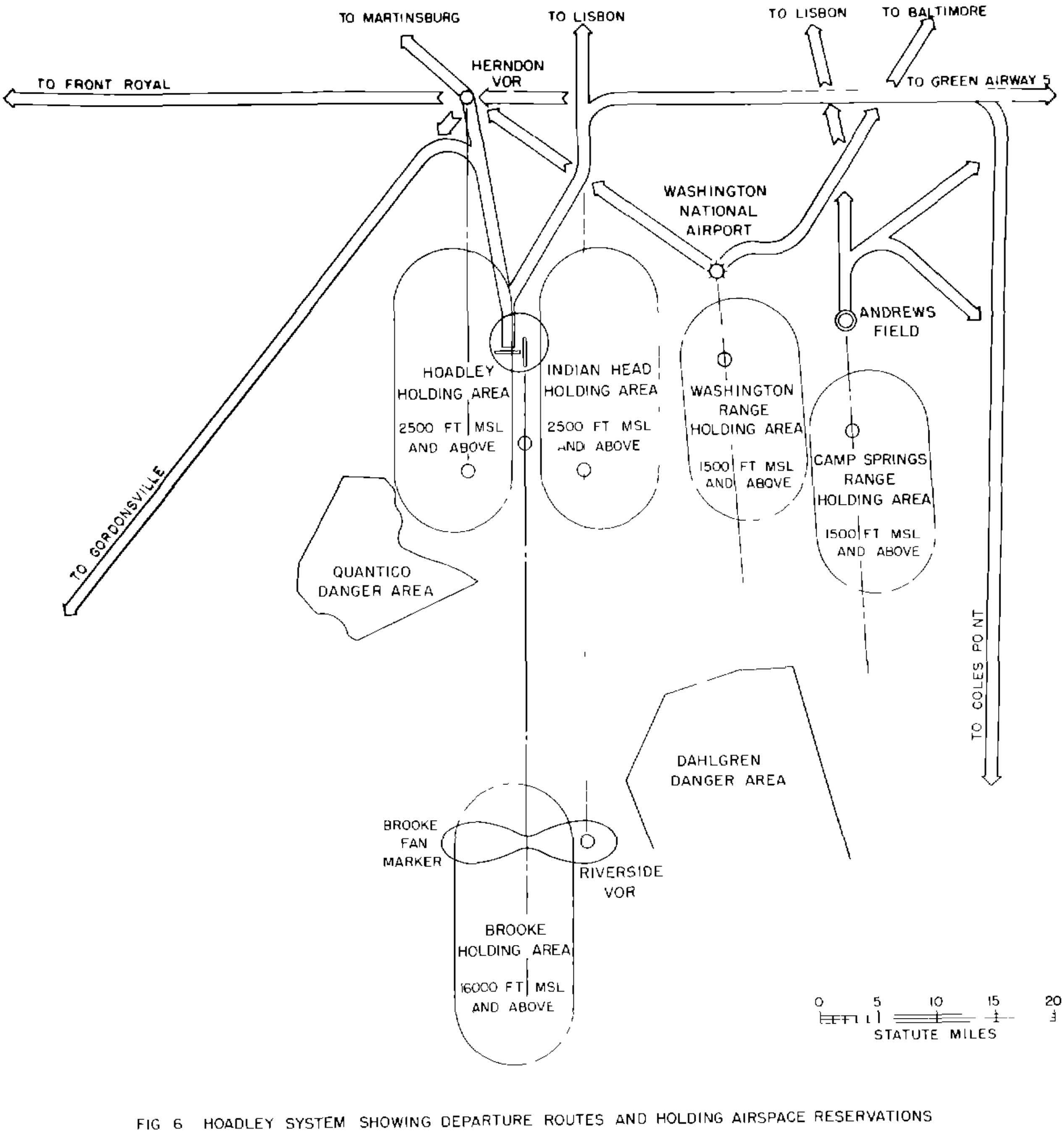


FIG 6 HOADLEY SYSTEM SHOWING DEPARTURE ROUTES AND HOLDING AIRSPACE RESERVATIONS

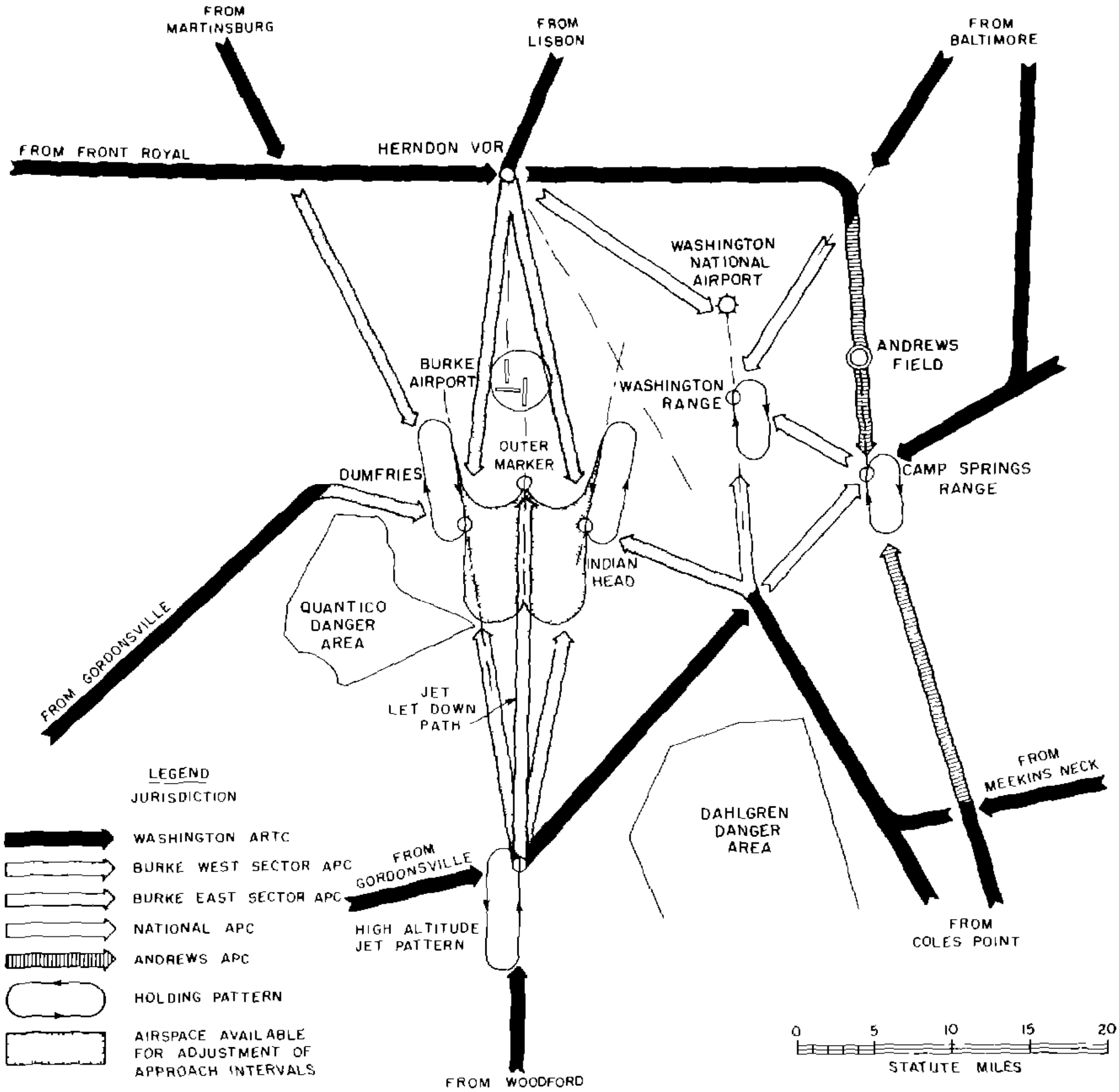


FIG 7 DUMFRIES SYSTEM SHOWING ARRIVAL ROUTES AND HOLDING PATTERNS

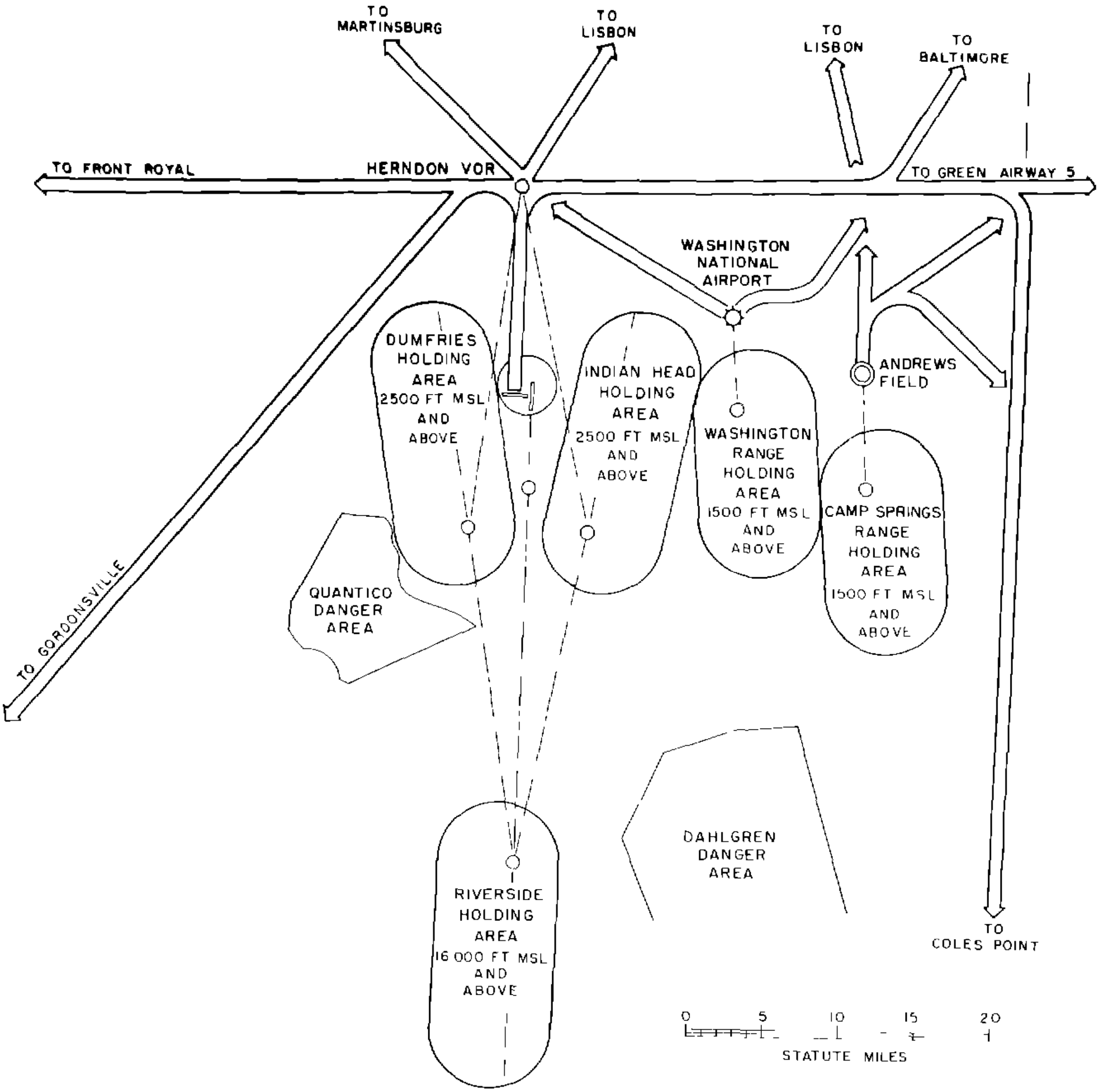


FIG 8 DUMFRIES SYSTEM SHOWING DEPARTURE ROUTES AND HOLDING AIRSPACE RESERVATIONS

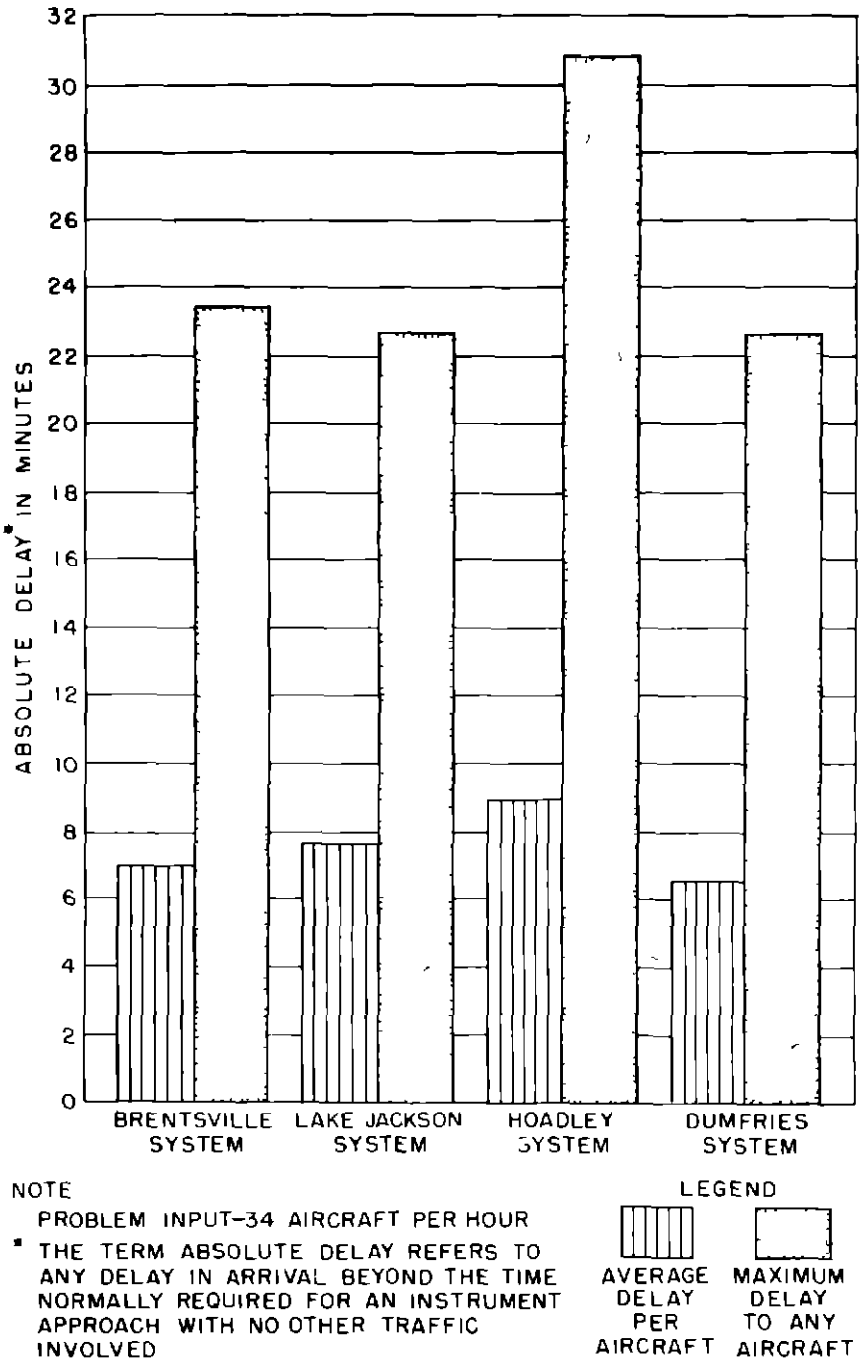
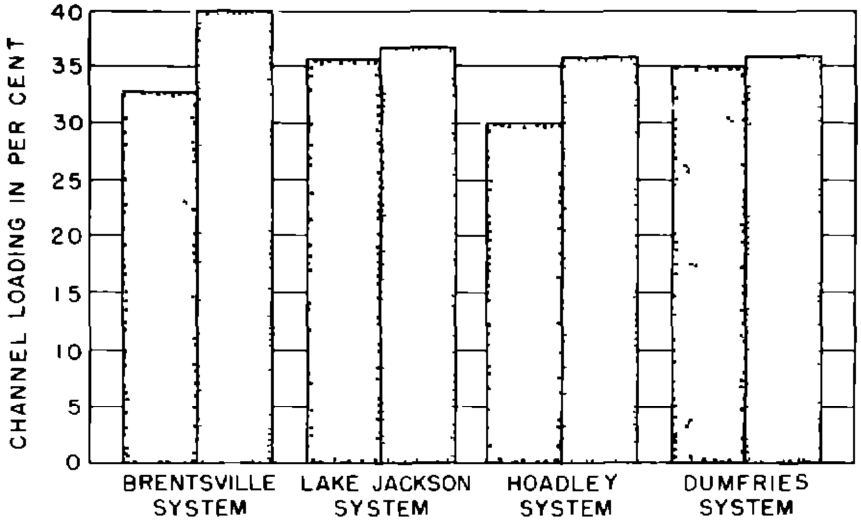


FIG 9 ABSOLUTE DELAYS



$$\text{COMMUNICATIONS CHANNEL LOADING} = \frac{\text{TIME CHANNEL IN USE}}{\text{RUNNING TIME OF PROBLEM}}$$

NOTE
PROBLEM INPUT — 34 AIRCRAFT PER HOUR

LEGEND

EAST SECTOR   WEST SECTOR

FIG 10 COMMUNICATIONS CHANNEL LOADING

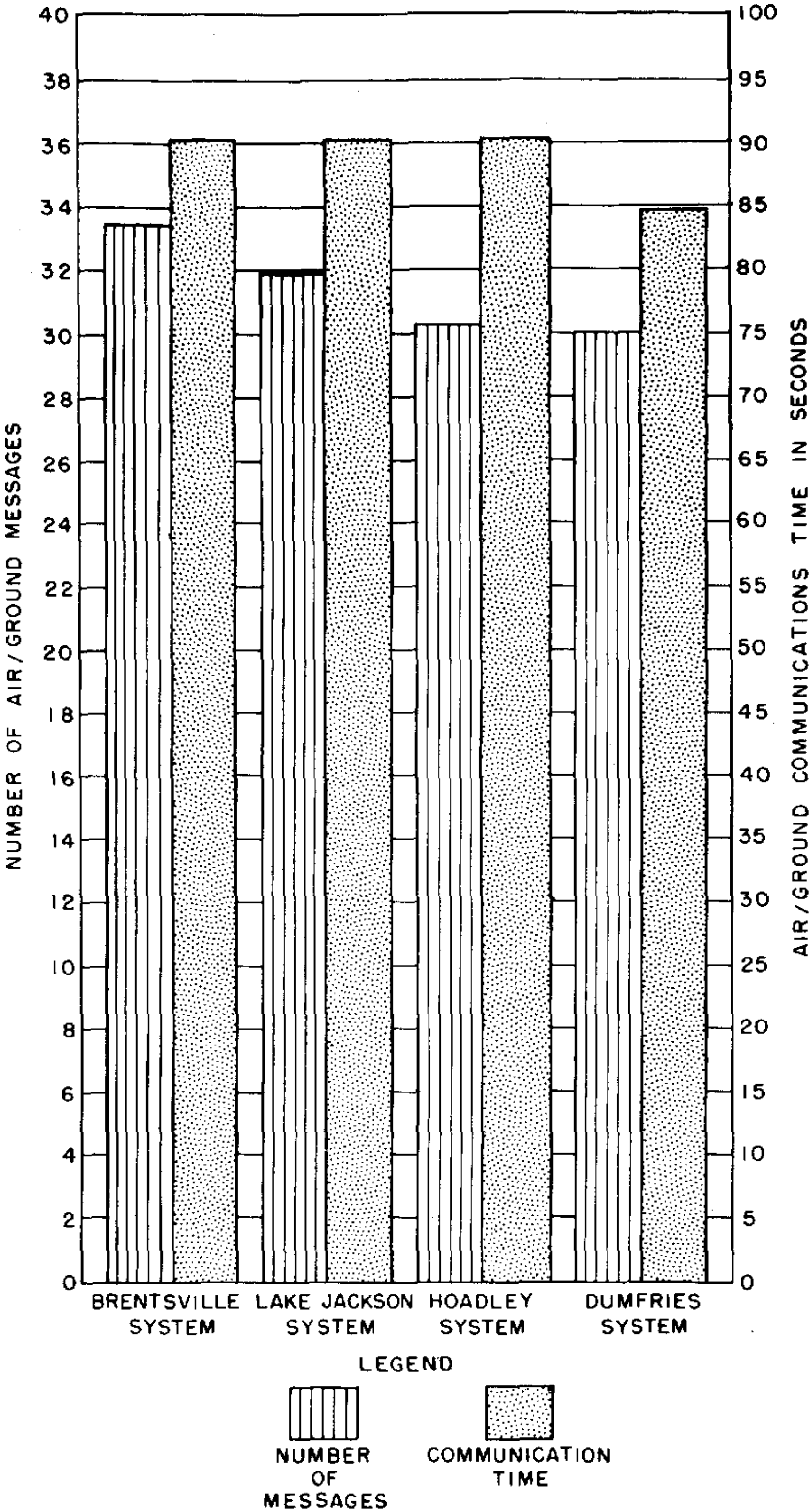
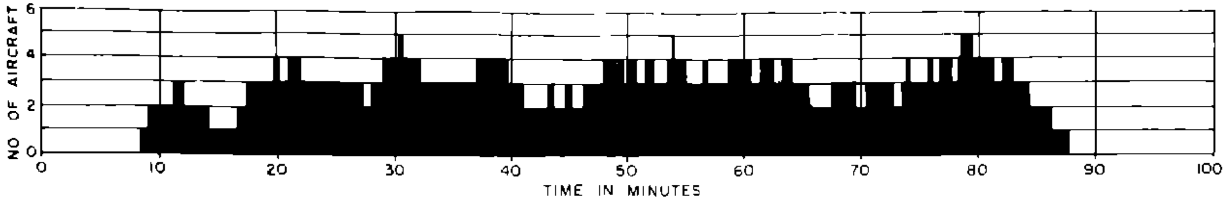
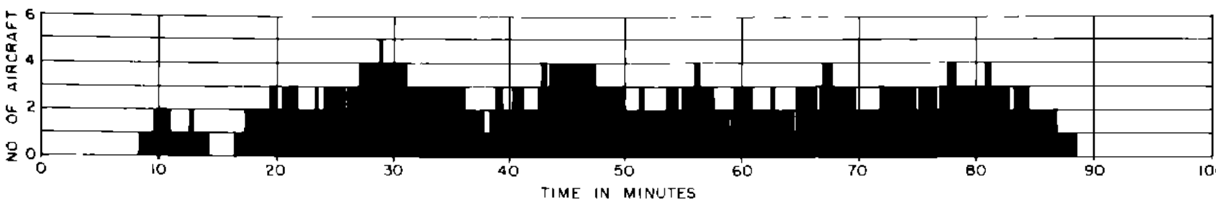


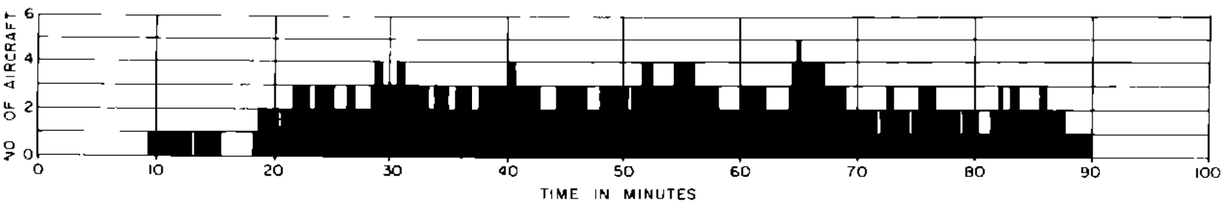
FIG. 11 AVERAGE COMMUNICATIONS REQUIRED PER ARRIVING AIRCRAFT



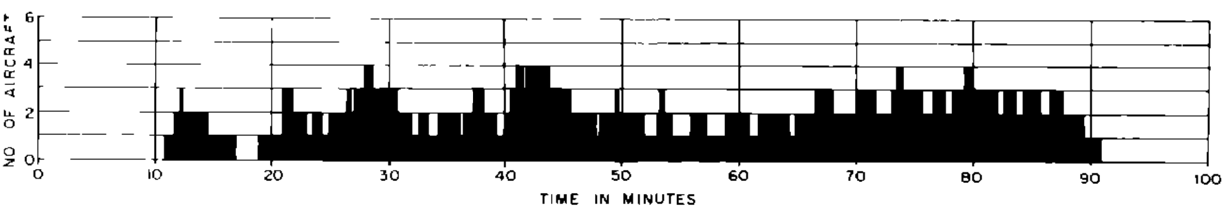
BRENTSVILLE SYSTEM—RUN NO 9



LAKE JACKSON SYSTEM—RUN NO 2



HOADLEY SYSTEM—RUN NO 2



DUMFRIES SYSTEM—RUN NO 2

NOTE

GRAPHICAL ANALYSIS OF ONE TYPICAL RUN FROM EACH OF FOUR SYSTEMS TESTED SHOWING THE NUMBER OF AIRCRAFT UNDER SIMULTANEOUS RADAR NAVIGATIONAL GUIDANCE ENROUTE BETWEEN THE HOLDING FIXES AND THE OUTER MARKER

FIG 12 RADAR NAVIGATIONAL WORKLOAD