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SIMULATION TESTS OF PROPOSED ATC PROCEDURES APPLICABLE TO FUTURE OPERATIONS IN THE WASHINGTON TERMINAL AREA

FOR LIMITED DISTRIBUTION

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SUMMARY

This report describes a simulation study of air traffic control procedures, routes, and airport configurations applicable to future use in the Washington terminal area after the proposed Washington Chantilly Airport is commissioned and civil jet aircraft are in regular operation. This study was conducted through the use of the dynamic air traffic control simulator at the FAA Technical Development Center.

Tests indicated that the use of a common IFR room, to handle all arrival and departure operations in the Washington terminal area, offered a number of advantages over the separate approach control facilities presently in use. Other tests showed that the runway configuration originally proposed for Chantilly Airport by the former Airways Modernization Board offered no measurable advantages, from an air traffic control veiwpoint, over the layout developed originally by the former CAA Office of Airports. Additional tests were conducted to develop a new parallel airway configuration to serve all major airports in the Washington terminal area as independently as possible. Other changes were made to improve the handling of military jet arrivals and departures at Andrews Air Force Base.

INTRODUCTION

The eventual need for a supplemental airport to handle increasing civil air traffic in the Washington terminal area had received serious consideration by the CAA and FAA ever since the Washington National Airport began operations in 1940. Numerous simulation studies were completed at the Technical Development Center (TDC), Indianapolis, Ind., to evaluate the possible use of proposed airport sites at Andrews, Burke, Baltimore, Belmont Bay, and Chantilly.[1 2 3 4] As a result of these studies, the Chantilly site finally was selected, and funds were appropriated by the Congress to start construction of the Chantilly Airport.

In July 1958, an additional simulation study was requested by the CAA Office of Air Traffic Control (OATC) in order to resolve a number of problems relative to airway layouts and control procedures for future operation of the Washington terminal area. At a preliminary conference of OATC, Region 1, Andrews Air Force Base (AFB), and TDC personnel, the project objectives and terms of reference were drawn up. Four weeks was spent in the development of new route layouts and procedures prior to the start of the simulation tests on August 18, 1958.

OBJECTIVES

The primary object of this project was to develop routes and control procedures for the Washington terminal area, including the proposed Chantilly Airport, to meet the following system requirements:

1. Maximum over-all traffic capacity for the various airports in the area.

2. Minimum interference between traffic flows at adjacent airports, with complete independence of Baltimore Friendship from other airports in the Washington complex.

[1] C. M. Anderson, F. S. McKnight, T. K. Vickers, and M. H. Yost, "Preliminary Study of Traffic Control Systems for the Proposed 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 Baltimore Friendship Airport at Increased Traffic Densities," Technical Development Report No. 316, July 1957.

[4] T. E. Armour, D. S. Schlots, T. K. Vickers, and Roger S. Miller, "Air Traffic simulation Tests of Three Proposed Sites for the Washington Supplemental Airport," Technical Development Report No. 332, November 1957.

3. Simplicity of control procedures, with a minimum of coordination, communication, and other control workload.

4. Maximum adaptability to presently installed navigation aids. However, relocation, deletion, or addition of specific aids would be considered where desirable.

5. Maximum flexibility. A change in the direction of landing at any airport should have a minimum effect on sector jurisdiction or clearance procedures.

6. Capability of continuous safe operation during periods when radar is inoperative.

7. Provision for expeditious jet operations in and out of Chantilly Airport and Andrews AFB, including the use of a new approach procedure from the northeast into Andrews.

In conjunction with item 3, above, considerable study was given to the concept of combining various control agency functions in a common IFR room.

A secondary objective of this study was to determine the relative advantages of a runway alignment and configuration proposed by Airways Modernization Board (AMB) representatives, in lieu of the original layout developed by the CAA Office of Airports for the Chantilly Airport.

ASSUMPTIONS

The following assumptions were made in the conduct of this study:

1. Bolling and Anacostia Airports. It was assumed that Bolling AFB and Anacostia Naval Air Station (NAS) would be deactivated in 1961, and that their flight activities would be transferred to Andrews AFB, increasing the number of Andrews operations to approximately 350,000 per year. It was assumed that Andrews would require an IFR capacity of 40 operations per hour, with a ratio of three jet operations for every two operations of propeller-driven (prop) aircraft. Approaches would be made to either Runway 1 or 19, using ILS approach to Runway 1 or GCA or TVOR approach to Runway 19.

2. Washington National Airport. It was assumed that Washington National Airport would be used, at the present operational rate, by prop aircraft only. The ILS system would continue to be used for a north approach to Runway 36 and the Georgetown MH facility would be used for a southeast approach to Runway 15.

3. Davison Army Airport. It was assumed that Davison Army Air Field (AAF) at Fort Belvoir, Va., would operate with prop aircraft and would generate approximately five operations per hour. TVOR, ADF, or GCA would be used for northwest approaches to Runway 32 and GCA for a southeast approach to Runway 14.

4. Chantilly Airport. It was assumed that at least 60 per cent of the traffic landing at Chantilly Airport would be civil jets and prop jets. The anticipated traffic density would be comparable to the arrival and departure rates at National Airport. Runway 18-36 would be the primary ILS runway. Available wind data indicate that IFR operations would be predominantly north.

5. Restricted Areas. It was assumed that a portion of restricted area R-38, which is presently available for flight operations most of the time, still would be available for use in any airway configuration considered in these tests. This includes the portion of R-38 lying north of a line 5 statute miles south of, and parallel to, a line connecting the Quantico range station and the Charlotte Hall homing facility. Recognition was given to the following restricted areas during the terminal area tests: (1) R-35, Chesapeake Bay; (2) R-37, Quantico; and (3) R-40, AP Hill.

6. Civil Jet Procedures. Previous simulation studies had shown that a marked improvement in airport acceptance rates could be achieved if jet aircraft could be descended en route so as to start their approaches from close-in, low-altitude, feeder points instead of from high-altitude holding patterns. Therefore, it was assumed that the approach procedures for civil jets would conform to those used presently for prop aircraft.[5] During the simulation tests described in this report, all jet aircraft turns were made at the rate of 1 1/2° per second instead of the standard rate of 3° per second used by other aircraft.

7. Separation Standards. With the exception of certain dual-approach tests run in conjunction with the AMB airport configuration study, all simulation tests in this program utilized present separation standards as set forth in the ANC and Radar ATC Procedure Manuals. Present 10-mile airway widths and current TSO-N20A holding airspace criteria were utilized throughout the test program.

8. Electronic Aids and Facilities. It was assumed that adequate communications and radar coverage would be available throughout the area under consideration. All en route navigation was based on VORTAC, rather than LF, facilities.

TERMINAL AREA EVALUATION METHODS

The first phase of the test program was devoted exclusively to terminal area operations, with the objective of developing the best possible approach and departure routes and control procedures for Chantilly,

[5]Paul T. Astholz and Tirey K. Vickers, "A Preliminary Report on the Simulation of Proposed ATC Procedures for Civil Jet Aircraft," Technical Development Report No. 352, December 1958.

National, and Andrews. Comparisons of separate and common IFR room operations were conducted. As a result of this phase, additional studies were made to develop several revised systems for use in the en route tests.

Abbreviations used on simulation maps are listed in Table I. Details of the traffic sample used in the terminal area phase are listed in Tables II and III.

Because of limitations in the number of available personnel and simulator targets, it was not possible to simulate all operations at all airports simultaneously. As a result, various tests included all departures from all airports or all arrivals to all airports. Other tests included all arrivals and departures at a maximum of two airports at a time.

Airport acceptance rates and communications data were recorded for use in comparing the performance of the various systems. Communications for each sector included complete control instructions, weather data, pilot reports, and acknowledgements. Test results are summarized in Figs. 1, 2, and 3.

TERMINAL AREA TEST PROCEDURES

System A.

This system was suggested by the Office of Air Traffic Control. In tests of this system, it was assumed that Chantilly, National, and Andrews had separate approach control facilities.

North Operations. See Fig. 4.

Inbound traffic for Chantilly was cleared to Ashburn, Casanova, and McLean. Two approach controllers vectored arrivals to the south outer marker for ILS approaches.

Inbound traffic for National was cleared to Springfield and Riverdale. The Springfield holding pattern was aligned in a north-south direction to provide additional clearance from the east vector pattern at Chantilly. Two approach controllers vectored arrivals to the outer marker for ILS approaches. The Springfield controller also controlled arrivals into Davison.

Inbound propeller-driven aircraft destined for Andrews were cleared initially to Pit. Jet arrivals were cleared to Brooke and Patuxent River. In the initial tests, only 12 Andrews arrivals per hour were included. One Andrews approach controller was able to handle this load satisfactorily. Under heavy traffic conditions, it would have been desirable to use one approach controller for prop traffic and an additional approach controller for jet traffic.

South Operations. See Fig. 5.

Casanova was not used as a primary feeder fix for Chantilly when operations were shifted from north to south. Ashburn and McLean continued in use, with an approach controller handling each sector, vectoring arrivals to the north outer marker for ILS approaches.

Springfield and Riverdale continued in use for south operations at National, with one approach controller handling each fix, vectoring arrivals to Georgetown for southeast approaches to Runway 15.

Chestertown replaced Brooke, and was used in conjunction with Patuxent as a feeder fix for jet penetrations into Andrews. Pit continued in use as a feeder fix for prop aircraft.

System B.

North Operations. See Fig. 6.

In the initial tests of this system, inbound traffic for Chantilly was cleared to Ashburn and Linden, with two approach controllers vectoring traffic in the area west of the ILS course to the south outer marker for ILS approaches. This arrangement produced a very inefficient and confusing radar operation, which soon was changed. The north outer marker was substituted in place of Ashburn, and the area east of the ILS course utilized for this flow. This change improved the traffic picture somewhat by making the two radar vector patterns essentially independent of each other. However, the east pattern still was too long for efficient operations.

Woodbridge and Riverdale were used as feeder fixes for National arrivals, with one approach controller handling each fix, vectoring arrivals to the outer marker for ILS approaches.

Andrews operations were virtually unchanged from the arrangement used with System A. Pit was used for prop arrivals, and Brooke and Patuxent for jets.

South Operations. See Fig. 7.

For inbound traffic to Chantilly, Ashburn and Linden were used as feeder fixes. In this case, Ashburn blocked the Linden vector path, producing the same sort of inefficient arrangement which was encountered in the initial north operation. This procedure created a high coordination workload and reduced the capacity of the system virtually to that of a single-fix operation.

At National, Springfield was used as the west feeder fix instead of Woodbridge. Riverdale remained in use as the east feeder fix. One approach controller handled each fix, vectoring arrivals to Georgetown in an arrangement practically identical to that used in System A.

Andrews continued to operate with the same feeder fixes which were used for north operations. The jet penetration path from Brooke was 60 miles in length, much too long for efficient operations.

System C.

This system incorporated proposals of the Planning and Procedures personnel of Region 1. Control was conducted from five ASR indicators during most of this test. Later, a superimposed panoramic radar display (SPANRAD) was used to test the feasibility of combining National and Andrews in a joint approach control facility.

North Operations. See Fig. 8.

Inbound traffic for Chantilly was cleared to Linden and Remington, with one approach controller handling each fix, vectoring aircraft to the south outer marker for ILS approaches. Although both patterns fed into the ILS from the same side of the ILS course, the system was an improvement over the initial arrangement used in System B in that the traffic from one pattern did not have to go through the other pattern to reach the final approach course. This arrangement, while not as efficient as an ideal twin-feed system blending traffic from both sides of the ILS course, had the advantage of opening up a large area east of the ILS course for the use of departure traffic.

Inbound traffic for National was cleared to Woodbridge and Andrews south outer marker. One approach controller handled each fix, and vectored arrivals to the National outer marker for ILS approaches.

Prop aircraft bound for Andrews were cleared to Huntingtown. Jet aircraft used Brooke and Patuxent as feeder fixes. Care had to be taken, particularly with Brooke approaches, to make sure that Andrews arrivals had altitude separation from National arrivals in the vicinity of the Andrews outer marker.

South Operations.

System C was not tested for south operations.

System D.

This system was developed as a result of previous tests on Systems A, B, and C.

North Operations. See Fig. 9.

Arrivals. Inbound traffic for Chantilly was cleared to Arcola and Core. One approach controller handled each fix, and vectored aircraft to the south outer marker for ILS approaches.

Inbound traffic for National was cleared to Springfield and Riverdale. One approach controller handled each fix, and vectored arrivals to the outer marker for ILS approaches.

Andrews prop arrivals were cleared to Potomac and Pit. Jet arrivals were cleared to Brooke and Patuxent. One prop approach controller and one jet approach controller vectored aircraft to the south outer marker for ILS approaches.

Departures. Northwestbound departures from Chantilly had an unrestricted climb route to Dawsonville. Southwestbound departures tunneled under the Arcola stack before proceeding on course to Casanova or Locust Grove. Northeastbound departures tunneled under the inbound route north of Core and subsequently were integrated with National departures on a common route to Westminster.

The climb of southbound National departures was restricted until the aircraft were well clear of Springfield and in many cases, until passing Quantico. Any operation at Davison complicated the use of this route further. National westbound departures via Herndon were provided one altitude beneath Core arrivals and above Chantilly departures. National's northbound departures climbed unrestricted, and the northeastbound departures were tunneled beneath the arrival route north of Riverdale.

Andrews south, southeast, and southwestbound departures, via Patuxent or Meekins Neck, were tunneled until well past Pit. Departures via Baltimore and Chestertown had no restrictions. Westbound prop departures were routed via Georgetown and were integratedd with National departures on a common route to Herndon, necessitating a lengthy restriction at low altitude.

South Operations. See Fig. 10.

Arrivals. Inbound traffic to Chantilly from the west and south was cleared to Arcola. The east feeder fix was moved from Core to Boyds in order to open up an unrestricted departure route to New York. One approach controller handled each feeder fix (Arcola and Boyds), and vectored aircraft to the north outer marker for ILS approaches.

Inbound traffic to National was cleared to Springfield and Riverdale. One approach controller handled each fix, and vectored arrivals to Georgetown for approaches to Runway 15.

Andrews jet penetrations were started from Chestertown instead of Brooke. All other fixes were the same as those used for the north operation, although Potomac became a secondary, rather than a primary, feeder fix. One approach controller handled prop operations; another handled jet operations.

Departures. Departures from Chantilly generally had unrestricted climbs on course, except for a brief tunnel to stay under westbound National departures in the vicinity of the south outer marker.

Westbound and southbound departures from National had to tunnel under the Springfield stack. Once clear of that area, they had unrestricted climbs on course. Northeastbound National departures tunneled under the Riverdale stack at 3,000 and then had unrestricted climb to Baltimore.

Andrews departures tunneled under the Pit stack and then had unrestricted climbs to the northeast or southeast. Westbound Andrews departures normally were cleared to climb southeast of Pit to an altitude 1,000 feet above any terminal area traffic before proceeding back across the terminal area on course. It was assumed that all jet scrambles from Andrews took off north and climbed on an east heading toward Cordova.

System E.

Concept.

The operation of a multiairport terminal area primarily is a distribution problem in that the total input of arriving aircraft, coming from all directions, must be distributed to the various airports in such a manner that each aircraft arrives at its desired destination. Similarly, the total output of departures from the various airports must be distributed to the various routes in such a manner that each aircraft ultimately proceeds toward its desired destination. Since, in either case, there is not necessarily any correlation between the direction of the route and the location of the terminal airport within the terminal complex, a large amount of crossfeeding or circuitous routing is inevitable. One possible way of improving operational efficiency is to develop a route layout which simplifies the crossfeeding problems.

System E represents an attempt to handle the distribution of arrivals by providing a means of crossfeeding individual aircraft across the center of the area to their desired destinations. For all arrivals except military jets the feeding system consist of four outer fixes and a center fix, arranged schematically as shown in Fig. 11. During the simulation tests, the crossfeeding function was handled by a coordinating controller, who accepted control of arriving aircraft at the four outer fixes and fed individual aircraft across the terminal area as necessary to proceed to the appropriate feeder fix, where the aircraft was handed off to the approach controller. In this system, point-to-point navigation across the area was accomplished by the pilot.

In some cases, the coordinator had three choices of operation from an outer fix. This can best be illustrated by defining the choices of action available for an aircraft at Lisbon en route to Chantilly during north operations.

1. Aircraft were cleared over Core with a radar handoff being made with the Chantilly east arrival controller.

2. Arrivals were handed off at Lisbon, from which point the Chantilly east controller vectored the aircraft on the downwind leg east of the airport.

3. Handoffs were made to the Chantilly west arrival controller when arrivals reached Lisbon, and the radar vector was accomplished on the west side of the airport.

This flexibility allowed the coördinator to maintain an even balance of traffic between the two Chantilly arrival controllers. It was necessary for arrival controllers to keep the coordinator advised when an altitude was available at the holding fixes. During the final simulation tests, a frontal passage and change of landing direction was simulated. The three major airports started the problem with arrivals and departures landing and taking off to the south. Chantilly then switched to a north operation. Approximately 20 minutes later, National changed to a north operation; within another 10 minutes, Andrews also made a change to north operations. Before completion of the problem, operations at Chantilly reverted back to south operations while National and Andrews continued with south operations.

North Operations. See Fig. 11.
Arrivals.

Chantilly: Arrivals from Stafford and Lisbon were vectored direct to the final approach course. Traffic from Largo was recleared to Core and normally was changed to the Chantilly arrival controller as the flight approached Core. Three options, previously described, were available from Lisbon.

National: Largo and Stafford traffic was vectored direct to intercept the ILS course. Linden arrivals proceeded to Core where a radar handoff was accomplished. Inbounds from Lisbon were recleared to Core or Georgetown, and radar handoff was made to one of the National controllers. From Georgetown, the aircraft could be handed off to either the east or west controller for the final vector.

Andrews: The majority of prop aircraft destined for Andrews were routed to Largo or Stafford, from which points the Andrews controller vectored arrivals direct to the final approach course. However, when it became necessary for an Andrews arrival to be cleared to either Linden or Lisbon, crossfeeding over Core was utilized with a radar handoff. Jet penetrations were made from Brooke and Patuxent.

Departures.

Due to a shortage of personnel, departure control for the three major airports was divided between two controllers. In actual operations, it is probable that four controllers would be required to handle this function. Many of the departure routes were used jointly by National and Andrews; therefore, departure control was divided and assigned by routes rather than by airports.

The west departure controller was responsible for all aircraft departing from Chantilly. In addition, he controlled the two routes from Georgetown over Lisbon and Dawsonville. The control of the remaining routes was the responsibility of the east controller.

The jet scramble route east of Andrews was used for prop aircraft departures as well as for scramble departures. High-performance aircraft departing in a westerly direction also used the jet scramble route as a departure route, climbing to 1,000 feet above the highest altitude in use within the terminal area. Upon reaching such altitude, aircraft reversed course and proceeded directly on course.

South Operations. See Fig. 12.
Arrivals.

Chantilly: Radar vectors were made from Lisbon and Linden to the final approach course. Arrivals from over Largo were recleared to Core and a radar handoff was made between the coordinator and the Chantilly arrival controller. Aircraft cleared to Stafford were recleared to Core by the coordinating position and then handed off to the Chantilly arrival controller. Traffic and workload permitting, an optional procedure allowed a handoff at Stafford without reclearance to Core. When the Chantilly arrival controller assumed control of an arrival at Stafford, he had the choice of vectoring the aircraft direct to final approach course or reclearing it from Stafford direct to the south outer marker and then vectoring to the final apporach course.

National. Vectors to final approach course were made directly from Largo and Lisbon. Arrivals from over Stafford and Linden were crossfed over the Core VOR.

Andrews: Andrews arrivals were handled in the same manner as in north operations.

Departures.

All departures during the south operations were controlled by the same procedures as during north operations. Departures from Chantilly were required to make a right turn after takeoff and were vectored to the preferential outbound airways.

Westbound high-performance aircraft departing from Andrews made their climb on a heading of 090° or direct to Meekins Neck, and then reversed course after reaching the required altitude.

System F. See Figs. 13 and 14.

Dynamic tests of this system were not as extensive as desired, due to the limited simulator time available. However, all phases of System F were tested in different combinations during runs on Systems A, B, D, and E. This system was in fact identical to System E, with the exception of Pit being substituted for the Largo prop stack and Chestertown replacing Brooke when landings were made to the south.

TERMINAL AREA TEST RESULTS

System A.

The locations of Casanova, Ashburn, and McLean were not conducive to close-in, short-path radar vectoring at Chantilly. The alternate use of Ashburn or Casanova, dependent on landing direction, required a change in clearance limit by the Air Route Traffic Control (ARTC) Center whenever a wind-shift occurred. The use of Casanova instead of Ashburn, when landing north at Chantilly, caused a considerable reduction in the acceptance rate.

Identification of targets at Springfield was considered difficult, due to the inability of the Springfield arrival controller to distinguish between arrivals holding south of Springfield and those targets being vectored for a north landing.

Considerable workload was imposed upon the Andrews arrival controller who was required to vector both conventional aircraft and jet arrivals. It was noted that the one conventional feeder-stack at Pit was unable to handle the traffic load being simulated. When switching to south landing operations, the controller workload increased considerably by reason of the extremely long vector path required to move a jet from Brooke to north final approach course. For this reason, subsequent studies of this system included the use of Chestertown as a jet feeder fix when making south landing at Andrews. However, when a wind-shift occurred, it was necessary to continue vectoring those aircraft in the Brooke holding stack until the ARTC Center could change the clearance limit to Chestertown, in order to continue a steady flow of traffic.

System B.

In this system, the use of Linden and Ashburn as feeder stacks for both north and south landings at Chantilly required a crossfeeding of traffic from the two stacks. Heavy controller coordination was necessary. In addition, the acceptance rate was reduced and delays were extensive. Long radar vectors were necessary when vectoring from Linden for a south approach and when vectoring from Ashburn for a north approach.

In subsequent studies, during north operations aircraft were cleared to the Chantilly north ILS O/M instead of Ashburn. This allowed the east arrival controller to vector north arrivals down the east side of the airport instead of crossfeeding from Ashburn below the Linden holding pattern; however, the use of the north O/M did not reduce the length of the radar vector path.

A map study disclosed that it likewise would be possible to eliminate the crossfeeding of Linden traffic below the Ashburn pattern during south operations. Linden traffic could be cleared to the south ILS O/M and then vectored along the east side of the airport. Due to limitations of time, however, this procedure was not tested for south landings at Chantilly.

The use of Woodbridge as a second feeder stack on the west side of National provided a shorter vector path for north arrivals. When Springfield was utilized for both north and south landings, it was necessary to start aircraft on a long downwind leg to establish a usable vector path. In some instances, it was necessary to commence the vectors from the outbound extremity of the Springfield holding pattern rather than at the holding fix.

The use of Woodbridge when landing north enabled the controller to vector directly to a base leg and also to distinguish more positively between his arrival vector traffic and holding traffic in the approach stack. The use of Springfield and Woodbridge as alternate feeder stacks, however, precluded the use of a common clearance limit for all types of operation.

Disadvantages of this system for Andrews were similar to those noted in System A; long radar vectors were necessary from Brooke, when landing south, because of the lack of jet-penetration feeder fix from the northeast. In addition, prop traffic was too heavy to be handled adequately from one conventional holding stack at Pit.

System C.

The location of feeder stacks for Chantilly in this system will enable operations to continue unaltered in the event the present TSO-N20A holding pattern is increased in size. However, this type of feeder system extended the area of maximum coordination from the final approach course to a point along the common base leg, therefore increasing the amount of coordination between the arrival controllers.

The workload imposed upon the National east arrival controller was extremely high. Coordination constantly was at a very high level, inasmuch as the east National controller had to coordinate not only with the west National controller, but also with the Andrews approach controller vectoring conventional-type arrivals from Huntingtown to land at Andrews.

In this system, as in Systems A and B, no provision was made for jet penetrations from the northeast at Andrews. In addition, it was necessary that the Andrews approach controller insure altitude separation at the Andrews L/F range station between his arrivals and aircraft holding at the Andrews range in the event of a missed approach.

System D.

The location of Arcola in System D provided a common feeder fix for both north and south operations and allowed equidistant vectors for landing in either direction.

Because of the proximity of National and Chantilly, it was not possible to establish a common feeder stack on the east side of Chantilly which would function adequately for both north and south landings. McLean was the clearance limit for all arrivals from the north or east. However, when landings were made to the north, the approach controller recleared McLean traffic over to Core, from whence radar vectors were conducted for a north landing.

Tests indicated that a change in the location of the Riverdale east feeder fix was not desirable. However, a revision or relocation of the holding fix on the west side was necessary. The use of Springfield as a common fix for both north and south operations appeared desirable. The only proposed operational change was concerned with the direction of holding at Springfield. In order to provide the easiest vector path to one final approach course, it was advisable to hold north of Springfield when Washington traffic was landing north, and to hold southeast of Springfield when Georgetown approaches were in progress.

This system included Potomac as a second holding stack to handle prop aircraft landing at Andrews. This helped greatly in reducing the overload of traffic using the Pit holding stack, as reflected in tests of Systems A, B, and C. Tests proved that a jet penetration fix from northeast of Andrews was necessary. The use of Chestertown provided quicker and easier access into Andrews when landing to the south.

System E.

Simulation tests indicated that the terminal area controllers' workload was increased slightly using this configuration. This was caused primarily by the longer vector paths utilized between feeder fix and approach gate. However, it was felt that the extra workload would be duly compensated for by the reduction of en route problems and workload. The controllers substantiated this later during tests of en route System II. The inherent flexibility of System E provided a near-automatic balance of traffic between any two controllers who were vectoring to a single ILS. It is important to note that a change of landing direction at any one airport had little effect on the arrival rate at either of the three major airports. The terminal area data, Figs. 1 and 3, show that Andrews had slightly higher delays and slightly lower arrival rates than National or Chantilly, but this was to be expected because of the long jet penetrations.

The Brooke jet penetration again proved too long for efficient operation. Largo was not an ideal prop feeder fix, because of the long vectors when landing north and the difficult identity problems encountered when landing south.

System F.

Following the simulation runs, detailed map studies indicated that the Pit holding pattern was superior to Largo. Inasmuch as Pit and Chestertown had been tested previously in several systems, they were incorporated in System F when landings were made to the south. This system appeared to have many advantages over the previous maps. It provided the capability of a steady flow of arrivals when landing direction changed at any of the three major airports. This flexibility was a great aid to the ARTC Center, since only a small portion of the arrivals required rerouting. As in System E, it was a flexible system with the ability to maintain a balanced flow of traffic among the arrival controllers. The controller opinions indicated that System F probably was the biggest asset to Andrews operations, and was equally as good for National and Chantilly traffic as any of the other systems tested.

EN ROUTE EVALUATION METHODS

Scope and Conduct of Test.

This phase of simulation was concerned primarily with the selection of the most adaptable en route airways structure possible coincident with the existing navigational facilities and any future planning provisions. The en route test studies described herein are divided into two major parts, and will be referred to as System I and System II. System I refers to Maps I and I-A, and System II refers to Maps II and II-A.

Four experienced radar control personnel from the Washington ARTC Center and four radar controllers from the Washington Tower were detailed to TDC for the three weeks' duration of the tests. These controllers simulated en route and terminal radar control operations, using direct communications with the various aircraft. Each controller was teamed with an assistant controller, who handled data posting and landline communications using the flight progress board and the interphone system. Both common IFR room and independent approach control configurations were tested during simulation runs of en route Systems I and II. The simulated en route Center utilized different combinations of two SPANRAD displays, three flight progress boards, and two slant scopes. Typical views of these operations are shown in Figs. 15 and 16.

Traffic Sample.

The traffic sample used for the en route phase of this study contained an input of 318 flights in 100 minutes. The en route study was divided into north and south phases, providing an input of 201 flights in the north phase and 183 flights in the south phase.

The input of 201 flights in the north phase included 107 departures and 94 arrivals. Of the 94 arrivals worked in the test period, 71 flights landed at Chantilly, National, and Andrews. The remaining 23 arrivals landed at the four minor terminals, namely, Davison, Quantico, Glenn L. Martin, and Baltimore Friendship. The arrival load handled in the north study at Chantilly, National, and Andrews averaged 44.3 aircraft per hour.

The input of 183 flights in the south en route study included 104 departures and 79 arrivals. Of the total 79 arrivals worked in the 100-minute period, 59 flights landed at the three major airports. The remaining 20 arrivals landed at the four minor terminals. The total arrival load handled in the south operation at the three major airports averaged 37 aircraft per hour.

Communications Measurements.

Communications data are presented graphically in Fig. 17.

Personnel.

The personnel who participated in the en route tests were experienced radar controllers from the Washington ARTC Center and the

Washington National Tower. From the standpoint of human performance, the results are believed to be indicative of those which could be expected from a typical group of radar controllers.

At the conclusion of the en route tests, a critique was held, and a tape recording was made of all opinions expressed by the controllers who had participated in the tests. The opinions and recommendations expressed were relied upon to a large extent in the final evaluation results.

General Procedures.

In conducting these tests, it was assumed that air route surveillance radar (ARSR) equipment would provide reliable coverage to at least 25,000 feet mean sea level (MSL). Also, it was assumed that radar vector procedures would be used for the following:

1. Sequencing of aircraft en route to holding fixes, and outbound from departure terminals until established on preferential airways.

2. Guiding aircraft from the holding fixes to the final approach course for subsequent ILS approaches.

3. Maintaining longitudinal or lateral separation between departing aircraft and other aircraft until ANC separation is established.

4. Establishing longitudinal separation between arriving aircraft en route to the final approach gate. The spacing chart used is shown in Fig. 18.

The en route airway structure surrounding the Washington terminal area is dependent, to a very high degree, upon the placement of the holding fixes feeding the various airports. Considerable time was spent analyzing the effect the relocation of present navigational aids would have on the over-all traffic flow. A list of location identifiers used for these tests is shown in Table I.

In some tests, both departures and arrivals were restricted to blocked altitude levels. Other tests were made using "odd" altitudes for departures and "even" altitudes for arrivals. Departure routes, tunneled below inbound en route traffic, were tested and evaluated using ANC as well as radar separation.

Every effort was made to develop a flexible traffic system which would not penalize jet airline operations by imposing circuitous routings and restrictions on climb after leaving the terminal airport. Generally, this was accomplished by the use of parallel airways and preferential routings.

Arriving aircraft were controlled through the ARTC airspace and handed off to approach control at the appropriate release point. Prior to takeoff, departures were given short-range clearances based on the use of radar separation, with handoffs being made to the Center as quickly after departure as possible.

EN ROUTE TEST PROCEDURES

System I.

This system, illustrated in Fig. 19, was the original arrival and departure airway system proposed by TDC. No data were obtained from this test due to system saturation long before the problem time had expired. This indicated clearly that alterations in route structure were required before the system could function satisfactorily.

Map I-A, illustrated in Fig. 20, was developed as a result of weaknesses noted in Map I, and from the associated tests of terminal area Systems A, B, C, and D. Ten simulation tests were made on this route structure, for a total operating time of 13 hours 45 minutes. Four of these simulation runs were used for training purposes to familiarize personnel with the operation of equipment used in dynamic simulation tests. The six remaining runs furnished data information for comparative evaluation.

Since an insufficient number of targets were available to run all arrivals and departures, it was necessary to divide the sample problem into "north" and "south" portions. Each portion was tested for both landing directions at the three major airports. In addition, Chantilly operations were switched occasionally from Runway 18 to Runway 36 and back again to simulate changes in wind direction. In all cases, however, allowance was made for the airspace which would have been occupied by other aircraft not being simulated in the particular test.

Initial tests of Map I-A were conducted with all landings and takeoffs to the north. Arrivals were fed to Arcola and Core, from which points they were radar vectored to final approach course for landing on Runway 36-R at Chantilly. The altitudes in the Arcola and Core holding stacks ranged from 3,000 to 7,000 feet and were controlled by Chantilly approach control. Departures took off on either Runway 36-L or Runway 36-R, tunneling at 2,000 feet under the approach stack at Arcola until clear of the holding and vector area before being released to ARTC radar control.

Aircraft landing at National were cleared to the approach stacks at Springfield and/or Riverdale for subsequent vector to a landing on Runway 36. Departures were made from Runway 33, and tunneled beneath arrival traffic proceeding from Manassas to Springfield. Southbound departures were released to Center departure control after passing Stafford.

Prop aircraft landing at Andrews were cleared to Potomac Intersection for a radar vector to the Andrews ILS course, landing on Runway 36. Jet aircraft were cleared to Brooke and Patuxent River for radar vector to the same runway. Departures on Runway 36 were tunneled beneath the holding pattern at Pit and were released to Center departure control after clearing the TSO holding-pattern airspace, and then were allowed to climb unrestricted to Patuxent River or Meekins Neck.

In order to separate jet and prop departures at Andrews, the prop aircraft were vectored via Pit direct to Rock Point. These departures were restricted to altitudes of not above 9,000 feet until reaching Rock Point. Separation between jet penetrations from Patuxent River and departures en route to Rock Point was provided by requiring the jets to maintain at least 10,000 feet until clear of the Rock Point routing and established on the Andrews south ILS course.

Subsequent simulation runs utilized departure routings via Pit, V557, to Patuxent River for both jet and props. Arriving prop aircraft received clearance to Pit from the south via Meekins Neck, V213N, and V544. In addition, this routing also was used for Baltimore arrivals from the south. Baltimore traffic was handed off to the National approach controller at Pit and then was vectored to the final approach course, landing east or southeast at Baltimore.

During this phase, Center operations were conducted from a single SPANRAD. The approach control functions were divided into three separate operations, with an approach controller handling Chantilly, another working National traffic, and a third controller handling Andrews arrivals. The approach controller vectoring traffic into National also handled the arrivals into Davison and the Andrews controller conducted approaches into Quantico.

When simulation of Map I-A was switched to a south arrival and departure operation at the three major airports, the following procedures were used:

Chantilly arrivals from the north were routed via Martinsburg V42 to McLean. Aircraft from the New York area were routed via Pottstown V39 detour, V39 Frederick, and V551 to McLean. From the south and southeast, all aircraft were sent to Flat Rock V155, Gordonsville V39 Linden, direct to Arcola. Arrivals from the west and southwest also converged at Linden en route to Arcola. An alternate arrival route from the west was via St. Thomas V265 detour, V39 Frederick, and V551 to McLean. Approach control assumed jurisdiction at Arcola and McLean, from which they vectored the arrivals to Runway 18-R.

National arrivals from the west and northwest were routed via St. Thomas V265 Westminster, Dayton, and Riverdale. From the northeast, traffic arrived via Westchester V166 V3, Pikesville, Dayton, and Riverdale. From the south and southeast, the aircraft converged on Flat Rock, thence via V555 Manassas, direct to Springfield. Routings from the southwest were via Gordonsville V16, V555 Manassas, direct to Springfield. From Riverdale and Springfield, the aircraft were vectored to Georgetown for landing on Runway 18.

Andrews prop arrivals from the northeast were cleared to Pit via Kenton, V213 and V544. From the south and southeast, they were cleared to Potomac via V157. Traffic from the southwest was routed to Potomac by one of two possible routes, Pinegrove, V540 and V144, and were restricted to 6,000 feet or above until clear of V3. Andrews approach control vectored the props from Pit and Potomac to Runway 18.

Andrews jet arrivals were cleared to either Brooke or Patuxent, descending to 20,000 feet before commencing their penetrations. After completing several runs, landing on Runway 18, Chestertown was used in place of Brooke as a penetration fix.

Chantilly departures were made from Runway 18-L, with tunneling restrictions imposed to Dawsonville, Herndon, and Casanova.

National southbound departures used Runway 18, with a radar vector to Stafford. Northbound, the departures tunneled under Riverdale en route to the Baltimore VOR, thence via V31 to Hanover, or V123 to Port Deposit. Those aircraft headed west were cleared via Hanover and Harrisburg, then turned westbound.

Andrews prop departures used Runway 18, and tunneled under Pit en route to Patuxent or Meekins Neck. This route served aircraft headed west, south, or southeast. Those headed north were tunneled under Pit, and vectored to intercept V123E.

Andrews jet departures also tunneled under Pit, then climbed unrestricted to Patuxent or Cordova. Those jets whose destination lay in a westerly direction climbed via V557 or V16 until clear of other terminal traffic, then reversed course toward Gordonsville or Front Royal.

A system of blocked even and odd altitudes was utilized with Map I-A at points where major traffic flows crossed. Even altitudes of 6,000, 8,000, 10,000 feet, and so forth, were assigned to arrivals on V265 and V39. Odd altitudes of 7,000, 9,000, and 11,000 feet and above, were assigned to Riverdale arrivals on V3 and McLean arrivals via V42. Chantilly departures received short-range clearances to Hanover, via V251 at odd altitudes of 3,000, 5,000, and 7,000 feet and above. National and Andrews northbound departures received short-range clearances at even altitudes of 6,000 feet and above via the Baltimore VOR and LF range. This system of blocked altitudes allowed departure and arrival control to interlace their traffic at Westminster, Detour, Pike, and Hanover.

System II.

This system encompassed tests of an air route structure compatible with terminal area Systems E and F. The area within an 80-nautical-mile radius of the Washington metropolitan terminal area was simulated. Present locations of navigational aids were utilized where practical. However, due to the need for parallel one-way airways, a few facilities were relocated and some new ones added, where necessary. These changes are indicated by comparing the present system, Fig. 21, and the Region 1 master plan, Fig. 22, with System II maps. The airway configurations tested in System II are illustrated in Figs. 23 and 24.

Traffic destined to Chantilly, National, Davision, and Quantico was cleared by the Center to the nearest of the four major terminal feeder fixes. These fixes, located north, east, south, and west of the terminal area, were Lisbon, Pit, Stafford, and Linden. Altitudes used in these holding patterns were 4,000 to 8,000 feet, inclusive.

Prop aircraft landing at Andrews were cleared by the ARTC Center to either Largo or Stafford. Jet arrivals were cleared to Brooke or Patuxent River at a minimum altitude of 20,000 feet, and the jet scramble route always was predicated on a north takeoff, with right turns out, as shown in Figs. 23 and 24.

The ARTC Center utilized Frederick, Shadyside, Brooke, Casanova, and Martinsburg as outer holding fixes at altitudes of 6,000 feet and above. Traffic held at Casanova was recleared to either Stafford or Linden and traffic held at Martinsburg was recleared to either Linden or Lisbon.

Departures were changed to Center radio frequency upon completion of a radar handoff from terminal departure control to ARTC radar control. This handoff was accomplished after all terminal conflictions were resolved. In this phase, the majority of heavily traveled routes were designed to cross prior to the change to ARTC control. In addition, the terminal control facility was responsible for separating traffic until such departures were past the terminal feeder fixes. At this point, several of the routes allowed an unrestricted climb to cruising altitude.

During Phase II tests, Baltimore traffic was handled by the ARTC Center. Departures were controlled until past all possible areas of confliction, and arrivals were controlled as far as the Baltimore VOR.

EN ROUTE TEST RESULTS

System I.

Simulation tests, discussions, and a thorough study of Map I, Fig. 17, disclosed the following weaknesses:

1. The ARTC Center soon was saturated with traffic and reached the point of breakdown.

2. Inter-sector coordination was excessive because of numerous crossing traffic flows.

3. Conflictions occurred regularly at Locust Grove between converging arrival traffic on V16 and V39.

4. Chantilly arrivals via V39 conflicted with National and Andrews departures on V286 just south of Casanova.

5. Andrews westbound departures were penalized unduly by the excessive tunneling distance imposed on them.

To correct the problems noted on Map I, the following changes in airway structure and accompanying procedures were made and are reflected on Map I-A, Fig. 18:

1. V555, between Manassas and Flat Rock, was changed from an outbound to an inbound routing and was utilized by National traffic in place of Chantilly traffic. This provided an unrestricted descent route to Springfield via Manassas.

2. V539, between Arcola and Cumberland, was added to provide a route for Chantilly southbound departures. Aircraft on this route were restricted only with respect to eastbound National and Andrews arrivals, cruising at 6,000 feet or above, on V144.

3. V157, which had been used as a southbound airway from Andrews, was reversed to serve inbound traffic with a route to the Potomac holding pattern.

4. V39 was moved west, in the vicinity of Gordonsville, so as to align the airway parallel with V539.

5. Chantilly southwestbound departures, cleared via Arcola, Casanova and V140, were restricted to altitudes of 5,000 feet or below until clear of V39. Chantilly arrivals, cleared to Arcola via Gordonsville, V39 Linden, were at altitudes of 6,000 feet or above.

Following several simulation runs of Map I-A, it was apparent that the Andrews westbound prop departure route was an unsafe operation because of the long radar vector, and the fact that the props were being cleared into the face of jet penetrations. Rock Point departures subsequently were discontinued, and V557 or V559 was used for both prop and jet departures.

System II.

Simulation tests, discussions, and a thorough study of Map II, Fig. 23, disclosed the following weaknesses:

1. The location of Largo holding pattern was such that misidentification of holding and landing traffic was a fairly common occurrence.

2. There was an insufficient number of airways east of Andrews to handle the programed arrival and departure traffic.

3. Jet penetrations from Brooke to Runway 18 at Andrews were of excessive length, and too much of the penetration path was at low altitudes.

To correct the deficiencies noted on Map II, the following changes in airway structure and accompanying procedures were made on Map II-A, Fig. 24:

1. The Pit VOR was used as an east terminal feeder fix in place of Largo. This move eliminated the confused radar picture north of Andrews that existed when landings were made on Runway 18.

2. V518, between Largo and Woodstown, was determined to be unnecessary and was removed.

3. V44 was extended east of Baltimore to the Kenton VOR, to provide an entrance and exit route for Baltimore traffic.

4. V516, west of Dover, was added so as to provide an Andrews departure route during north operations, and an Andrews penetration route during south operations.

5. V544 connected the Pit holding pattern with Preston to serve prop arrivals from the east.

6. A departure route from Andrews to Meekins Neck was added to facilitate departure routing to the east from both National and Andrews.

7. A fix at Chestertown was established to provide a second jet penetration to Andrews when landing Runway 18. This eliminated the long flight path from Brooke VOR.

Simulation tests that followed the above map changes showed a marked improvement in the ease of handling both Andrews traffic and other aircraft operating to and from the east. Terminal arrival traffic destined for the three major airports was controlled from the common IFR room, utilizing slant scopes as shown in Fig. 25. The arrival coordinator who controlled the traffic distribution by crossfeeding from fix to fix was the IFR room's "kingpin." The successful operation of the common IFR room was due primarily to this position because one supervisor had the traffic picture of all three airports. This reduced the terminal coordination to only that necessary between one arrival supervisor and one departure supervisor. The terminal SPANRAD departure console in shown in Fig. 26.

CHANTILLY AIRPORT TESTS

AMB and CAA Layouts.

A proposed configuration for a tangential runway system at Chantilly was submitted by the Airways Modernization Board for comparison with the layout designed by the CAA Office of Airports. A limited number of tests were run to evaluate several combinations of holding and vector patterns.

Taxi distances and expansion capabilities of the AMB and CAA runway configurations were compared in a map study to determine their relative advantages. Comparative illustrations of the two proposed airport layouts are shown in Fig. 27. The locations of the three primary runways in each proposal are similar. The addition of a fourth runway to each configuration results in a double V runway system when added to the CAA proposal, and in a tangential runway system when added to the AMB proposal.

One of the biggest advantages of the double V system is its adaptability to expansion of terminal facilities, whereas the tangential system, by its basic layout, would form a basic limit to the future expansion of terminal facilities within the confines of the four runways.

The AMB proposal would provide a greater distance between parallel runways and would allow a minimum taxi distance for east and west landings and/or takeoffs.

Dual Approach Operations.

Initial simulation tests were made to determine the capabilities of the AMB runway configuration, utilizing the dual ILS approach systems shown in Figs. 28 and 29. For test purposes, arrivals from the Chantilly traffic sample were doubled to create a total input of 50 aircraft per hour. Departures were restricted to only 12 per hour because of the limited number of targets available. Control was conducted alternately from PPI scopes and a SPANRAD unit. When the SPANRAD was used, comparative tests were made with and without radar tracking identification markers.

Three different control procedures were tested, as described below and illustrated in Fig. 30.

1. Independent Operation. Separation, during ILS approach, was provided only with respect to aircraft in the same lane, and without regard to traffic activities in the opposite lane.

2. Altitude Separation at Turn-On. Normal radar separation was provided between successive aircraft in the same lane. In addition, a 500-foot altitude separation at turn-on was provided between aircraft in opposite approach lanes. This was accomplished by moving the turn-on points at least 5 miles beyond the associated outer marker, and maintaining the 500-foot separation until the aircraft intercepted their respective glide slopes.

3. Longitudinal and Vertical Separation. Normal radar separation was provided between successive aircraft in the same lane. In addition, at least 3 miles' longitudinal separation was established from aircraft in the opposite lane.

System G.

This four-stack system is shown in Fig. 28. For north operations, control was divided between a west arrival controller and east arrival controller. The west controller vectored from Plains and Middleburg to Runway 2-L, and the east controller vectored from Sterling and Manassas to Runway 2-R. The airspace normally used for vectoring is shown in Fig. 28. Departures used Runway 30-L and made a left turn after takeoff. Southbound departures were restricted below the pattern at Middleburg and were radar vectored until clear of the holding pattern at Plains.

For southeast operations, control was divided between a north controller and a south controller. Arrivals to Runway 12-L were vectored from Dawsonville and Boyds by the north controller. The south controller vectored from Plains and Middleburg to Runway 12-R. Vector patterns are illustrated in Fig. 28. Each arrival controller worked independently of the other controller, providing a 500-foot altitude separation at turn-on, as described previously. Northbound departures used Runway 20-L for take-off, made a left turn out, and were tunneled under the Boyds holding pattern.

System H.

As a result of simulation and a subsequent map study of System G, the feeder fixes used in this system were relocated. These changes are illustrated in Fig. 29. The primary reason for making these changes was to test the feasibility of using a common feeder fix to serve approaches for northeast, southeast, and southwest landings. The Arcola holding pattern was altered to conform with the landing runway in use, so that the aircraft was always established on the downwind leg when it was over the fix. Approaches to Runways 20-L and 20-R were not tested, but are illustrated in Fig. 29 to show the possibilities of a common feeder fix. Each ILS was operated as an independent system, with a 500-foot separation at turn-on, until the aircraft were established on the final approach course.

CHANTILLY AIRPORT TEST RESULTS

Runway Alignment.

Tests showed that the slightly different runway alignments of the AMB proposal, about 15° clockwise from the corresponding alignments of the CAA proposal, had very little effect on the flow of terminal area traffic. Any advantage of the additional separation gained from National traffic toward the south was cancelled out by the reduced separation to the north. The original differences in alignments were produced by different interpretations of the same wind rose data.

System G.

Tests of System G showed that the use of four feeder stacks, arranged as shown in Fig. 28, resulted in numerous cases of less than standard radar separation, primarily because the aircraft from one stack had to pass by the other stack on the way to the final approach course. To reduce the number of potential conflicts, altitude separation was maintained between aircraft leaving the two stacks feeding the same runway until the aircraft were inbound on final approach course. This procedure dictated the use of a long, final approach course to provide room for descent. In turn, the additional length of the final approach course required additional separation between successive aircraft to reduce the possibility of overtaking, thus reducing the acceptance rate and thereby defeating the purpose of the additional stack.

The simulation tests showed that when the dual ILS approach paths were fed without providing positive separation between aircraft in opposite lanes, overshoots could produce an extremely hazardous situation. Overshoots were quite common during the initial tests of this system. The subsequent use of a 500-foot altitude separation between turn-ons in opposite lanes functioned very well during the simulation tests in eliminating this hazard.

Tests of the dual approach system using 3 miles' separation between aircraft turning on final approach in opposite lanes indicated that the acceptance rate possible with this procedure was little, if any, better than the acceptance rate of a single ILS approach lane.

System H.

The use of one feeder stack for each runway, as shown in Fig. 29, reduced controller coordination and workload, and released more airspace for the use of departures. The acceptance rate of this system was equal to that attained with the four-stack System F operation.

CONCLUSIONS

It is concluded that:

1. The geographical location of Chantilly necessitates a moderate tunnel distance, a circuitous routing, or an off-course climb to westbound aircraft departing from National and Andrews.

2. The airway structure should be designed to provide at least 60 miles of climb or descent routes that have no major flows of crossing traffic. However, if the required route would entail long, off-course climbs or circuitous routings to accomplish this, the necessary crossing of such traffic should take place within the terminal area instead.

3. Fewer restrictions were imposed on aircraft, and a resulting ease of control was noted, when independent arrival and departure routes were used.

4. Fewer procedural changes and reroutings were required when landing direction was changed if common feeder fixes were used, instead of one set of fixes for north operations and another set for south operations.

5. Simulation tests indicated that an additional jet penetration to Andrews from the northeast, using a fix similar to Chestertown, increased the recovery rate and decreased the penetration time.

6. The jet scramble corridor from Andrews also could be used for routine jet and prop departures when scrambles were not in progress.

7. From the limited Baltimore simulation and subsequent map studies, the controllers' consensus indicated that it would be advantageous to all airports in the metropolitan area if the primary ILS at Baltimore was changed to Runway 15 and the secondary ILS was established on Runway 28.

8. The air route structure, associated with a system of crossfeeding among terminals, needs fewer airways than a structure designed to provide each terminal with an independent set of arrival and departure routes.

9. When Chantilly, National, and Andrews radar approach and departure control functions were combined in a common IFR room, it permitted faster and simpler coordination among controllers, thus making better use of the available airspace than when they were run as separate facilities.

10. Simulation tests indicated that the common IFR room would operate with no increase in control positions and a probable decrease in data positions.

11. The combining of Chantilly, National, and Andrews approach control function in a common IFR room will aid the flow of traffic to and from the Baltimore Airport.

12. The route structure described in System II, Map II-A, lent itself to better "switchability" when the wind changed at any one airport and not the others. This route structure also was better suited to a common IFR room operation than any other system tested.

13. The preferential routings used in System II simplified the air route controllers' problems because of fewer crossing airways. However, it should be noted that the terminal controllers had more crossing routes and longer radar vectors than in System I.

14. Most of the airspace in restricted areas 35, 37, 38, and 40 will be needed in any system to sustain a high-rate traffic flow to and from the Washington area complex.

15. Vertical separation of at least 500 feet at turn-on should be provided between opposite lanes of traffic feeding into a dual approach system.

16. A dual ILS system that requires standard longitudinal separation between aircraft in separate lanes all the way to touchdown is no better than a single ILS system.

17. The CAA double V runway system for Chantilly is more adaptable to future terminal facility expansion than the plan proposed by the AMB.

18. The AMB tangential runway system provides a greater distance between parallel runways. It allows shorter taxi distances when operating on east or west runways, if aircraft always land inbound and take off outbound on the tangent. This advantage is obviated if parallel approaches or departures are used.

19. The selection of either the CAA or AMB proposed runway configuration would result in no appreciable difference in airway structure or potential traffic flow.

20. When utilizing parallel ILS systems, the complexities of vectoring from four feeder fixes obviate any theoretical advantages over the use of only two feeder fixes.

RECOMMENDATIONS

1. If traffic at the three major Washington airports develops as anticipated, common feeder fixes that are usable for either direction of landing should be adopted.

2. If the standard TSO-N20A holding pattern is increased in size, consideration should be given to implementing either terminal Systems B or F, as they both provide adequate room for the increased holding pattern airspace.

3. A system of preferential routes, similar to those tested in System II-A, should be employed in the Washington terminal area.

4. An additional Andrews jet penetration from the northeast, as illustrated in terminal System F, should be implemented.

5. An additional departure route from Andrews should be made available by utilizing the jet scramble corridor for other classes of departing aircraft.

6. That portion of V16 that lies between the Brooke VOR and the Kenton VOR should be abolished. Over traffic that formerly used this airway should be rerouted via V1 or V520.

7. National's airport surveillance radar (ASR) should be remoted to Chantilly Airport and the approach and departure control functions should be combined in a common IFR room. After sufficient operating experience is gained, Andrews' ASR also should be remoted to Chantilly Airport and the three approach departure facilities combined in the common IFR room quarters.

8. If the National and Andrews surveillance radar remoting proves successful, and the establishment of the surrounding airways has progressed sufficiently, consideration should be given to the feasibility of adding Baltimore operations to the common IFR room.

TABLE I

LOCATION IDENTIFIERS

ABU Ashburn VOR Int.
ACX Accomac VOR
ADW Andrews AFB
ANT Antioch VOR*
ARV Arcola LF/R

BAL Baltimore VOR and LF/R
BRV Brooke VOR
BRY Brushy Run VOR
BUL Beulahville VOR*
BYN Boothwyn VOR and LF/R Int.

CAH Charlotte Hall LF/Homer
CCV Cape Charles VOR
CES Chestertown VOR Int.*
CMB Cumberland VOR Int.*
COP Coles Point VOR
COR Cordova VOR*
CSN Casanova VOR

DAA Davison AAF
DAW Dawsonville VOR Int.*
DCA Washington National Airport
DOV Dover LF/Homer
DPT Dupont LF/R Int.
DUR Detour VOR*

EMI Westminster VOR
ENO Kenton VOR
ESR Westchester VOR

FAK Flat Rock VOR
FDK Frederick VOR Int.
FRR Front Royal VOR and LF/R
FTS Flint Stone VOR and LF/R Int.

GAP Gap VOR Int.*
GRV Grantsville VOR
GTN Georgetown LF/Homer
GTO Grottoes VOR Int.*
GVE Gordonsville VOR

HAN Hanover VOR Int.
HAR Harrisburg VOR and LF/R
HGR Hagerstown VOR Int.
HNT Huntingtown LF/Homer
HPW Hopewell VOR
HRN Herndon VOR Int.
HTY Hartly LF/R Int.

ILG Wilmington LF/R

JST Johnstown VOR and LF/Homer

KEL Kelton VOR Int.*
KES Kessel VOR*
KEY Keyser VOR Int.*
KMR Keymer VOR Int.*

LDS Leedstown VOR Int.*
LFI Langley AFB LF/R
LGO Largo VOR *
LIN Linden VOR*
LRP Lancaster LF/Homer
LSO Lisbon VOR Int.
LYH Lynchburg VOR

MAN Manassas VOR Int.*
MDB Middleburg VOR Int.*
MIS Mission VOR Int.*
MKD Meekins Neck VOR Int.
MLN McLean VOR Int.*
MNV Manakin LF/Homer
MOL Montelbello VOR
MRB Martinsburg VOR
MTN Glenn Martin Airport

NHK Patuxent River VOR
NRS Norris VOR Int.*
NYG Quantico LF/R

OOD Woodstown VOR
ORE Core VOR*

PDP Port Deposit VOR Int.*
PGV Pinegrove VOR
PHL Philadelphia LF/R
PIK Pikesville VOR Int.*
PIT Pit VOR*
PLS Plains VOR Int.*
POM Potomac VOR Int.*
PRI Price VOR Int.*
PRL Parnell Int.*
PRN Preston Int.*
PTG Petersburg VOR Int.
PTW Pottstown VOR

QRY Quarry VOR Int.*

TABLE I (continued)

LOCATION IDENTIFIERS

REV Remington VOR Int.
RIC Richmond VOR
RLY Relay VOR Int.
ROH Round Hill VOR*
RVD Riverdale LF/Homer

SBY Salisbury VOR
SHS Sharps VOR Int.*
SHZ Shadyside LF/Homer
SLM Sugar Loaf VOR Int.*
SPD Sheppards VOR Int.*
SRI Springfield LF/Homer
STF Stafford VOR Int.*
STG Sterling VOR Int.*
SXO Shenandoah LF/R Int.

THO St. Thomas VOR*
TPP Tappahannock VOR and LF/R

WDB Woodbridge VOR Int.*
WLA Washington Chantilly Airport

XBW Brightwood VOR Int.*
XDA Dayton VOR Int.*
XLG Locust Grove VOR Int.*

*Denotes unofficial designator.

TABLE II

TERMINAL AREA TRAFFIC DIRECTION SUMMARY

To - From	Per Cent of Total Traffic into Washington Area
Southwest	20
South	10
West	15
Northwest	15
North	5
Northeast	35
	100

TABLE III

EN ROUTE TRAFFIC DISTRIBUTION SUMMARY

Airport	NE A	NE D	N A	N D	NW A	NW D	W A	W D	SW A	SW D	S A	S D	Total
Andrews AFB	8	8	2	2	4	4	4	4	4	4	3	3	50
Washington National	9	9	1	1	4	4	4	4	5	5	2	2	50
Chantilly	9	9	1	1	4	4	4	4	5	5	2	2	50
Baltimore	-	-	-	-	-	-	3	3	3	3	3	3	18
Davison Army	1	1	-	-	1	1	1	1	1	1	-	-	8
Quantico NAS	1	1	-	-	-	-	-	-	-	-	-	-	2
Glenn L. Martin	1	1	1	1	-	-	-	-	-	-	-	-	4
	29	29	5	5	13	13	16	16	18	18	10	10	

Total Arrivals - 91

Total Departures - 91

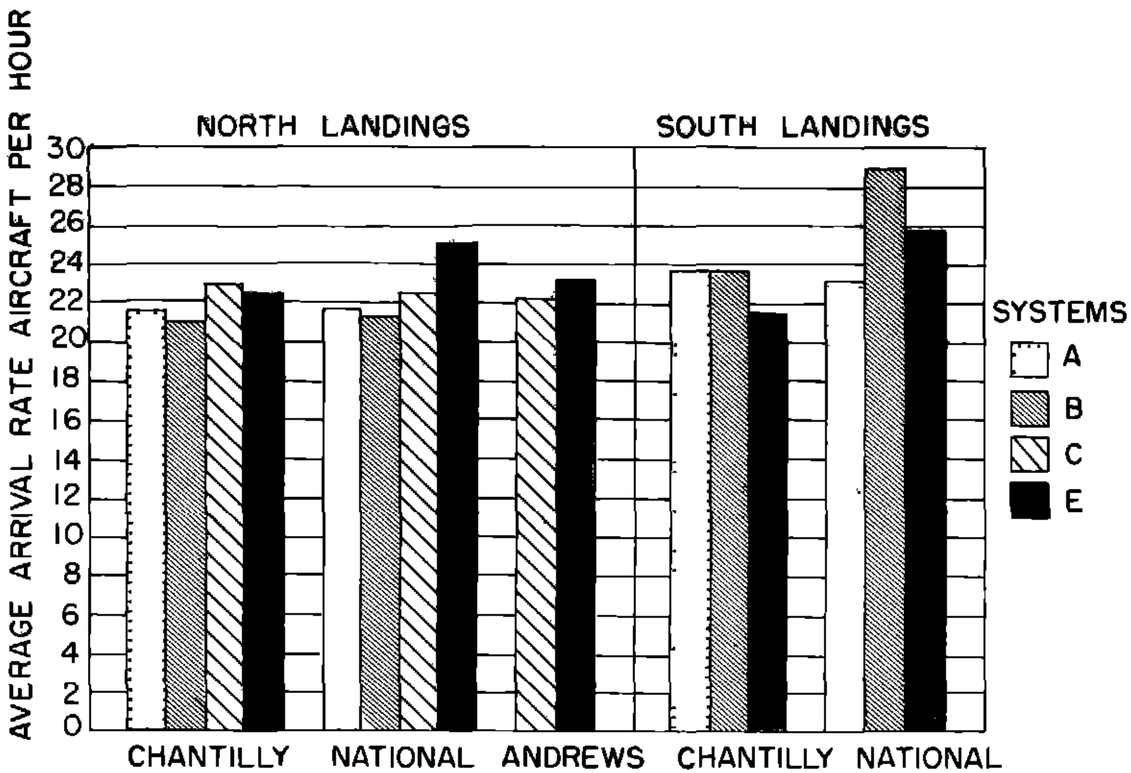


FIG I ARRIVAL RATES— TERMINAL AREA TESTS

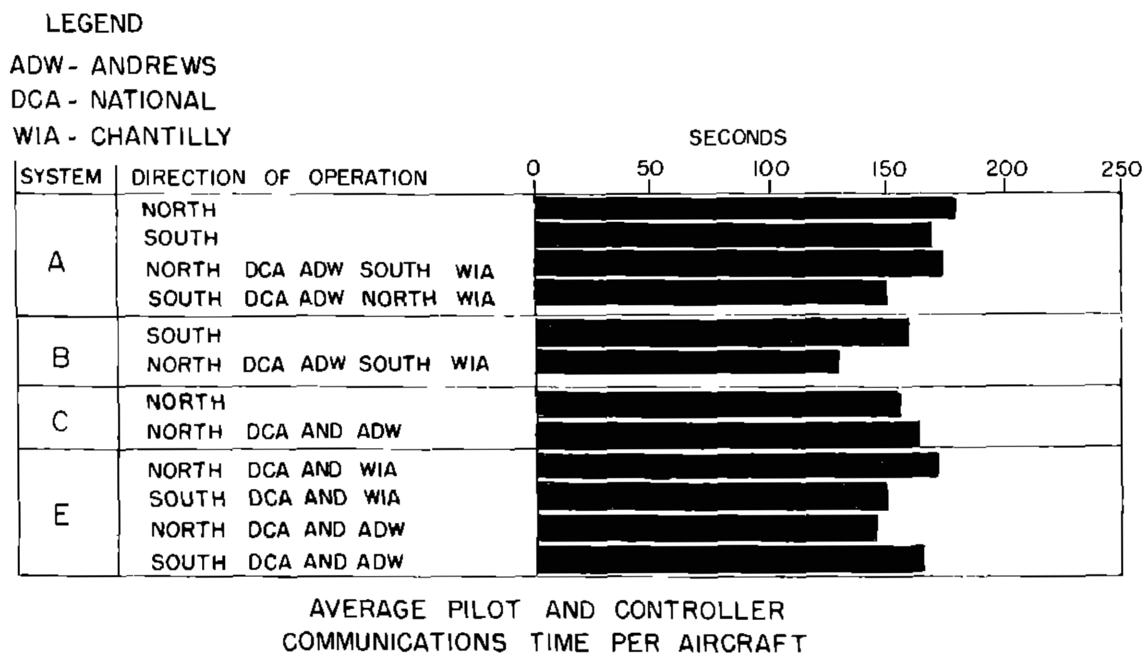


FIG 2 TERMINAL AREA COMMUNICATIONS

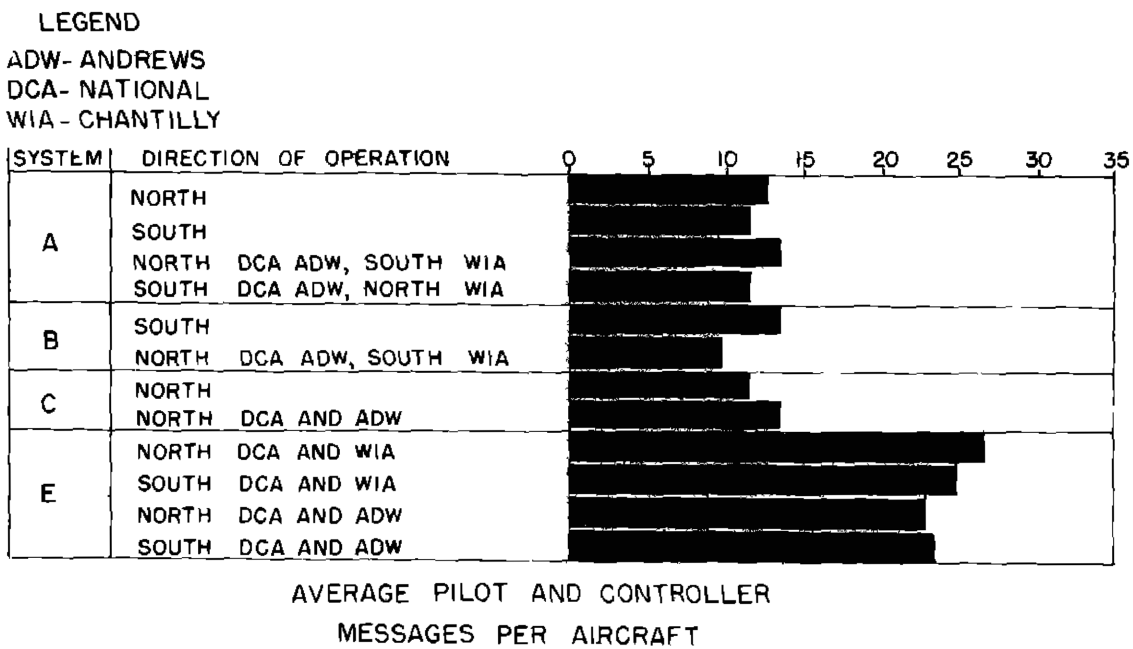


FIG 3 TERMINAL AREA CONTROL MESSAGES

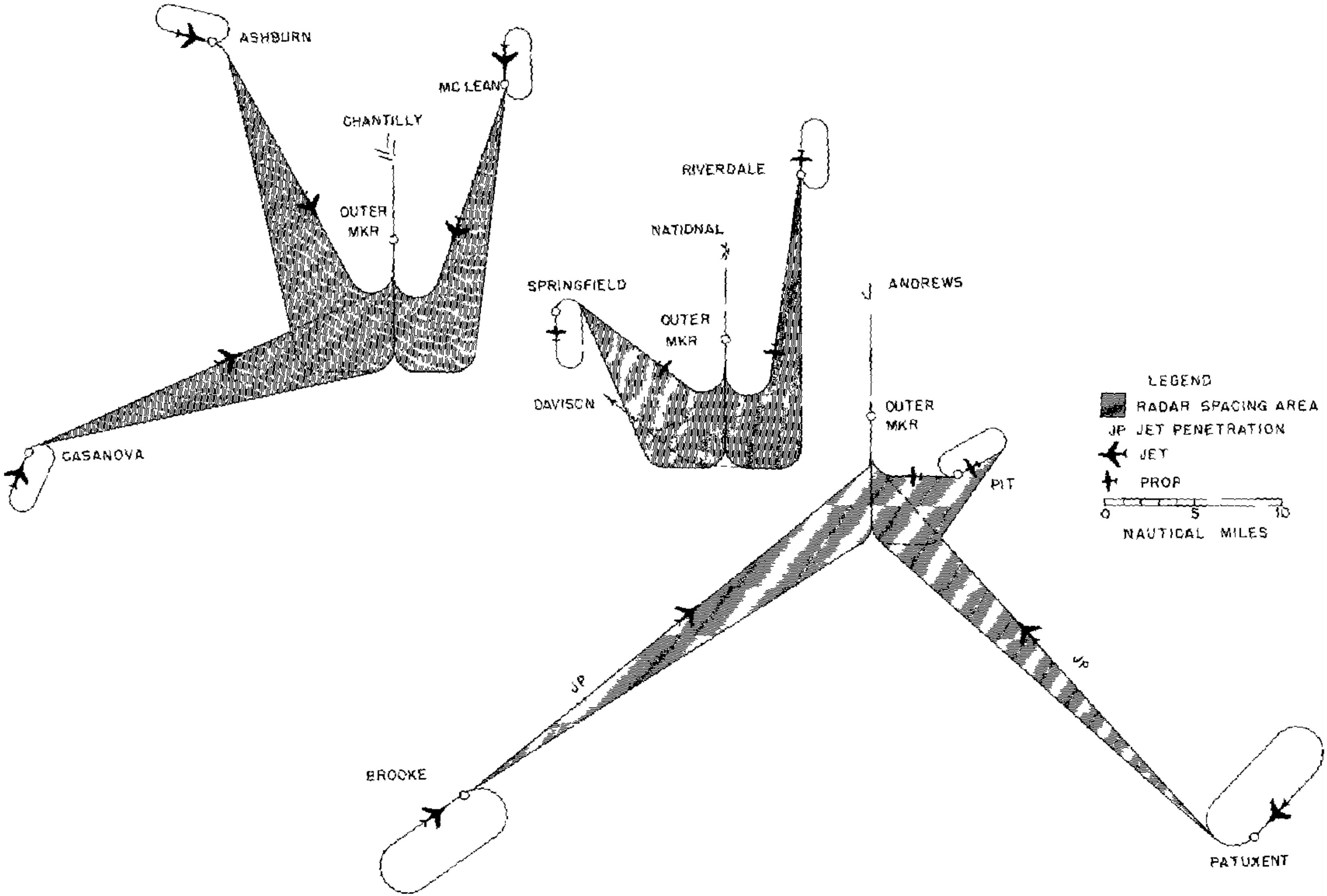


FIG 4 SYSTEM A NORTH OPERATIONS

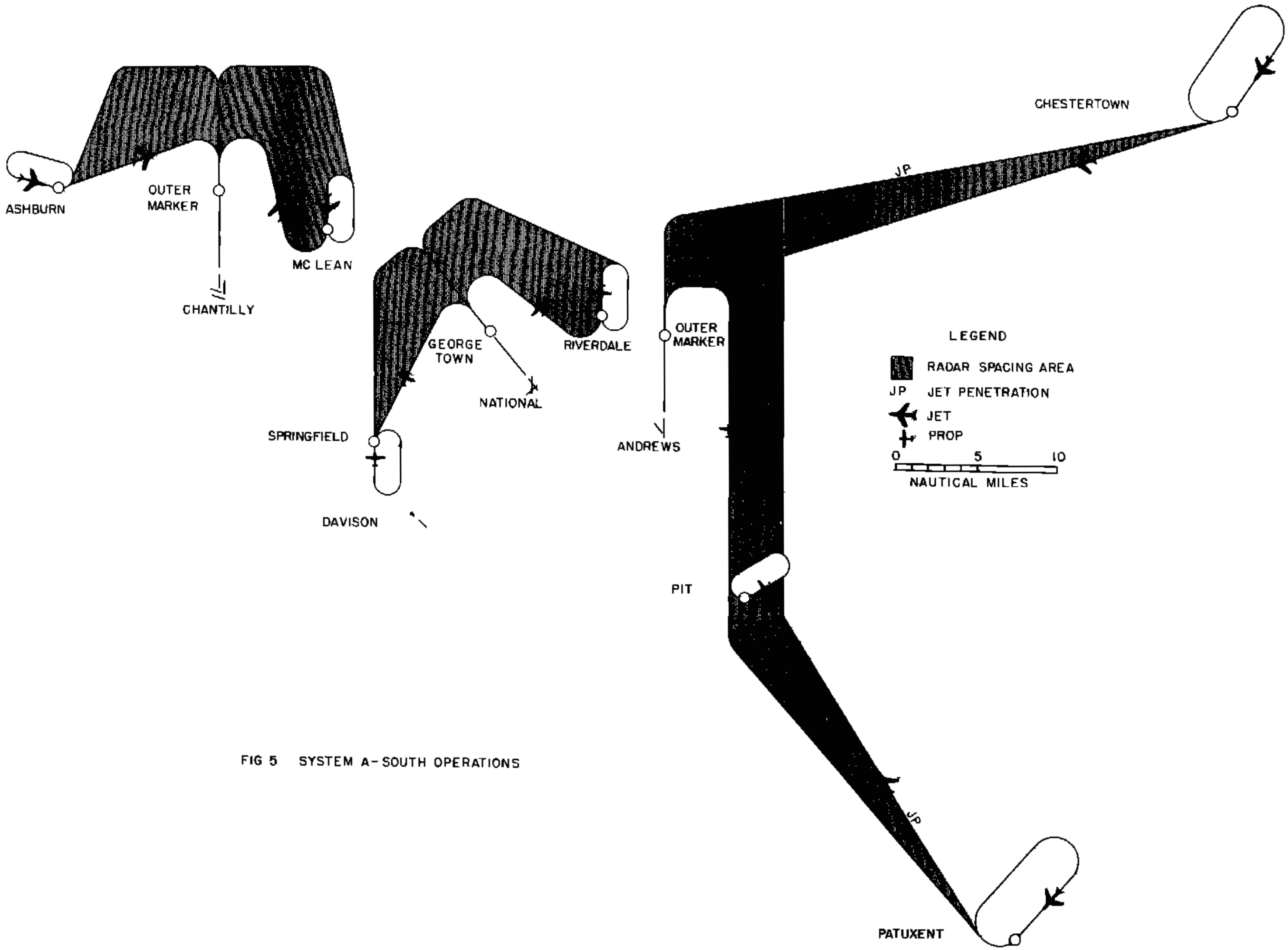


FIG 5 SYSTEM A-SOUTH OPERATIONS

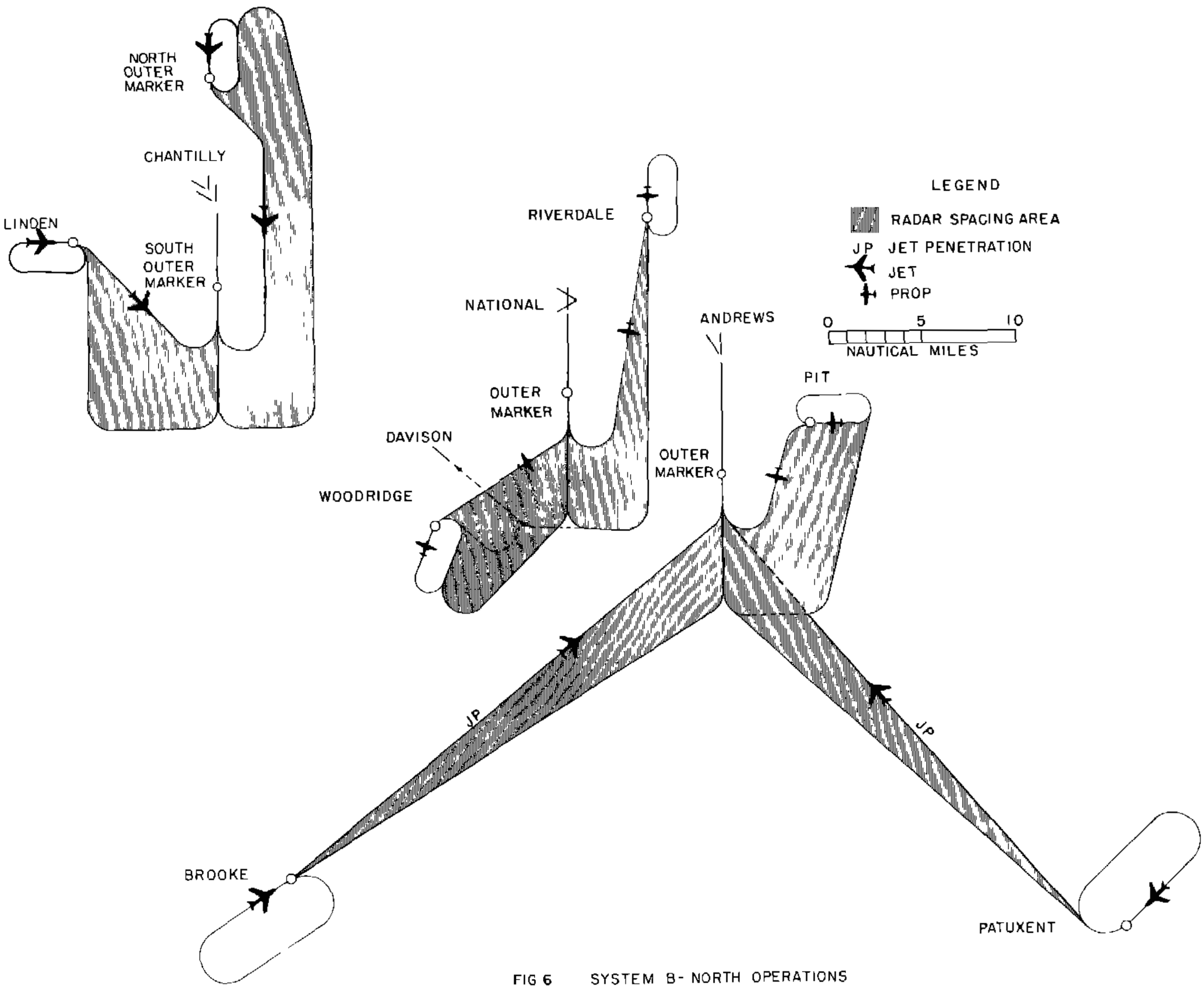


FIG 6 SYSTEM B- NORTH OPERATIONS

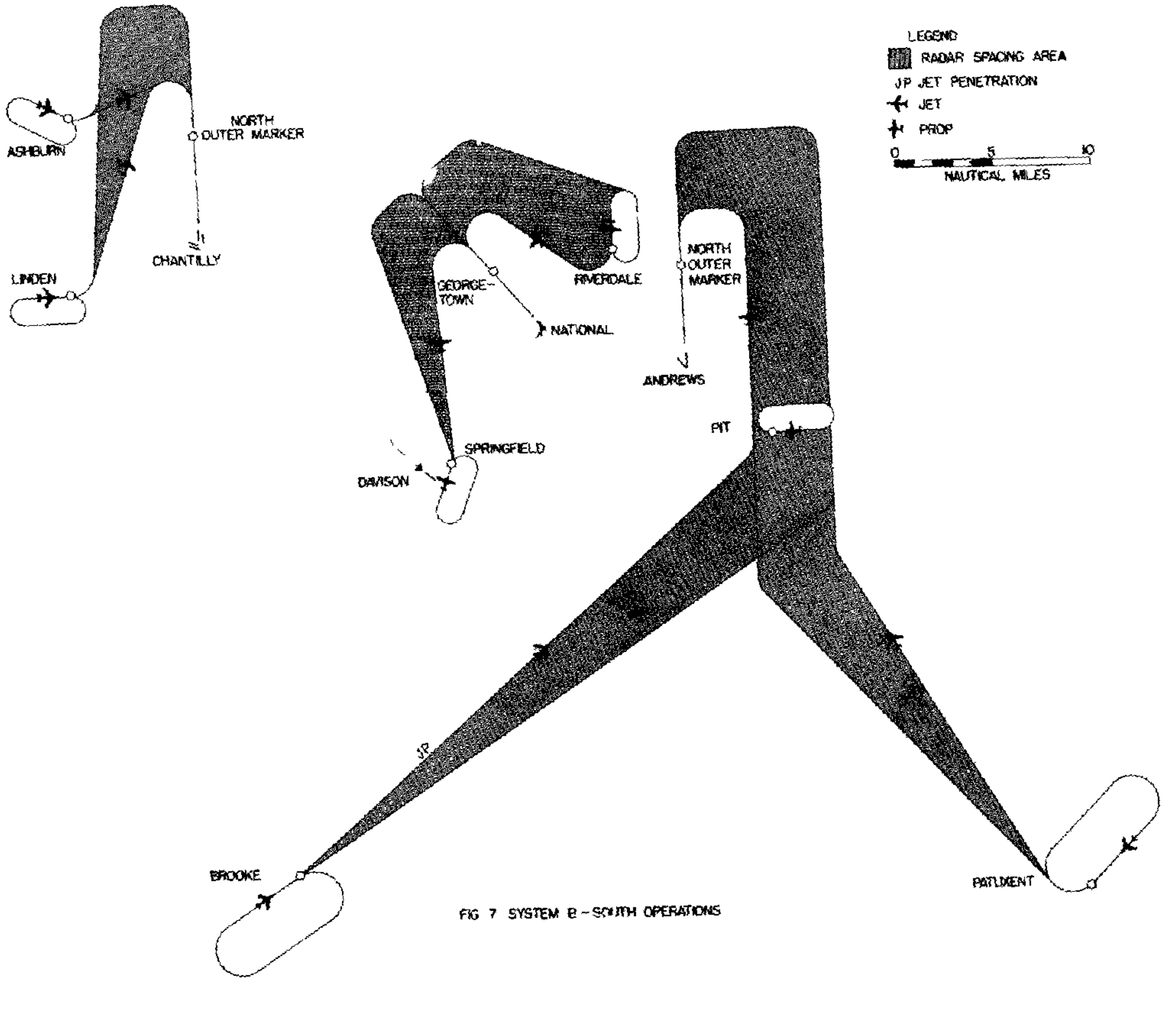


FIG 7 SYSTEM B – SOUTH OPERATIONS

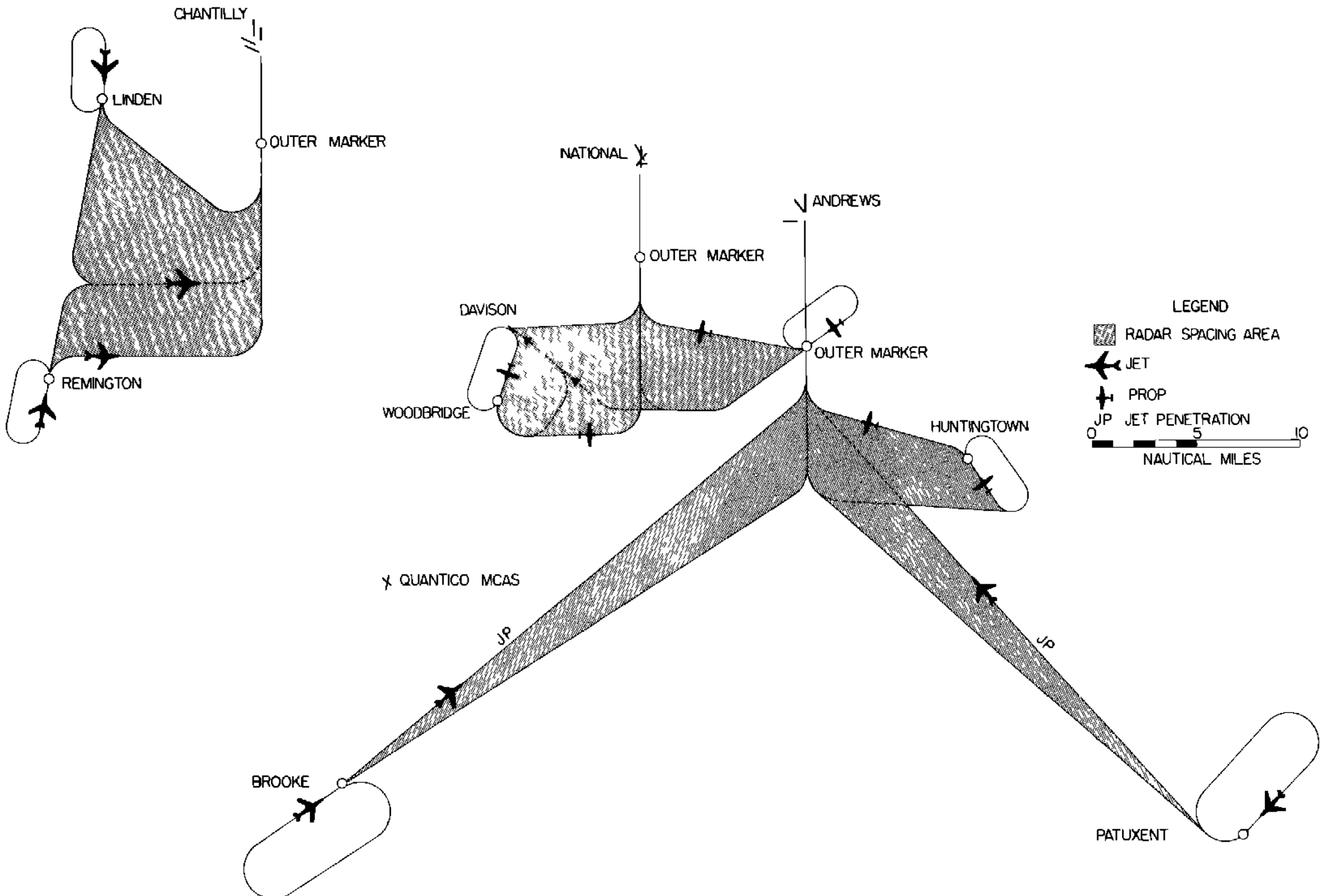


FIG 8 SYSTEM C-NORTH OPERATIONS

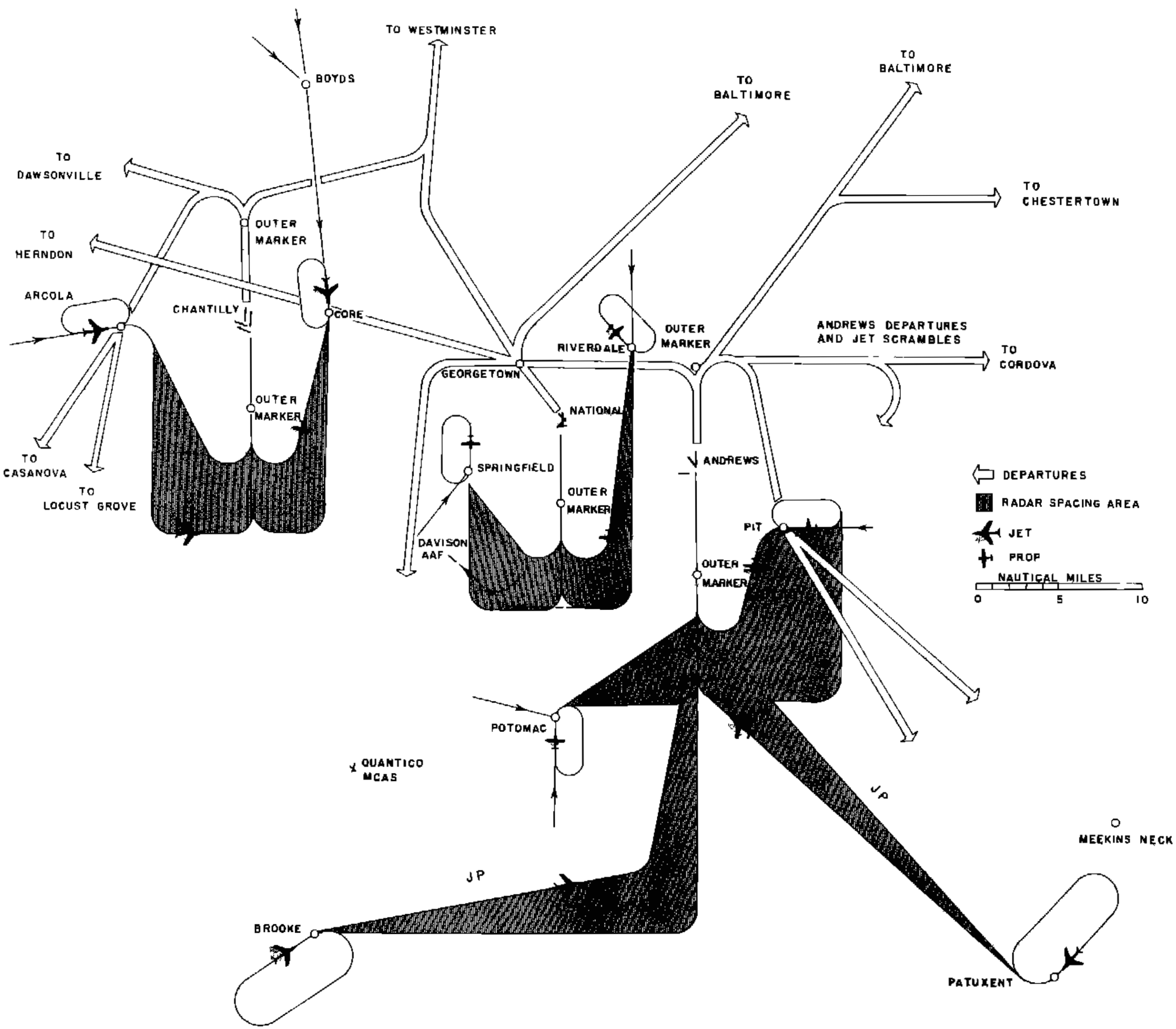


FIG 9 SYSTEM D NORTH OPERATIONS

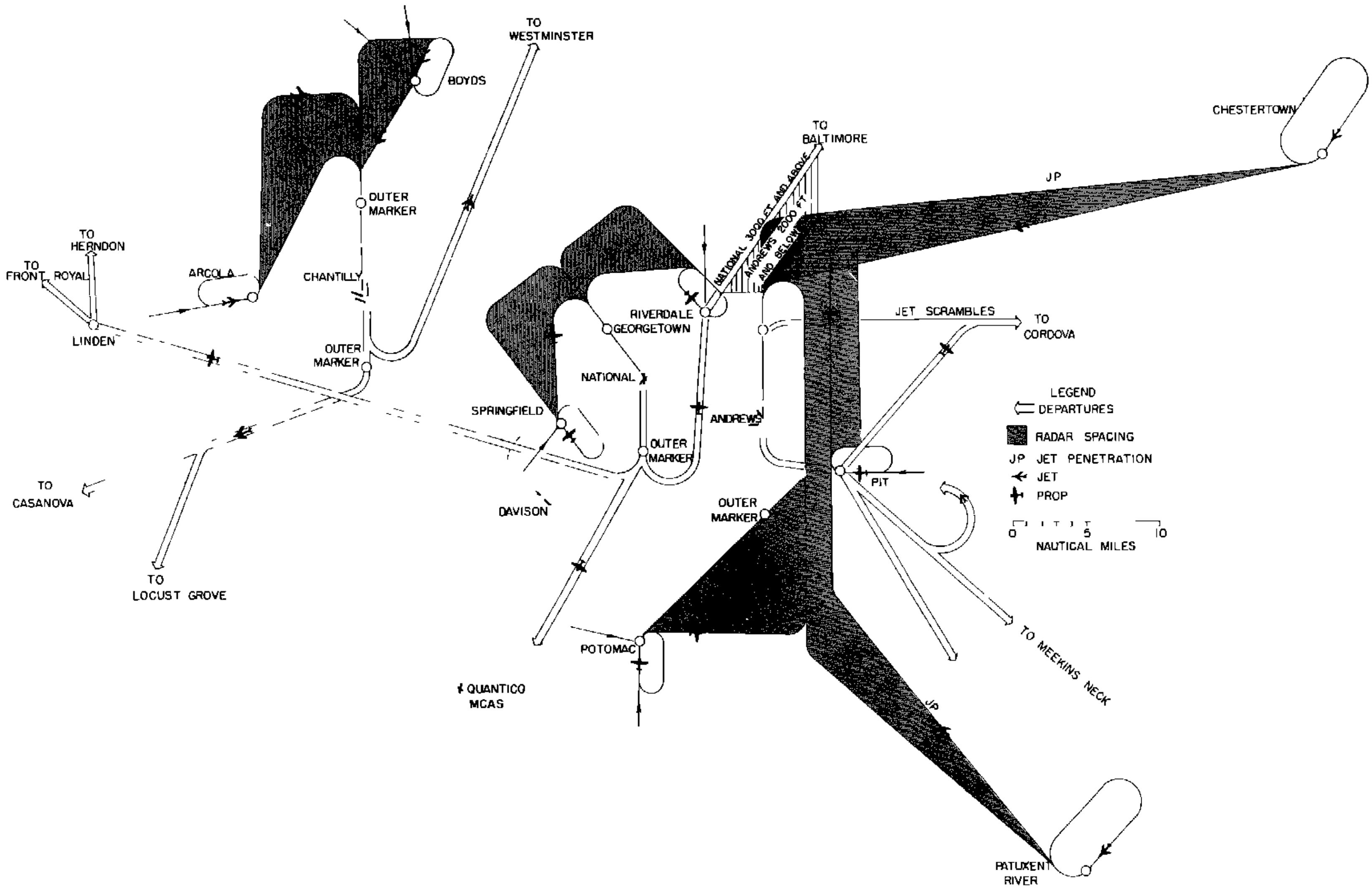


FIG 10 SYSTEM D SOUTH OPERATIONS

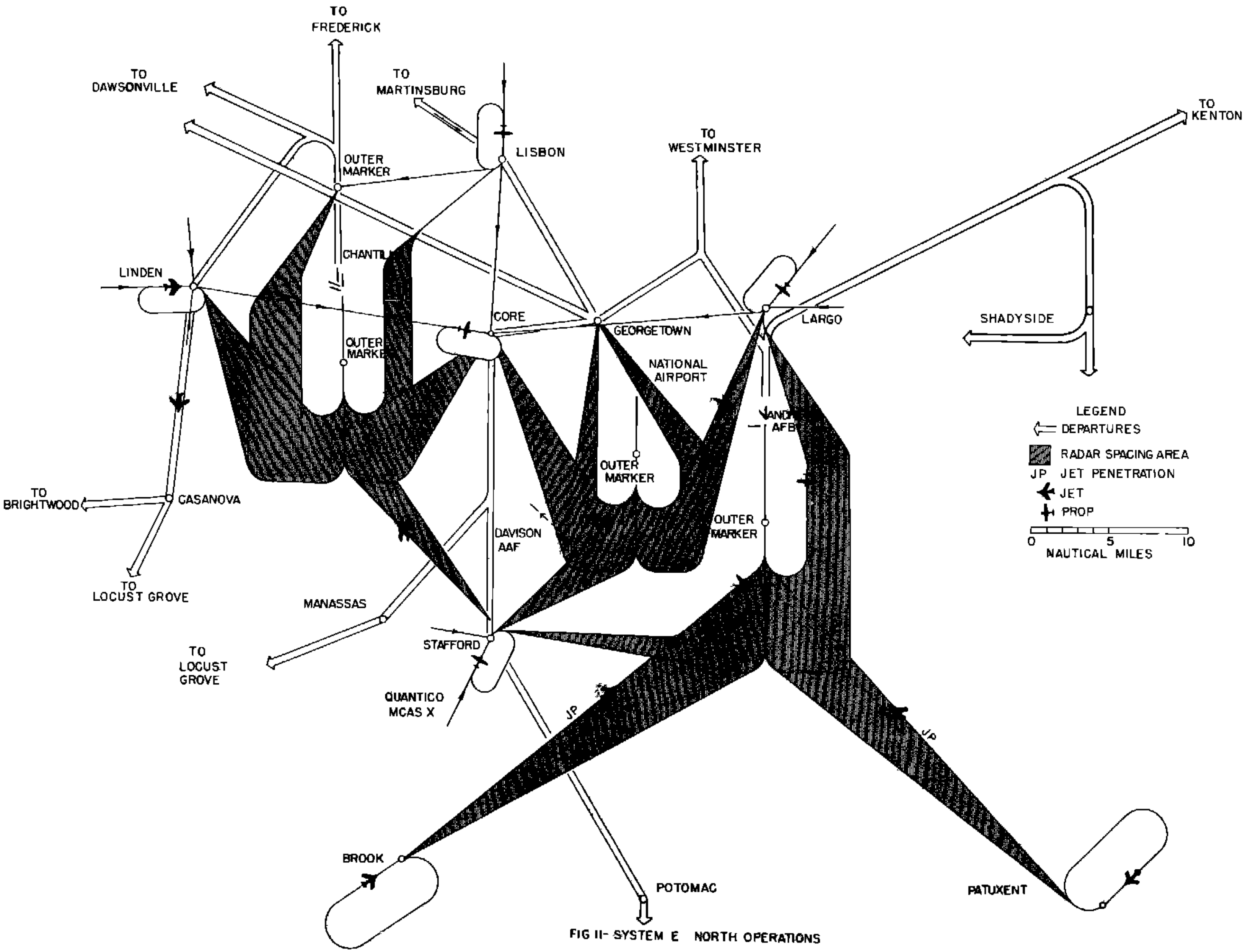


FIG II- SYSTEM E NORTH OPERATIONS

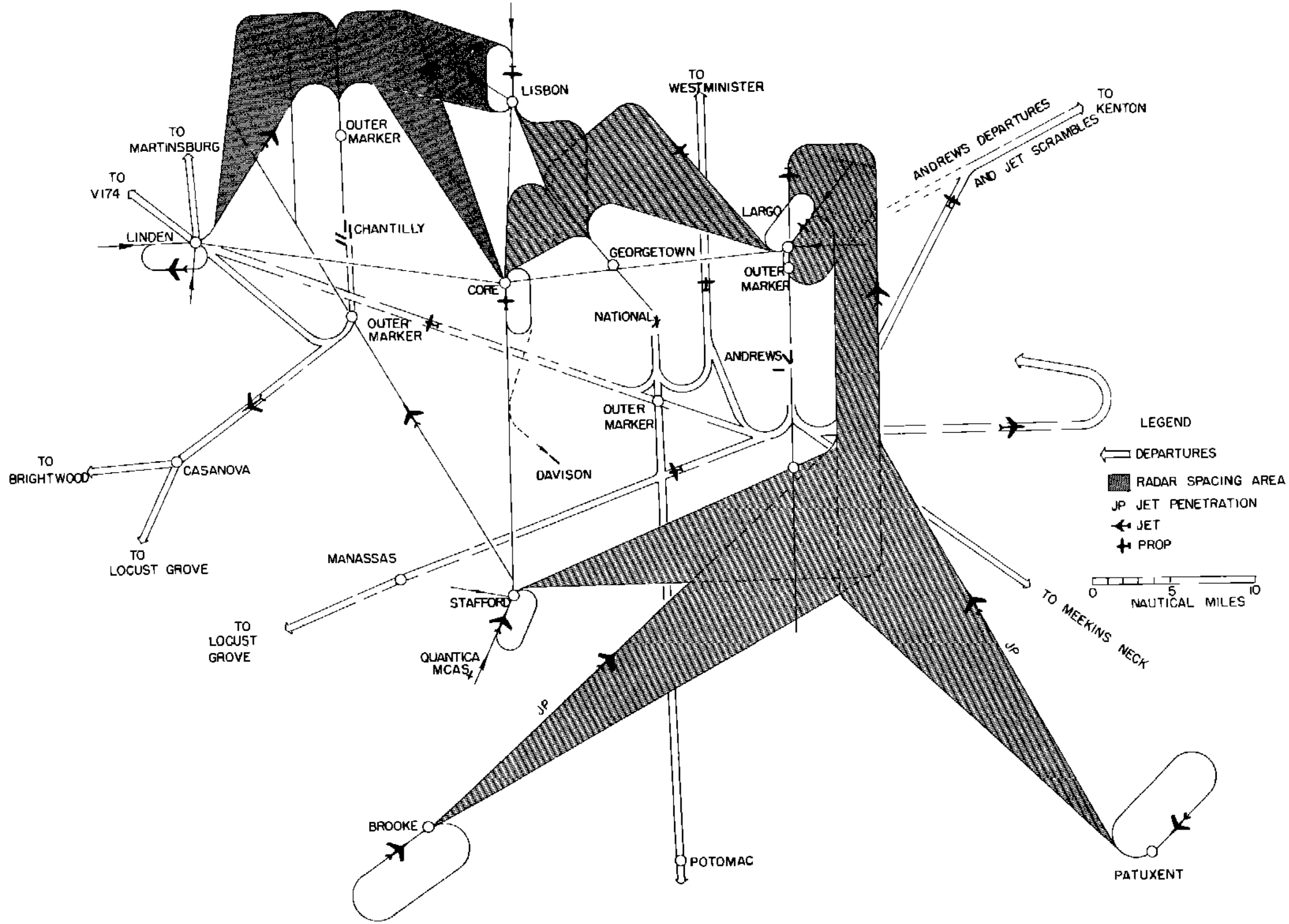


FIG 12 SYSTEM E SOUTH OPERATIONS

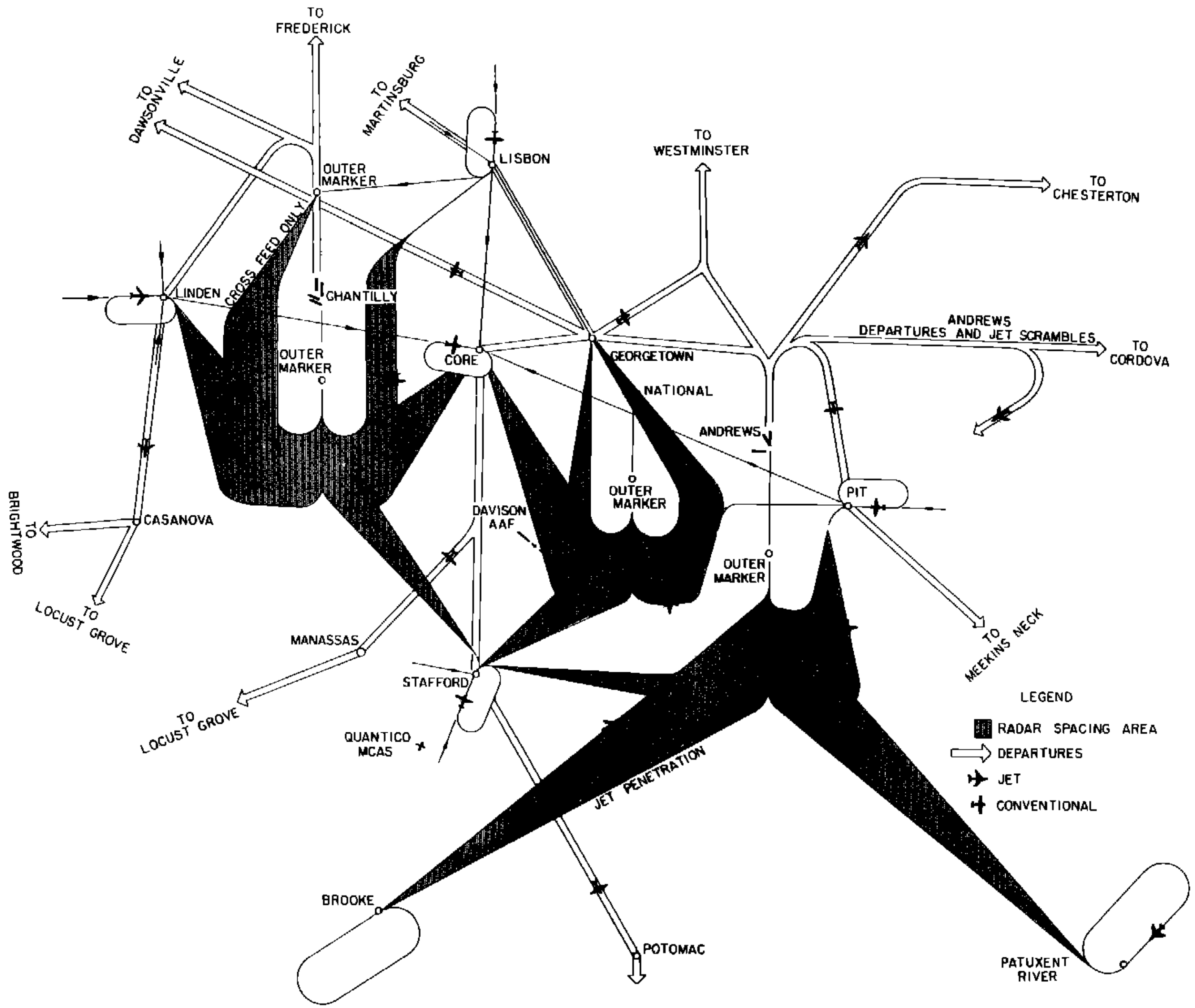


FIG 13 SYSTEM F - NORTH OPERATIONS

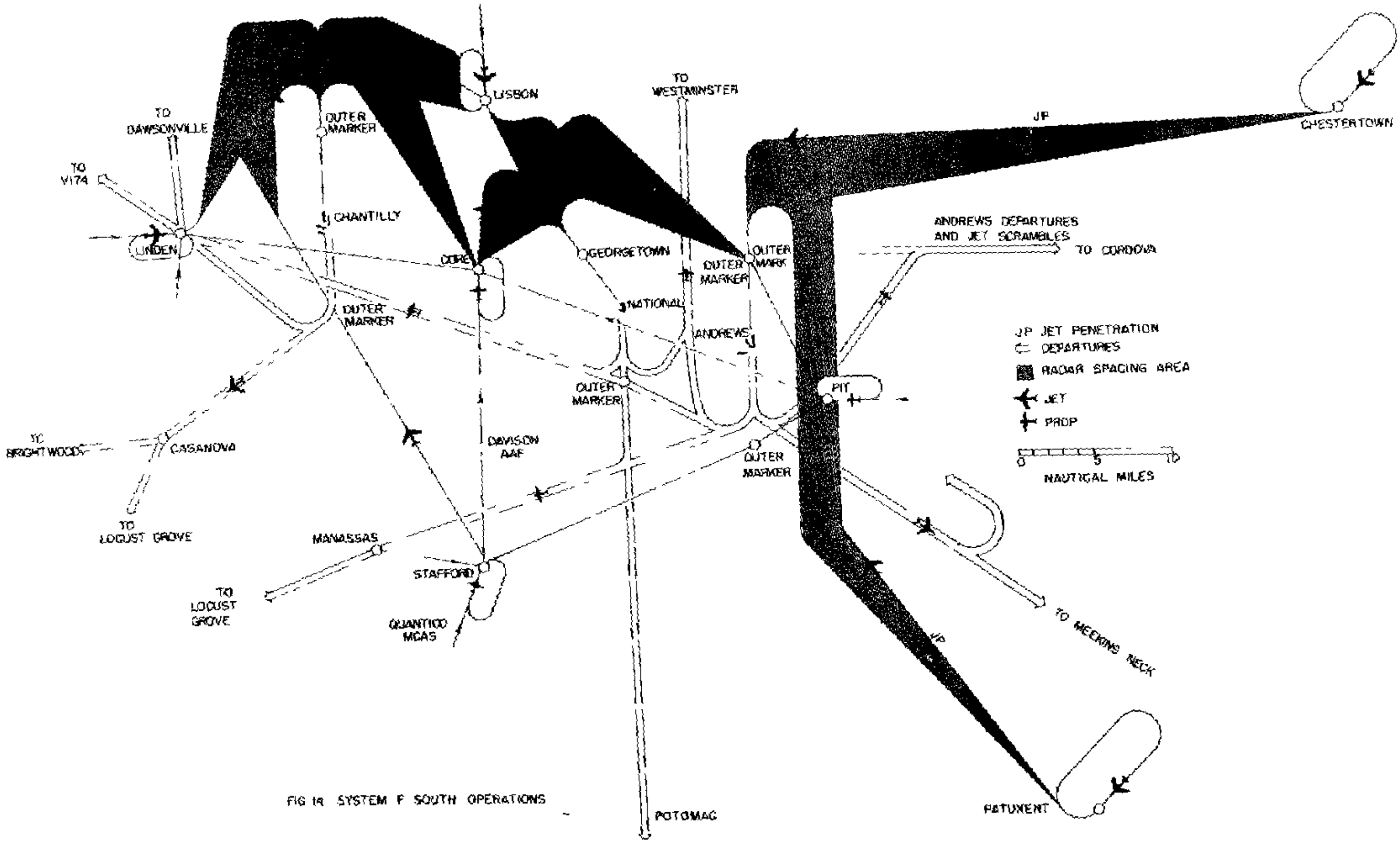


FIG 14 SYSTEM F SOUTH OPERATIONS

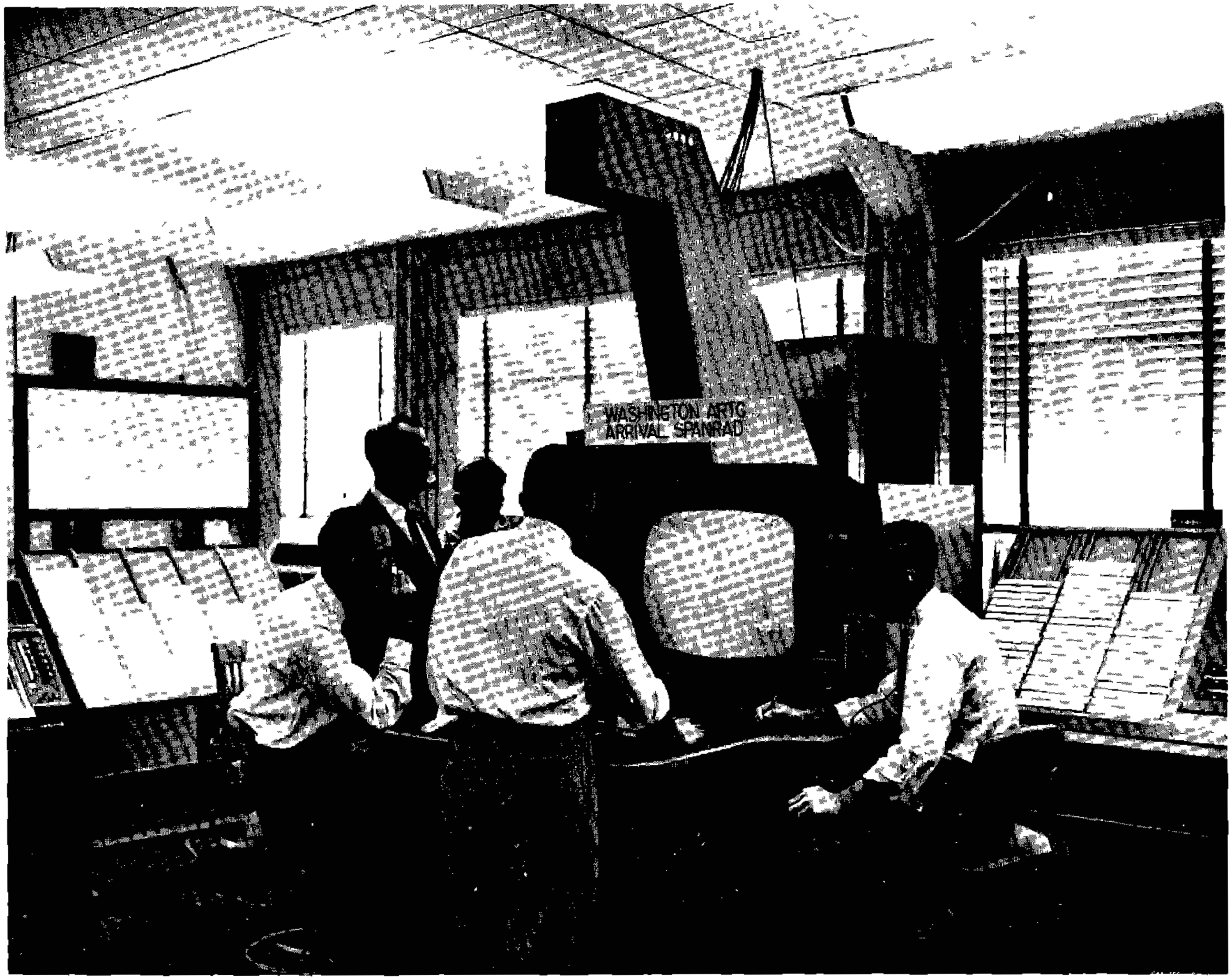


FIG. 15 SPANRAD DISPLAY USED IN ARTC ARRIVAL CONTROL

FIG 16 SPANRAD DISPLAY USED IN ARTC DEPARTURE CONTROL

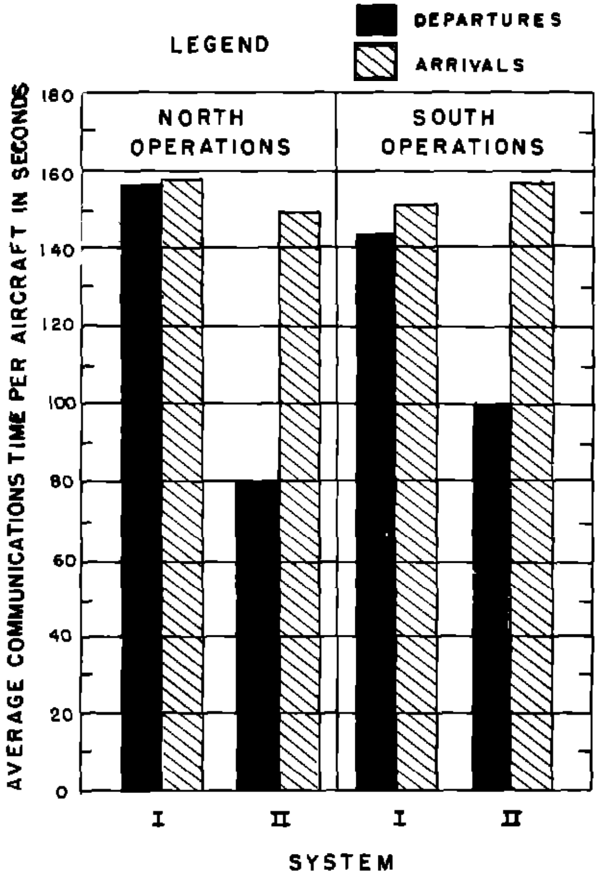
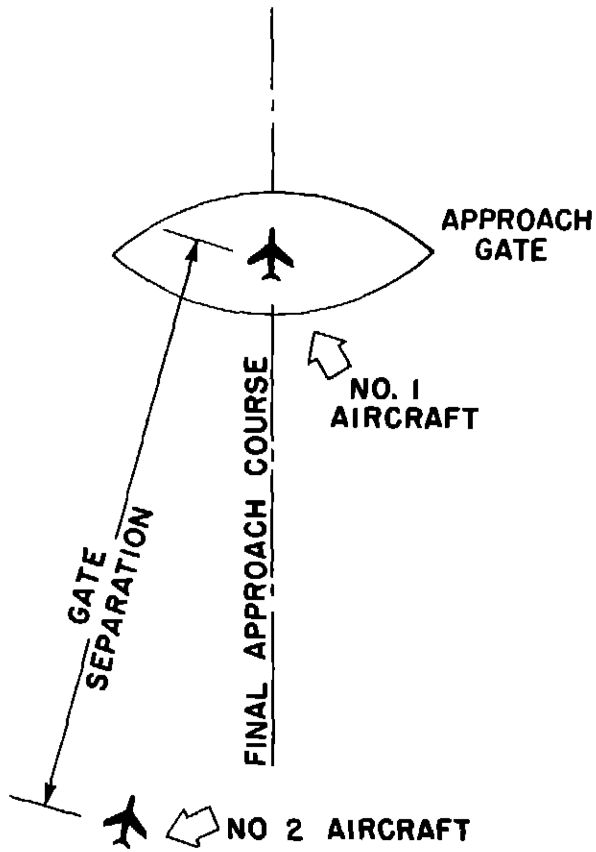


FIG 17 ENROUTE SYSTEM COMMUNICATIONS



OPTIMUM
AIRCRAFT SPACING

DISTANCE, APPROACH GATE TO TOUCHDOWN, 5 MILES

AIRCRAFT SEQUENCE		GATE SEPARATION (MILES)
NO 1	NO 2	
S	M	5 1
S	F	5 5
S	J	6 6
M	S	3 1
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	120	104
M	MEDIUM	140	122
F	FAST	150	130
J	JET	180	156

FIG 18 SPACING TABLE USED IN APPROACH CONTROL OPERATIONS

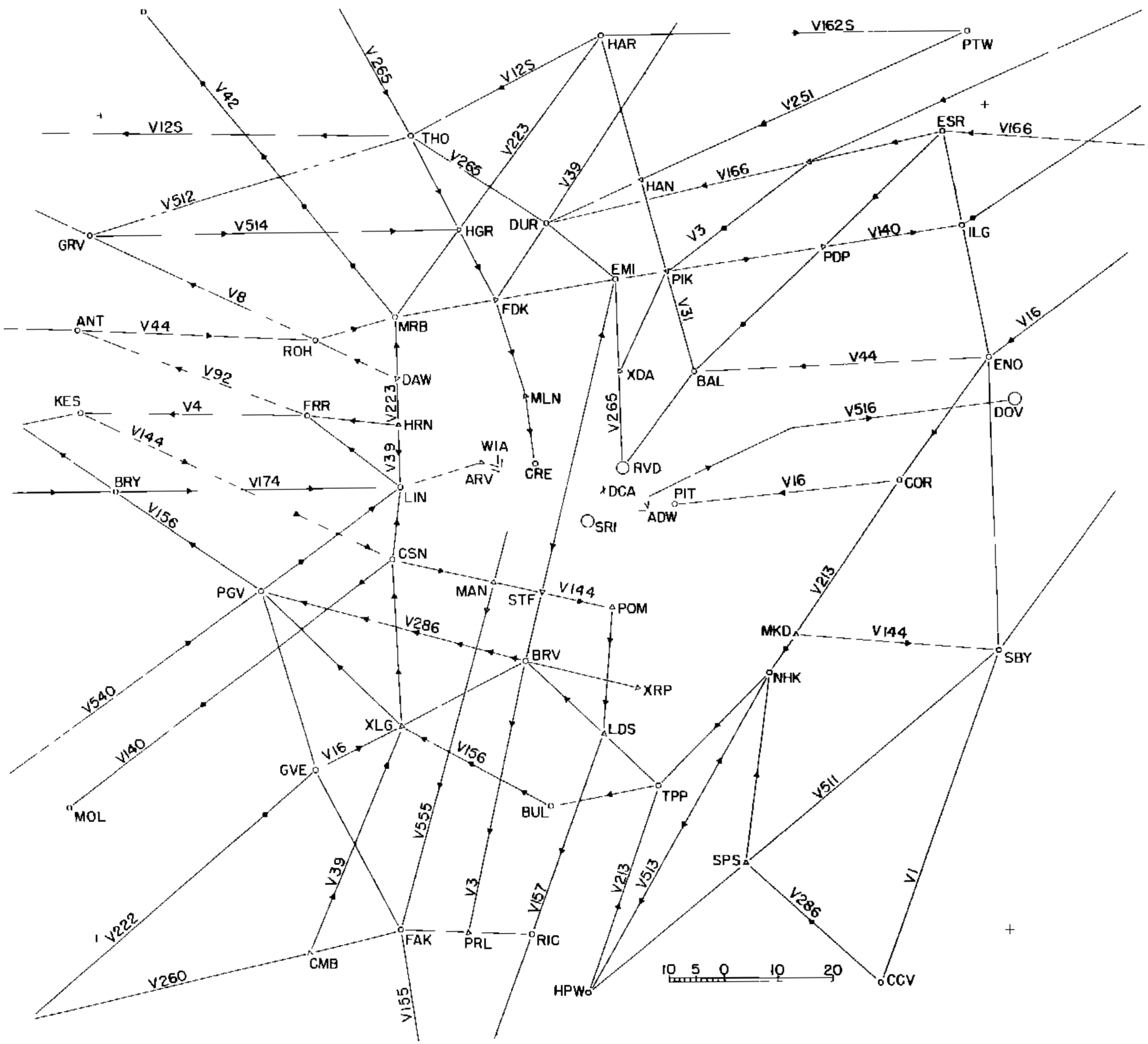


FIG 19 WASHINGTON AREA - PROPOSED SYSTEM I

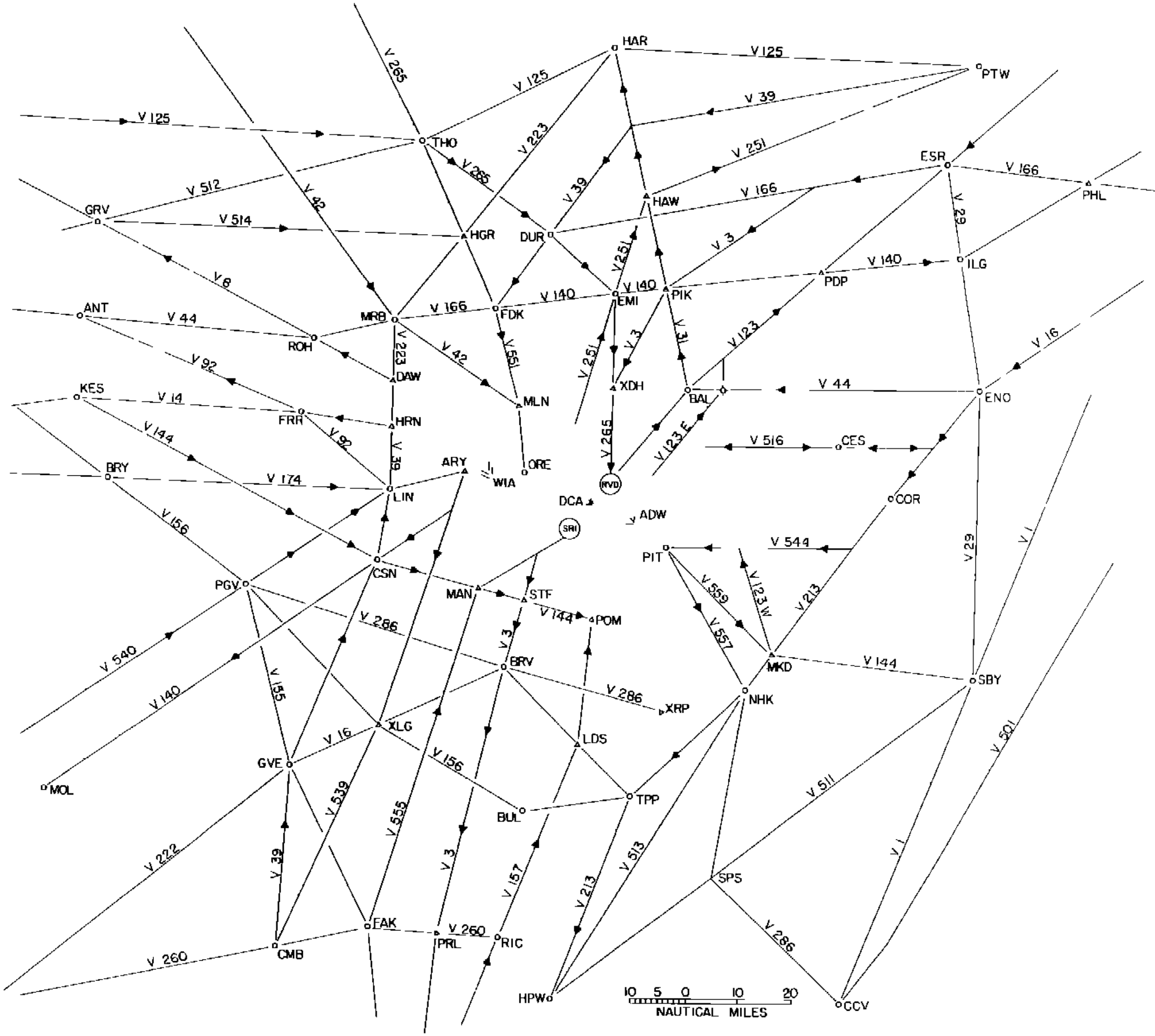


FIG 20 WASHINGTON AREA PROPOSED SYSTEM IA

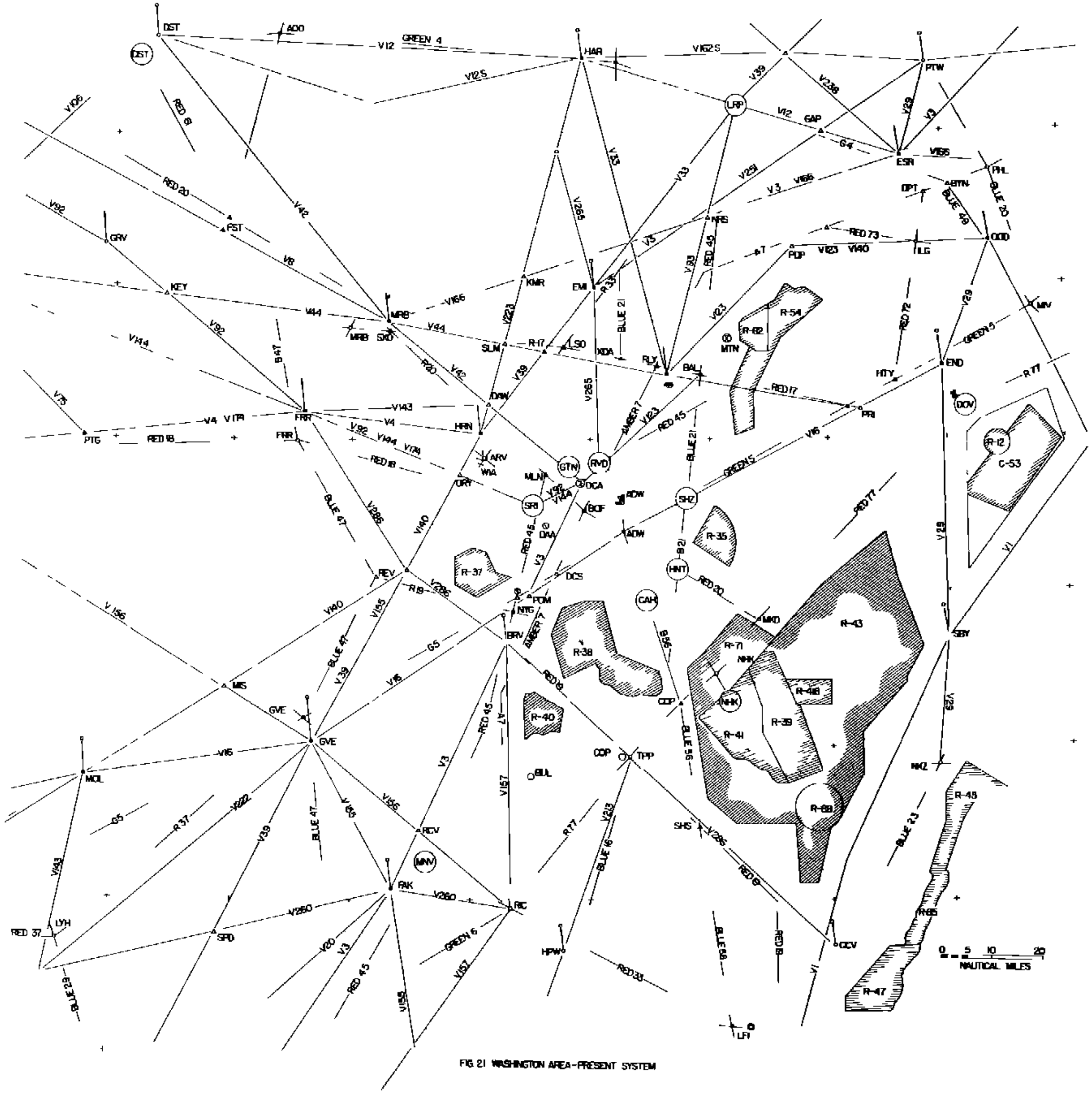


FIG 21 WASHINGTON AREA-PRESENT SYSTEM

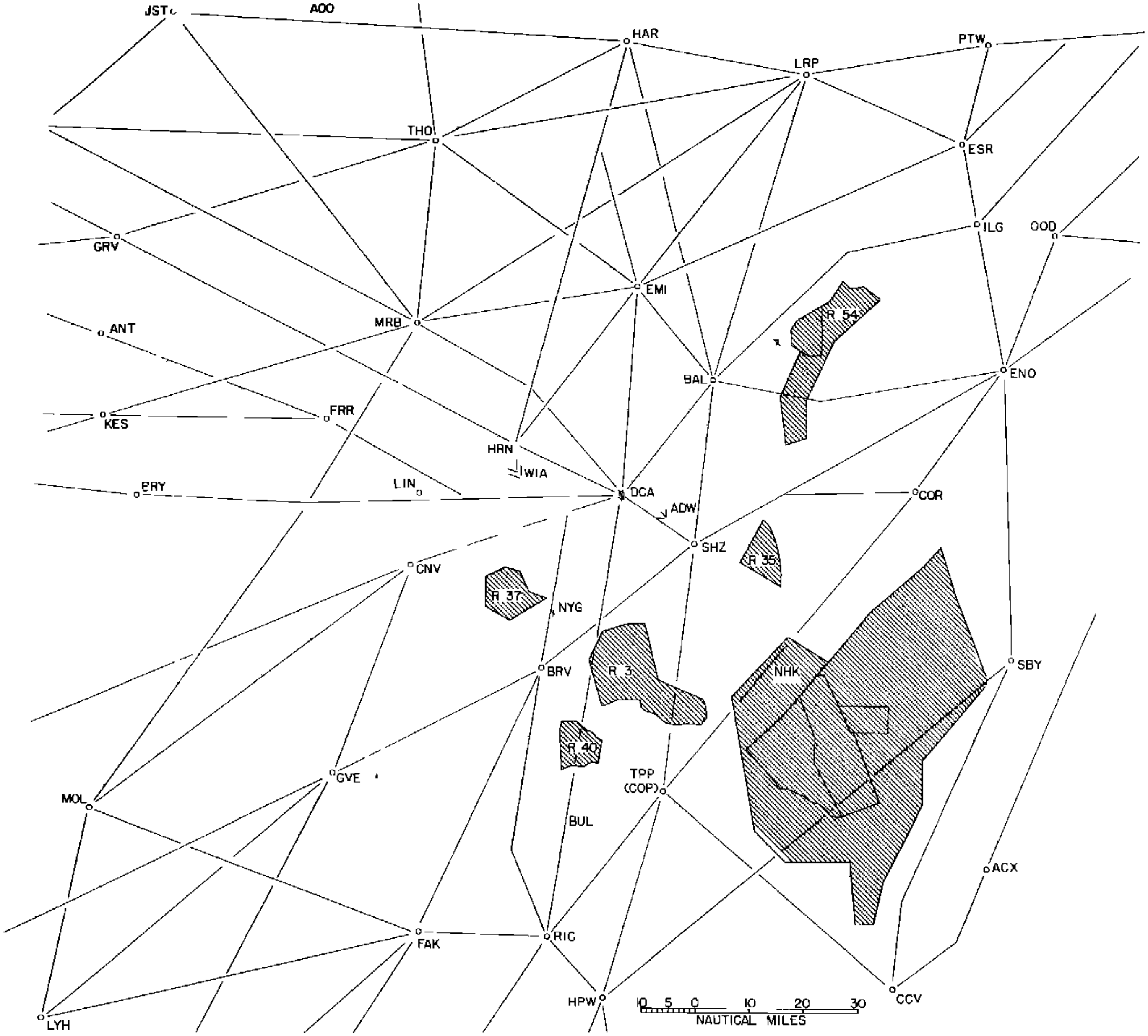


FIG 22 REGION ONE VOR AIRWAYS MASTER PLAN JUNE 4 1958

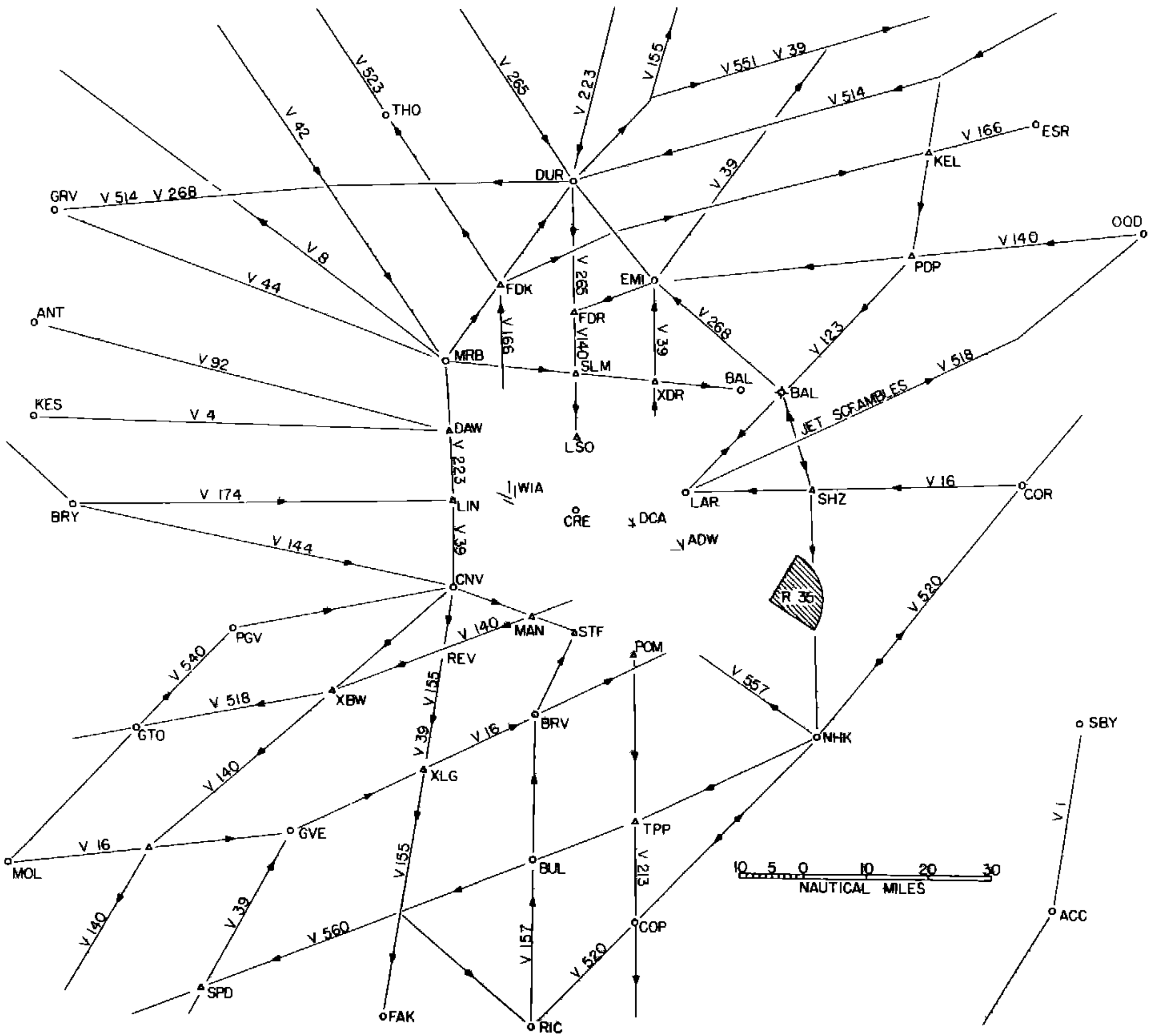


FIG. 23 WASHINGTON AREA - PROPOSED SYSTEM II

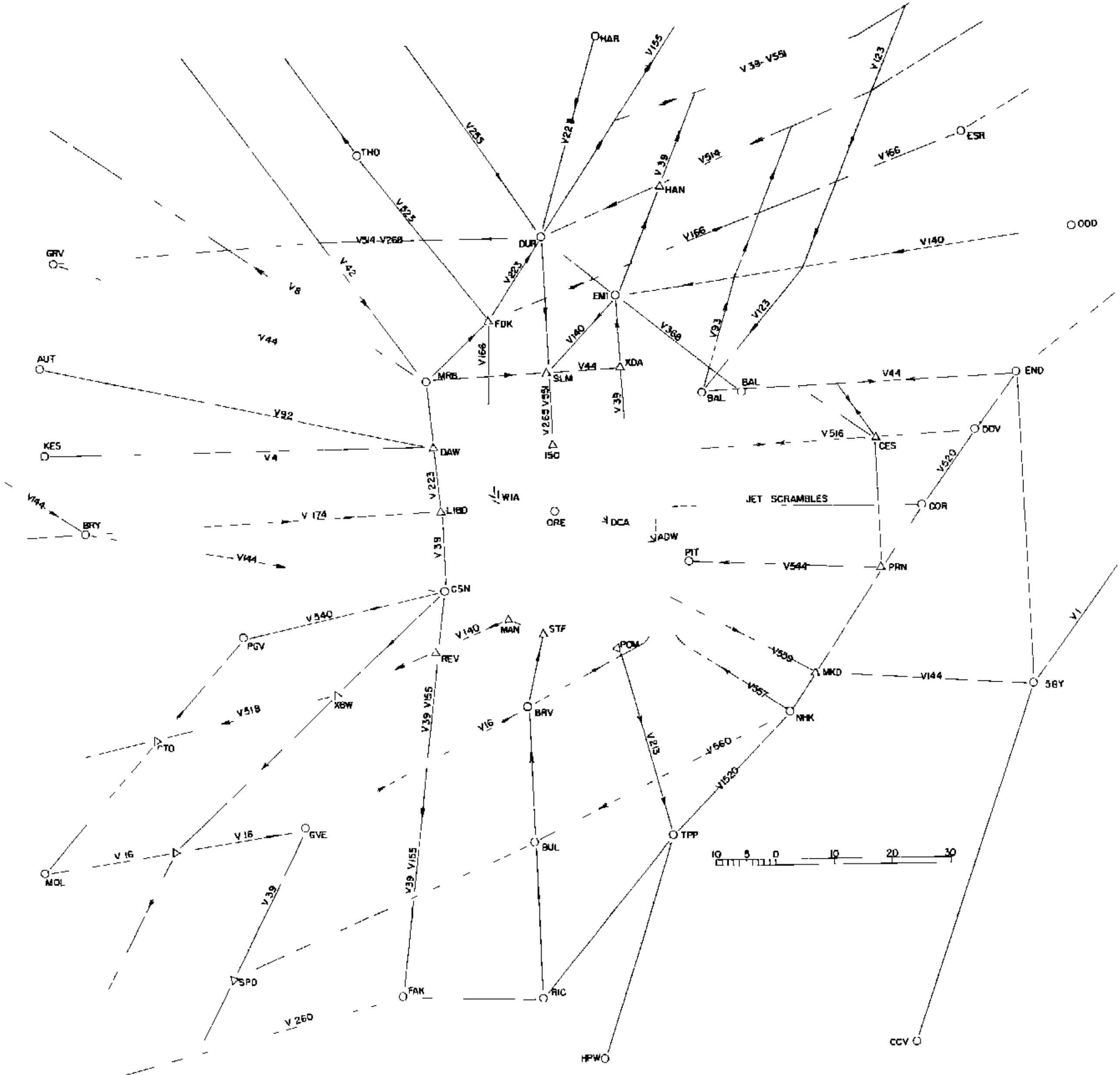


FIG 24 WASHINGTON AREA RECOMMENDED SYSTEM II A

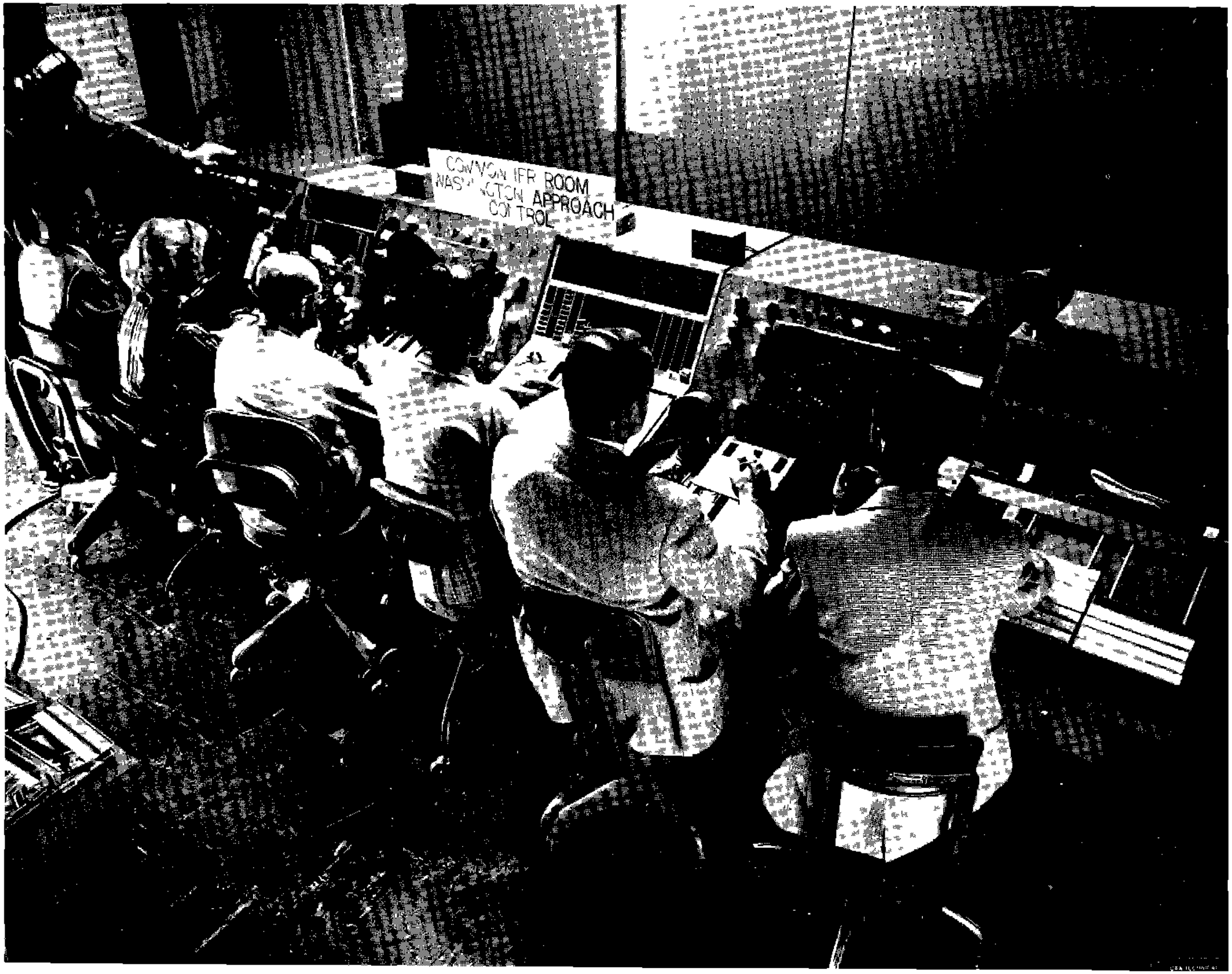
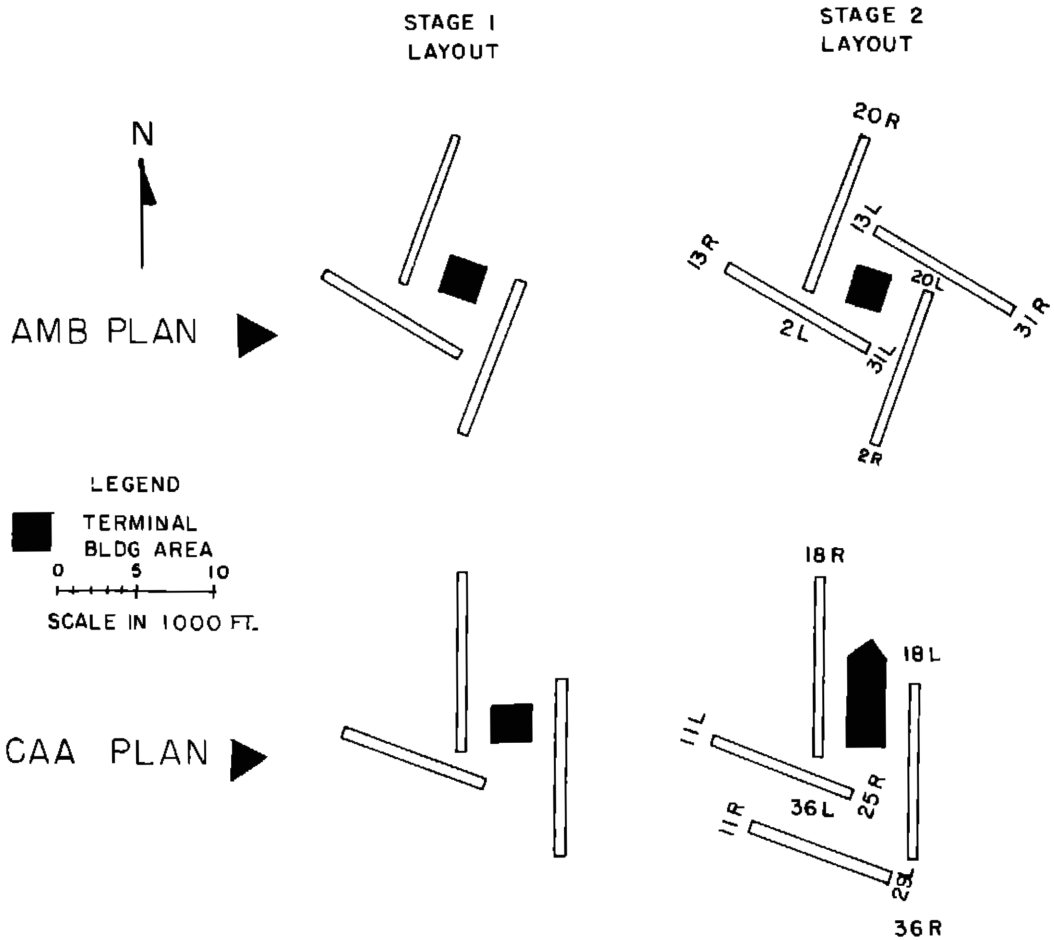


FIG. 25 ASR-3 TYPE SCOPES USED IN COMMON IFR ROOM TESTS

FIG 26 SPANRAD DISPLAY USED FOR DEPARTURE CONTROL IN TERMINAL TESTS



COMPARATIVE INTERFERENCE CHARTS FOR STAGE 2 LAYOUTS

X = COORDINATION REQUIRED

TAKEOFF	LANDING 2L	2R	20L	20R
13L		X	X	
13R	X	X	X	X
31L	X			X
31R	X	X	X	X

TAKEOFF	LANDING 18L	18R	36L	36R
11L	X	X	X	X
11R	X	X	X	X
29L		X	X	
29R		X	X	

FIG 27 POSSIBLE RUNWAY CONFIGURATION FOR CHANTILLY AIPORT

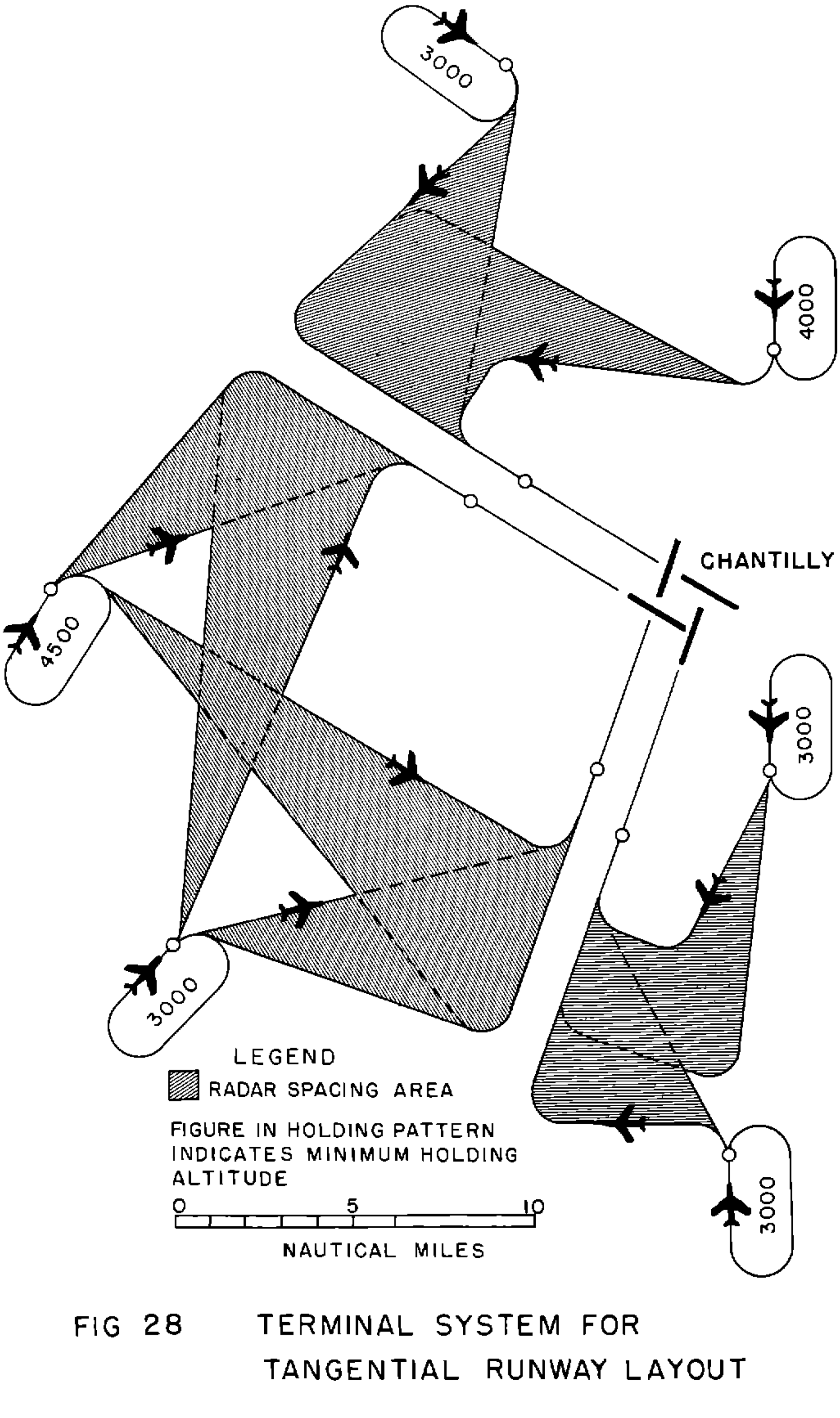


FIG 28 TERMINAL SYSTEM FOR TANGENTIAL RUNWAY LAYOUT

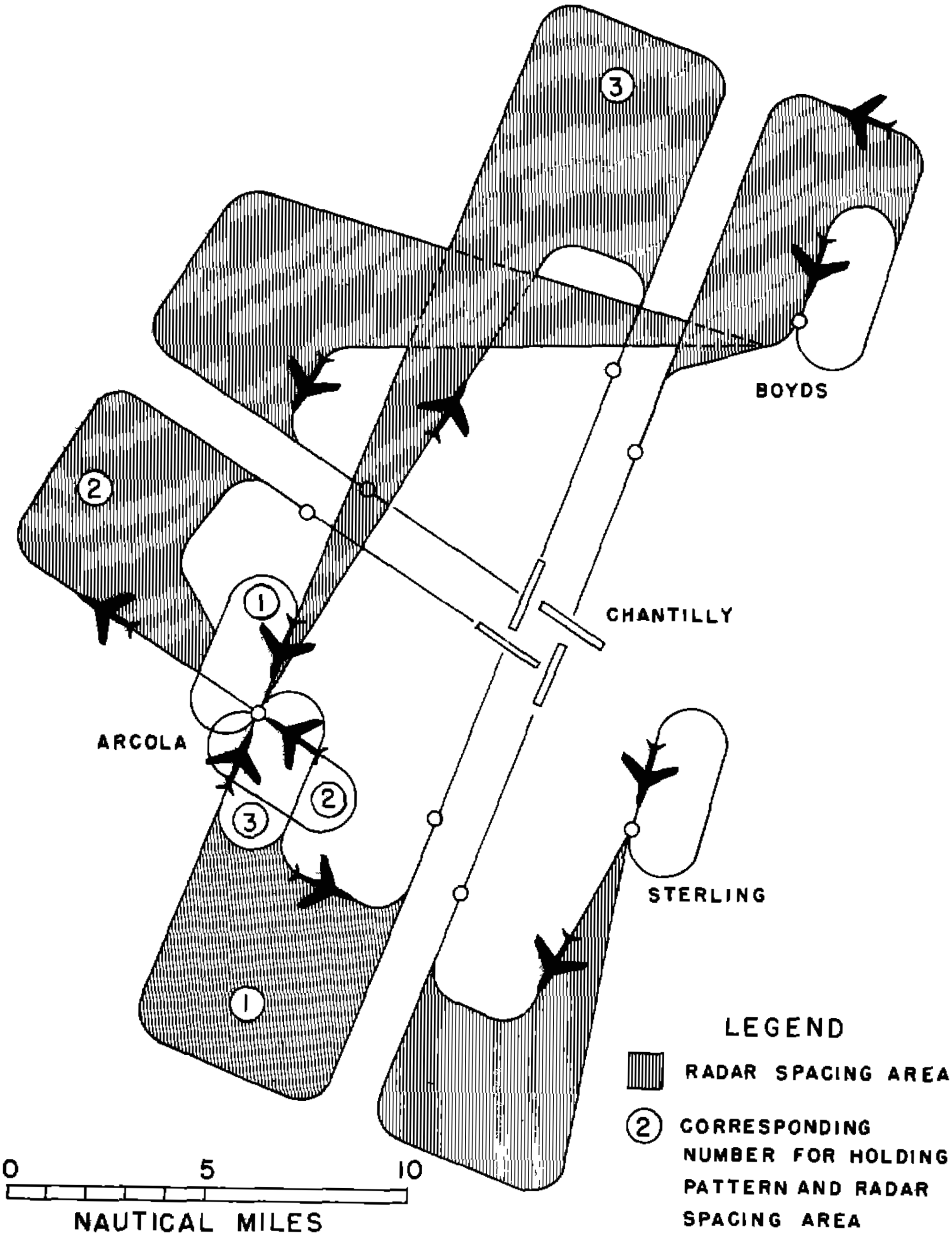
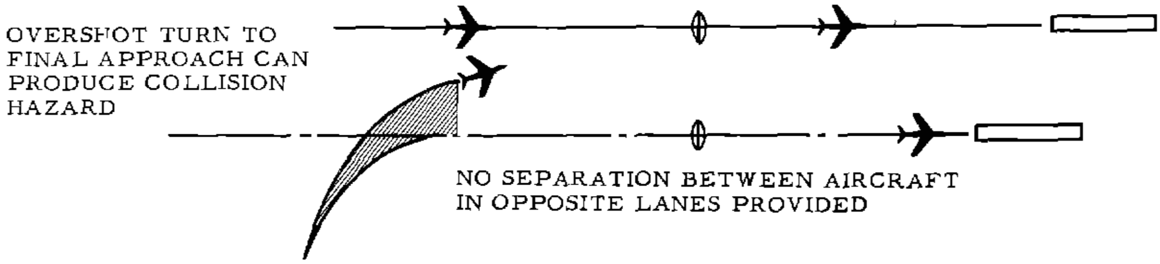
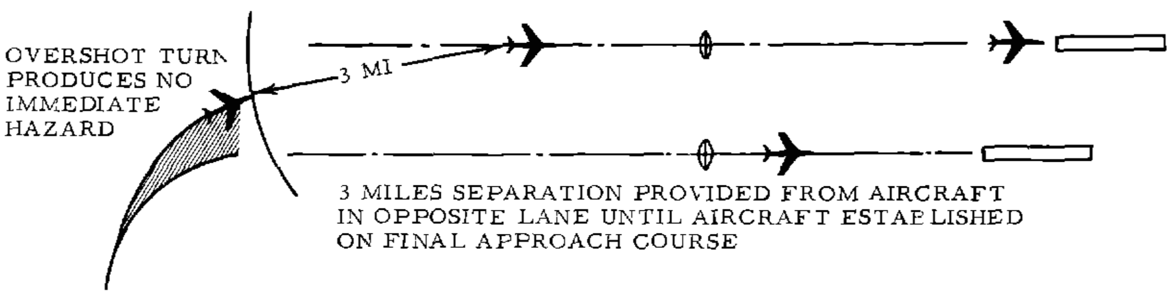


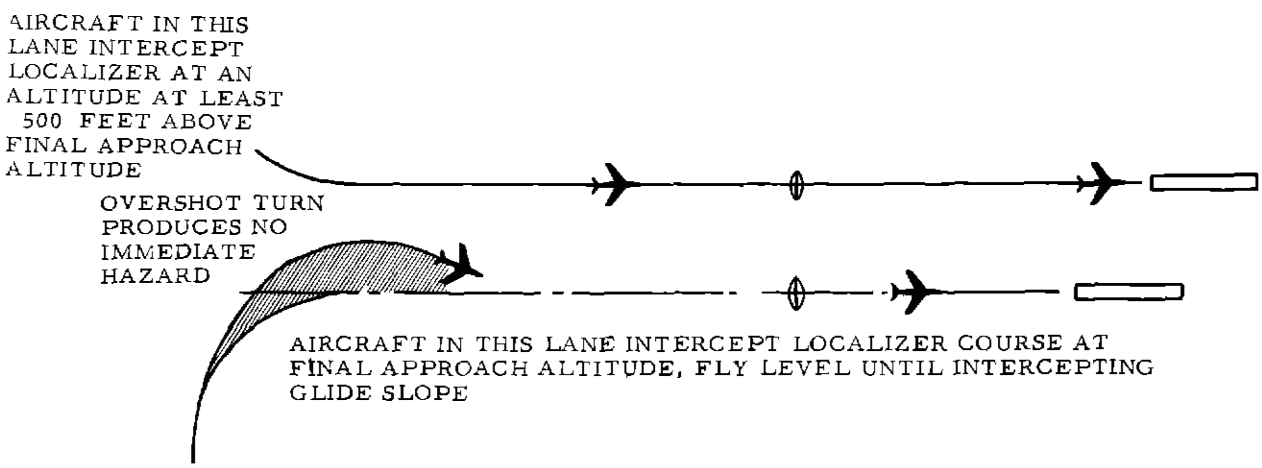
FIG 29 TERMINAL SYSTEM FOR TANGENTIAL RUNWAY LAYOUT



MODE A - INDEPENDENT OPERATIONS



MODE B - USE OF LONGITUDINAL SEPARATION



MODE C - USE OF ALTITUDE SEPARATION

FIG 30 PARALLEL APPROACH OPERATIONS