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# DYNAMIC SIMULATION TESTS OF BALTIMORE FRIENDSHIP AIRPORT AT INCREASED TRAFFIC DENSITIES

FOR LIMITED DISTRIBUTION

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# DYNAMIC SIMULATION TESTS OF BALTIMORE FRIENDSHIP AIRPORT AT INCREASED TRAFFIC DENSITIES


## SUMMARY

This report describes an air traffic simulation study which was made to determine the effects of using Baltimore Friendship Airport as the supplementary airport and civil jet terminal for the Washington Metropolitan Area.

Because of the proximity of the proposed Davidsonville Naval Air Station, its air-route operations were included in the simulation study, in order to observe the effects of each airport on the flow characteristics of the other.

The present route structure in the Washington-Baltimore area was found to be unusable with an increase of traffic at Baltimore. Present routes were modified, so as to by-pass Washington traffic around the Baltimore area, primarily to secure airspace for jet penetration. The resulting system required additional mileage for the high-density New York-Washington National Airport routes.

Without further major realignment of airways north and west of Baltimore, it is impractical to provide a non-radar jet penetration area. Therefore, the jet penetration used at Baltimore was a radar ground-controlled jet penetration utilizing a minimum of airspace. Because of this arrangement, the Baltimore terminal area system created a very high controller workload per aircraft and almost complete reliance on radar control procedures.

Terminal area tests indicated that if Instrument Flight Rule approaches were made to the southeast at Baltimore, an improvement in the landing rate was possible. However, the airspace required for a southeast landing utilized the independent departure route northeast of Baltimore, which was available with east landings.

Tests showed that Instrument Flight Rule operations at the proposed facility at Davidsonville Naval Air Station will further complicate an already cramped route structure and would have a particular restrictive effect on operations in and out of Washington National Airport and Andrews Air Force Base. In addition sufficient airspace to provide independent arrival and departure routes in the Washington-Baltimore area, would not be available without utilizing portions of most restricted areas.

During the course of this program, a number of new procedures were developed and tested for the integration of jet traffic in the terminal area.

## INTRODUCTION

In February 1957, the Office of Air Traffic Control requested the Technical Development Center to conduct a simulation study of the Baltimore area. The purpose was to determine what additional air traffic problems would be caused by increased conventional traffic, and the addition of civil jet transports at Baltimore Friendship Airport.

Previous to this request, in November 1956, the Office of Air Traffic Control had requested the Technical Development Center to conduct a simulation study of a proposed naval air station near Davidsonville, Maryland. The results of this study are included in another report.[1] Because of the additional traffic generated at Baltimore and Davidsonville, it was considered necessary to combine the air-route phases of the two simulation projects in order to observe the effects of this additional traffic on the route structure within 80 miles of Washington.

It was assumed that all civil jet traffic operated from the Baltimore Friendship Airport because it is believed that runways at Washington National Airport are unable to handle this type of aircraft.

Furthermore, it was learned that the National Guard operations at Baltimore Friendship Airport would be transferred to the Glen L. Martin Airport. The alignment of the instrument approach was not determined. In consideration of arrival and departure routes northeast of Baltimore, it was considered more efficient to land these aircraft to the northwest. Due to the proximity of Harbor and Martin Airports to the Friendship Airport, it was considered desirable that Baltimore approach control handle all Instrument Flight Rule (IFR) traffic at these airports.

During a preliminary planning conference, it was understood that Anacostia Naval Air Station (NAS) would be closed, and their operations transferred to Davidsonville Naval Air Station. It was also understood that if Anacostia operations were moved to Davidsonville, Bolling Air Force Base would close, and transfer operations to Andrews Air Force

[1] Clair M. Anderson, Thomas Armour, A. B. Johnson, Donald S. Schlots, and Tirey K. Vickers, "Simulation Tests of IFR Operations at the Proposed Davidsonville Naval Air Station," Technical Development Report No. 315, June 1957.

Base (AFB). Therefore, during these tests, it was assumed that no traffic was operating from Anacostia NAS or Bolling AFB. Several Technical Development Center (TDC) air traffic controllers spent a period of time in the Washington-Baltimore area observing operations and gathering background material for this study. The simulation tests were completed in June 1957.

## EVALUATION METHODS

Traffic Samples.

Flight progress strips from the Washington Air Route Traffic Control (ARTC) Center were analyzed to determine the traffic flow characteristics of the various routes in the Washington-Baltimore area. The traffic of the four busiest hours was compressed into a two-hour test sample. In addition, traffic was added at Baltimore Friendship Airport to raise its operations to 60 per cent of that of Washington National. Traffic was increased at Andrews AFB to simulate the closing of Bolling AFB. Traffic simulated at Davidsonville was arbitrary as to density because no past figures were available. Traffic densities of this sample are listed in Table I.

An additional high-density traffic sample was prepared for use in terminal area studies to develop optimum airport approach procedures. This sample consisted of a total of 18 jet aircraft and 13 propeller-driven (Prop) aircraft, and had an average density of 30 aircraft per hour.

Air Route Test Procedures.

For the air route phase of the simulation tests, three ARTC sectors were simulated; namely, an arrival sector, a departure sector, and an en route sector. All sectors were provided with a large, bright radar display. All operating positions were equipped with interphone and air/ground (A/G) radio-communications facilities. Baltimore, Washington, Andrews, and Davidsonville towers were simulated. These towers were equipped with arrival and departure scopes, as well as interphone and A/G radio-communications.

Because only 18 target projectors were available, it was necessary to divide the complex Washington-Baltimore area into north and south segments, and to run one segment at a time. Any essential traffic which was common to both segments appeared again in the program when the other segment was simulated.

Arrival traffic destined for Washington National Airport was not simulated beyond Riverdale, Springfield, and Doncaster. This was done in order to obtain better utilization of the available simulator targets. This appeared practical since the only major change in the Washington terminal area was the elimination of arrival and departing traffic at the Andrews range station.

The conclusions in this report are based primarily on observations made by some 12 air traffic controllers who worked on this simulation project. Simulation tests were as realistic as possible, but it was not practical to reproduce in the laboratory all the complications which might exist under actual operating conditions.

## AIR ROUTE TEST RESULTS

Route Layouts.

In order to retain as much of the existing system as practicable, the initial simulation tests of the area were conducted using the present navigation system layout, shown in Fig. 1. Tests showed that this layout was unworkable at the airport traffic densities simulated. It was apparent immediately that before Baltimore could accommodate an appreciable increase in traffic, it would be necessary to reroute Victor Airway 3 clear of the Baltimore area to provide room for jet penetrations. To provide additional routes to handle the increased traffic in and out of the Washington complex, numerous other modifications were employed, as shown in Figs. 2 and 3. These changes are itemized in Table II together with the specific reason for each modification. Later air route tests were conducted on the revised layout. Abbreviations used in route layout maps are listed in Table III.

Tests showed that the operation of the proposed Davidsonville NAS would further complicate an already cramped route structure and would have a restrictive effect upon Andrews AFB and upon traffic using V16/G5 airways.

At the light traffic rate of six arrivals and six departures per hour, simulated at Davidsonville during this phase of the tests, almost continuous interference was produced that denied other traffic the use of airways V16 and G5.

Map Studies For a Southeast Landing.

Many man hours were spent in drawing suitable route maps to accommodate a southeast landing at Baltimore. Figures 4 and 5 indicate two of the best maps derived from this effort.

While gathering the background information for this study, it was not possible to learn details of the proposed southeast runway at Baltimore. A visit to Baltimore Friendship Airport revealed that radio transmitting antennas north and northeast of the airport, forced cancellation of the Very-High Omnirange (VOR) approach to the southeast. These same antennas may require high initial altitudes for an Instrument Landing System (ILS) approach, depending on the exact location and alignment of the runway. Also it was learned that a large public institution is located at the southeast corner of Baltimore Friendship, near the present southeast runway. This area could be suitably by-passed by the new runway depending on runway location and alignment.

It appears from these map studies that it is practical to make approaches to the southeast at Baltimore Friendship. However, the improvement in the overall route pattern was not sufficient to warrant simulation of the en route structure. Table IV indicates the advantages and disadvantages in these maps when compared to the first of the modified systems.

Terminal Area Test Procedures.

A high-density terminal area phase of the test program was conducted in order to study jet operations in greater detail and to develop optimum approach procedures for Baltimore Friendship Airport. Four categories of jet aircraft were included in the traffic sample. Penetration speeds for each category varied with altitude as shown in Table V. All jet penetrations from an altitude of 20,000 feet were conducted at a standard descent rate of 4,000 feet per minute. The descent was flared below 5,000 feet to permit the aircraft to level off before starting down the final glide slope. At true airspeeds above 200 knots, all turns were made at a rate of 1 1/2° per second. At true airspeeds less than 200 knots, aircraft made turns at the rate of 3° per second. All aircraft characteristics assumed for these tests conformed to the best information available at the time.

Two approach controllers were used in the terminal area tests. One controller descended jet aircraft to the initial penetration altitude of 20,000 feet, guided them from the holding fix, cleared them for penetration, and subsequently transferred control to the second controller. The second controller vectored prop aircraft from the holding fixes and spaced all aircraft at proper intervals on the final approach course.

In these tests, it was assumed that ILS would be available as a final approach aid. For convenience in establishing optimum separation between arrivals, spacing reference lines 3, 5, and 7 miles from the approach gate were marked on the radar indicator, and a standard spacing table was used by the controller to insure safe separation between successive aircraft. Table VI shows this spacing chart.

Discussion of Present Low Altitude Control Procedures at Baltimore.

At present a relatively small number of instrument approaches are made at Baltimore by aircraft arriving at the higher altitude levels under Washington ARTC jurisdiction. This permits Washington ARTC to utilize the altitudes above 5,000 feet for en route aircraft and aircraft destined for Washington National Airport. The majority of aircraft making instrument approaches at Baltimore are from the low altitude tower en route control system. There are two types of low altitude activity controlled by the Baltimore tower. One concerns shuttle flights originating or terminating at Baltimore. The second category concerns flights handed off from one low altitude tower to another, and not landing at the intermediate terminal. There is considerable activity of the second type between Washington National Airport and airports to the northeast. The controller workload, generated by this traffic, is concealed from the Washington ARTC Center, as the aircraft are never under their jurisdiction. As traffic increases at Baltimore it is believed the tower will not have the airspace nor the time to accommodate this low altitude over traffic. Therefore, this existing workload will be imposed upon controllers at the Washington ARTC Center.

Measurements.

Delay measurements were recorded during the air route phase of the tests. Arrival delays were computed by comparing the theoretical time at which each aircraft should be over the approach fix on final approach (assuming that no other traffic were involved) with the actual arrival time of such aircraft over the approach fix.

Departure delays were computed by comparing the proposed departure time with the actual departure time. Because of a shortage of target projectors, all arrivals were taken off the screen at the outer marker, instead of being flown to touchdown. Therefore, the departure delays do not include the effects of runway occupancy by landing aircraft. The air route phase delay data are shown in Fig. 6.

No arrival delay measurements were made for aircraft at Washington National Airport since only minor changes were made in the terminal area. This traffic was simulated in the systems until their arrival at the approach clearance limit. All departing traffic from Washington National was simulated through the area, in order that a realistic en route environment would be maintained.

## TERMINAL AREA TEST RESULTS

General.

In developing holding and approach pattern layouts for this program, full cognizance was taken of the entire Washington-Baltimore area to insure that patterns did not overlap, or needlessly block usable departure paths, airway routes, or restricted areas. For this reason, full advantage could not be taken of ideal approach configurations for any single airport. Instead, the resulting systems represented compromises between various competing airspace requirements.

Approach System I.

In this system, shuttle flights between Baltimore and Washington National utilized two altitudes via the Don Intersection, as shown in Fig. 7. Washington departures were cleared to Don at 2,000 feet and Baltimore departures were cleared to Don at 3,000 feet. No holding was accomplished at Don Intersection. Shuttle departures were coordinated between towers, and if an arrival delay was anticipated, the aircraft took the delay on the ground at the point of departure. Since in all the shuttle systems tested, one or more of the routes required complete radar guidance, the controller workload was high for a few aircraft controlled.

At the traffic density simulated at Baltimore Friendship, it was desirable to provide prop aircraft with dual holding stacks. One stack was at the Baltimore VOR, and the other at a VOR intersection 23 miles west/northwest of the outer marker, referred to as the Damascus pattern. This distant location was necessary to provide a penetration area for civil jets at Baltimore.

Sufficient airspace to provide straight-in approaches from the west for civil jets was not available at Baltimore Friendship Airport without another substantial increase in route mileage for Washington arrivals from the northeast. Therefore, a teardrop type approach was utilized, leaving the Baltimore VOR outbound and returning to the Baltimore outer compass locator. Sufficient airspace was not available for full size jet penetration area. Therefore, the jet penetration shown in Fig. 7 is a ground-controlled penetration and may become unusable if radar is inoperative. Jet aircraft landing at the Glen Martin Airport were handled as Baltimore arrivals using the same penetration area as the civil jets. From the Baltimore outer compass locator, they were vectored to a northwest landing at Martin Airport. This final approach at Martin uses a portion of restricted area 54. The holding pattern airspace used in these tests for jet aircraft at the Baltimore VOR infringed on restricted area 54 as shown in Fig. 2.

Approach System 2.

This approach system utilized landings to the southeast with the jet penetration being made on the west side of the localizer as shown in Fig. 8. No altitude restrictions were necessary for the jet penetration as its path crossed only the very low altitude shuttle aircraft pattern, and did not cross any arrival or departure routes. Jet aircraft destined for the Glen L. Martin Airport were handled as Baltimore arrivals, and then vectored to a northwest approach as shown in Fig. 8.

Two holding patterns for prop aircraft were provided; however, the Jessup pattern was used only for Washington shuttle flights and was limited at 3,000 feet or below. The Pikesville pattern contained the remaining prop aircraft. At the density simulated, holding altitudes often reached 10,000 feet. Prop aircraft arrivals from the west were given circuitous routing to arrive at the Pikesville pattern from the north. This system provided for a non-radar controlled route for shuttle flights from Washington to Baltimore. However, shuttle flights from Baltimore to Washington still were necessarily controlled by radar as in Approach System 1.

Jet aircraft destined for the Glen L. Martin Airport were handled as Baltimore arrivals and were vectored to a northwest landing as shown in Fig. 8. Southeast landings for these aircraft were considered but no adequate system could be devised without complete disruption of the arrival and departure routes north of Baltimore.

Approach System 3.

This system used a southeast landing direction with jet penetrations conducted on the east side for the localizer course as shown in Fig. 9. The jet penetrations were restricted in their descents to maintain an altitude above 10,000 feet until clear of the departure airway, Victor 93. This did not affect the penetration to any extent and it is believed that it would not affect the departures to any degree. Two holding fixes were provided for aircraft in this system. Shuttle flights from Washington National and arrivals from the south, west, and northwest were cleared to the Relay holding pattern. Prop arrivals from other directions were cleared to the Baltimore VOR.

This system provided for a non-radar controlled route for shuttle flights from Washington to Baltimore. However, shuttle flights from Baltimore to Washington still were necessarily controlled by radar as in Approach Systems 1 and 2. Jet aircraft destined for Glen L. Martin Airport were handled as Baltimore arrivals and were vectored to a northwest landing as shown in Fig. 9. Southeast landings for these aircraft were considered but no adequate system could be devised without complete disruption of the arrival and departure routes north of Baltimore.

Measurements.

Communications data from the terminal area tests are shown in Fig. 10. Approach system acceptance rates are listed in Fig. 11.

Holding Patterns.

Table VII lists the areas required for Technical Standard Order (TSO) holding airspace reservations. Because of the critical shortage of airspace in the Washington-Baltimore area, extensive study was made during this project to possible methods of reducing these requirements. The dual-hinge pattern concept shown in Fig. 12A appears to be a practical method of exploiting air-derived distance information for this purpose. It also could be utilized by homing alternately on two radio stations as shown in Fig. 12B.

For a long time it was realized that aircraft entering holding patterns from the sides sometimes overshoot the boundaries of the TSO area as shown in Fig. 13A. This is particularly true for jet and high performance prop types of aircraft. To correct this condition, a new technique known as the tangential entry procedure, which is shown in Fig. 13B can be based on the use of either distance information or dual homing facilities. It avoids the large overshoots presently encountered and gets the aircraft lined up on the proper holding track in a minimum of time. Both techniques were advantageous in the simulation tests.

CONCLUSIONS

General.

During this program, the basic problem of integrating multiple-airport jet and prop operations in a severely confined area required the development of a number of techniques and procedures which are expected to have general application in other airport areas. The most important developments are listed below:

1. While not as easy to control as the offset holding pattern, it was found that the overhead pattern shown in Fig. 14B functions very well, provided that continuous target tracking is available through the use of either a beacon system or an offset primary radar.

2. Tests showed that the conventional teardrop pattern, as shown in Fig. 14A, is poorly adapted for radar spacing operations. From the time the turn is started by an aircraft at the outer end of the pattern, very little can be done to adjust the spacing of this aircraft behind the preceding aircraft. The triangular penetration path shown in Fig. 14B proved far superior. After the aircraft started a turn to the base leg heading, the radar controller could use path-stretching techniques to space this aircraft behind the preceding one.

3. It was found that approach spacing operations for jet aircraft are considerably more difficult to accomplish than those required for propeller aircraft because of:

a. The very slow turning rate of jet aircraft at high speeds.

b. The need for a relatively long uninterrupted descent path from the initial penetration altitude to the final approach altitude. For example, category 1 jet aircraft in this problem required approximately 32 nautical miles to descend from 20,000 to 2,000 feet.

c. The large variation between the initial penetration speed and the final approach speed.

To alleviate these problems the following techniques were developed:

1. Align the jet holding pattern in a direction which will allow aircraft to leave the pattern laterally, instead of at the end. This permits more flexibility and enables the controller to peel off successive aircraft at accurate intervals in spite of the very slow turning rate of the aircraft in the pattern. This pattern arrangement could not be used in certain cases due to the available airspace.

2. Require the pilot to report vacating each 5,000-foot level to keep the controller aware of the progress of the descent and enable him to keep the penetration path as short as possible and insure adequate time for the aircraft to reach the glide slope interception altitude.

3. Request the pilot to report when he is slowed down at the glide slope interception altitude to help the controller to anticipate when the aircraft will be able to make turns at the rate of 3° per second.

4. Conduct radar path stretching operations of jet and prop aircraft on opposite sides of the final approach course to simplify the spacing operation and also increase safety by eliminating most of the overtaking situations in the radar vector area.

Specific.

1. It is believed that a route structure similar to the modified route Systems A or C, depending on desired landing direction, will be necessary to accommodate a substantial increase of IFR traffic at Baltimore Friendship Airport.

2. Because the route changes in Systems A, B, and C were considered to be the minimum necessary to accommodate the traffic densities tested, it is

believed that traffic densities greater than those simulated cannot be adequately controlled without further major realignment of the airway structure.

3. In Approach System 1, the mixing of jet and prop transports seriously reduces the potential arrival rate at Baltimore Friendship Airport because of the distant location of the Damacus prop pattern. Approach Systems 2 and 3 were an improvement as far as terminal area arrival operations were concerned. See Figs. 8 and 9.

4. There is not sufficient area to establish standard non-radar controlled jet penetrations at Baltimore in any direction without complete reorganization of airways. Therefore, the Baltimore jet penetrations as depicted were ground-controlled and not necessarily usable if radar or beacon was inoperative.

5. To provide an area for ground-controlled jet penetration, it will be necessary to rearrange routes north and west of Baltimore, thus increasing route mileage for the New York-to-Washington traffic.

6. If the Baltimore terminal traffic increases to any extent, the Baltimore tower will not be able to continue the control of low altitude en route flights that presently proceed through their terminal area while operating between Washington National Airport and terminals to the north.

7. Because of the proximity of Harbor and Glen L. Martin Airports to Baltimore Friendship, one approach control facility should handle IFR operations at the three airports.

8. IFR operations at Glen L. Martin Airport will extend into restricted area 54, unless both landings and departures operate northwest of the airport.

9. National Guard jet aircraft destined for Glen L. Martin Airport will create a high controller workload because of the long aircraft vector path, and the amount of coordination necessary between arrival and departure controllers.

10. Over traffic operating on Victor 44 will seriously delay jet-type aircraft landing at Baltimore Friendship. To a lesser extent, they will also decrease the arrival rate of prop aircraft at Baltimore Friendship.

11. Operations at Davidsonville NAS will eliminate the possibility of obtaining shorter routes from Baltimore Friendship Airport to the south. Arrival and departure operations at Davidsonville to and from the north

and west through the Baltimore area will create a complex problem for the Washington ARTC Center and would create a heavy workload per aircraft.

12. It appears that any sizable increase of air route control efficiency in the present airway configuration will require one or more of the following basic changes.

a. Large reductions in the airspace presently allocated for restricted areas 37, 38, 40, 54, 71, 43, and caution area 55.

b. Reductions in the amount of airspace required for jet holding patterns.

c. Reduction of the present 10-mile width requirement for civil airways, leading to the establishment of more closely spaced parallel lanes.

RECOMMENDATIONS

Before additional IFR traffic is scheduled into the Washington-Baltimore complex, the use of as much of the restricted airspace as is necessary, should be secured to provide independent arrival and departure routes for the major airports. This will provide airspace for the development of a route system similar to modified Systems A, B, or C.

TABLE I

TRAFFIC DENSITY SAMPLE

| Airport | Traffic Density (Operations per hour) |
|---|---|
| Davidsonville | 12 |
| Andrews | 20 |
| Baltimore Friendship | 32 |
| Washington National | 50 |
| Over flights | 10 |

## TABLE II

### SUMMARY OF CHANGES MADE IN AIRWAY CONFIGURATION

RESTRICTED AREAS ALTERED

| | CHANGE | REASON |
|---|---|---|
| 1. | R-37 | To provide airspace for Airways Victor 3 - Victor 140 - Victor 904 |
| 2. | R-38 | To provide airspace for Airways Victor 904 and relocated Amber 7 |
| 3. | R-40 | To provide airspace for relocated Airway Amber 7 |
| 4. | R-43 | To provide airspace for Airway Victor 903 |
| 5. | R-54 | To provide airspace for Airway Victor 907 and Departure routes from Davidsonville, Andrews, Baltimore, and Washington |
| 6. | C-55 | To provide airspace for Airways Victor 268 and Victor 223 |

PROPOSED VOR LOCATIONS

| CHANGE | REASON |
|---|---|
| 1. ROUND HILL, VA., VOR | New independent arrival route to Washington from northwest |
| 2. HAYMARKET, VA., VOR | New independent departure route from Washington to west and southwest |
| 3. CASANOVA, VA., VOR | New independent departure route from Washington to west and southwest |
| 4. CHESTERTOWN, MD., VOR | New routes from Washington, Baltimore, Andrews, and Davidsonville to northeast, east, and southeast |
| 5. QUANTICO LF Range changed to POTOMAC, VA. VOR and relocated 4 statute miles northwest of present QUANTICO site | To provide new independent routes from Washington, Andrews, and Davidsonville to the west and southwest |

TABLE II (continued)

SUMMARY OF CHANGES
MADE IN AIRWAY CONFIGURATION

| CHANGE | | REASON |
|---|---|---|
| **PROPOSED VOR LOCATIONS** | | |
| 6. | Relocate WESTMINSTER, MD. VOR 6 1/2 statute miles northwest of present location | To provide more airspace for jet penetration at Baltimore |
| **NEW AIRWAYS PROVIDED** | | |
| 1. | Victor 901 | To provide a new route for northbound traffic from Davidsonville, Washington, and Andrews, independent of Baltimore |
| 2. | Victor 902 | To provide independent departure route from Washington to the west and southwest |
| 3. | Victor 903 | To provide a new route from Davidsonville and Baltimore to and from the south |
| 4. | Victor 904 | To provide new route for Davidson-sonville, Andrews, and Washington departures to the west |
| 5. | Victor 905 | To provide a departure route from Baltimore to New York and northeast |
| 6. | Victor 906 | To provide independent arrival route to Washington from the northwest |
| 7. | Victor 907 | To provide a route for Dover traffic to bypass Baltimore |
| 8. | Victor 908 | To provide a route to Davidsonville and Andrews from the north and northeast that will bypass Baltimore |
| 9. | Victor 909 | To provide a departure route from Washington to the northeast |

TABLE II (continued)

SUMMARY OF CHANGES
MADE IN AIRWAY CONFIGURATION

| CHANGE | REASON |
|---|---|
| ROUTE MODIFICATIONS OR PROCEDURAL CHANGES | |
| 1. Victor 3/39 moved west | To provide airspace for jet penetration at Baltimore |
| 2. Victor 44 closed to over traffic between Lisbon, MD, intersection and Baltimore | To allow jet penetration at Baltimore |
| 3. Victor 16/Green 5 closed to over traffic between Ingleside and Doncaster | To provide for Davidsonville-Andrews Radar Approach Control Area |
| 4. Blue 56 closed to over traffic between Coles Point and Andrews LF Range | To provide for Davidsonville-Andrews Radar Approach Control Area |
| 5. Red 20 closed to over traffic between Meekins Neck and Andrews LF Range | To provide for Davidsonville-Andrews Radar Approach Control Area |
| 6. Blue 21 closed to over traffic between Coles Point and Severna Park | To provide for Davidsonville-Andrews Radar Approach Control Area |
| 7. Red 77 changed to a major route replacing Victor 16/Green 5 | Davidsonville Airport |
| 8. Amber 7 realigned in vicinity of Doncaster and Grubbs | To provide independent routes for Washington, Andrews, and Davidsonville |
| 9. Victor 223 realigned to the west | To provide airway separation between Victor 223 and Victor 3/39 |
| 10. Andrews ADC Scramble procedures eliminated | Davidsonville Airport |
| 11. Victor 268 relocated at the new Westminster location | To provide independent departure routes from Baltimore, Andrews, and Davidsonville to the west and northwest |

TABLE II (continued)

SUMMARY OF CHANGES
MADE IN AIRWAY CONFIGURATION

| CHANGE | REASON |
| --- | --- |
| ROUTE MODIFICATIONS OR PROCEDURAL CHANGES | |
| 12. Victor 33 relocated to the east. | To provide jet penetration at Baltimore |
| 13. Victor 93 realigned from Lancaster VOR direct to Baltimore Outer Marker | To provide airspace for additional independent route to Baltimore from the northeast |
| 14. Delete Victor 123 from Riverdale to Baltimore LF Range | Baltimore increased traffic |

## TABLE III

## LOCATION IDENTIFIERS USED ON MAPS

| | |
|---|---|
| ADW | ANDREWS AFB, MD. |
| ARV | ARCOLA, VA. LFR |
| BAL | BALTIMORE, MD. (Friendship) |
| CAH | CHARLOTTE HALL, VA. Radio Beacon |
| CES | CHESTERTOWN, MD. - Proposed VOR |
| CNV | CASANOVA, VA. - Proposed VOR |
| DAV | DAVIDSONVILLE, MD. - Proposed NAS |
| DCA | WASHINGTON, D.C. |
| DCS | DONCASTER, VA. Intersection |
| DMS | DAMASCUS, MD. Intersection |
| DOV | DOVER, DEL. VOR |
| EMI | WESTMINSTER, MD. - Relocated VOR |
| ESR | WEST CHESTER, PA. VOR |
| FRR | FRONT ROYAL, VA. VOR |
| GBS | GRUBBS, VA. Intersection |
| GTN | GEORGETOWN, D.C. Radio Beacon |
| GVE | GORDONSVILLE, VA. VOR |
| HAR | HARRISBURG, PA. VOR |
| HMK | HAYMARKET, VA. - Proposed VOR |
| HNT | HUNTINGTON, VA. Radio Beacon |
| HRN | HERNDON, VA. VOR |
| ILG | NEW CASTLE, DEL. - Proposed VOR |
| ING | INGLESIDE, MD. Intersection |
| LRP | LANCASTER, PA. VOR |
| LSO | LISBON, MD. Intersection |
| MRB | MARTINSBURG, W.VA. VOR |
| MTN | GLENN MARTIN AIRPORT, MD. |
| NHK | PATUXENT RIVER, VA. LFR |
| NRV | NORRIS(ville), MD. Intersection |
| NYG | QUANTICO, VA. LFR |
| OOD | WOODSTOWN, N. J. VOR |
| PAR | PARKTON, MD. Intersection |
| PDP | PORT DEPOSIT, MD. Intersection |
| PHL | PHILADELPHIA, PA. - Proposed VOR |
| PTC | POTOMAC, VA. - Proposed VOR |
| RDH | ROUND HILL, W. VA.- Proposed VOR |
| RVD | RIVERDALE, MD. Radio Beacon |
| SBY | SALISBURY, MD. VOR |
| SHZ | SHADYSIDE, MD. Radio Beacon |
| SNV | SEVERNA PARK, MD. Intersection |
| SRI | SPRINGFIELD, VA. Radio Beacon |
| TPP | TAPPAHANNOCK, VA. LFR |

TABLE IV

ADVANTAGES AND DISADVANTAGES OF
MODIFIED SYSTEMS B AND C

MODIFIED SYSTEM B

| Advantages over System A | Disadvantages as compared with System A |
|---|---|
| 1. Possible to provide a very low altitude stack for use of shuttle flights from Washington to Baltimore. | 1. Only one stack available for use of prop aircraft arriving at Baltimore. |
| 2. Prop aircraft arrive at a point closer to approach course than the Damascus intersection. | 2. Additional traffic routed over Westminster VOR which will complicate control at this point. |
| 3. Aircraft enroute to Riverdale would have longer route for descent than when Damascus insection is used for Baltimore. | 3. Victor Airway 3 relocated via Germantown intersection to Riverdale to remain clear of jet penetration area at Baltimore. In so doing, the Georgetown to Martinsburg independent departure route was eliminated. This in turn forced the departure routes southward via Herndon VOR. Thus an independent arrival route from Grantsville to Springfield via Round Hill VOR was eliminated. |
| 4. Jet penetration equally as good as System A. | 4. Washington arrivals from the northwest converge at Front Royal, because of factor listed in Item 3 above. This will complicate control at Front Royal. |
| 5. Departure routes to northeast, east, and south are equal to System A. | 5. Prop aircraft arriving at Baltimore from the west fly 23 nautical miles further than in System A. |
| | 6. Prop aircraft departing Baltimore to the west fly 37 nautical miles further than in System A. |
| | 7. Arrivals at Riverdale fly 6 nautical miles further than in System A. |

TABLE IV (continued)
MODIFIED SYSTEM C

| Advantages over System A | Disadvantages as compared with System A |
|---|---|
| 1. Two close-in holding stacks for prop aircraft are provided. | 1. All northeast bound departures from Washington and Baltimore proceed via Chestertown VOR. This will complicate control at this point. |
| 2. Good shuttle route between Washington and Baltimore is provided. | 2. Additionally Washington northeast bound traffic was routed via Dover to secure additional independent climb area. This will complicate control in the vicinity of Dover AFB. |
| 3. Prop aircraft holding pattern to west of Baltimore is off Victor Airway 3. Once clear of this airway arriving aircraft will be in a position to descend without additional restrictions. | 3. The jet holding pattern at Baltimore uses a large portion of restricted area 54. |
| | 4. Victor Airway 3 relocated via Clarksburg intersection to Riverdale to remain clear of Relay holding pattern at Baltimore. In so doing, the Georgetown to Martinsburg departure route was eliminated. This in turn forced the departure routes southward via Herndon VOR. These factors forced elimination of an independent arrival route from Grantsville to Springfield via the Round Hill VOR. |
| | 5. Washington arrivals from northwest converge with other arrivals at Front Royal because of factors noted in Item 4 above. This will complicate control at Front Royal. |
| | 6. In order to provide a short-lower altitude departure route to the north from Baltimore it was necessary to complicate the jet penetration by placing an altitude restriction on descent until clear of Victor Airway 93. |
| | 7. When conditions require a west or northwest bound departure from Baltimore to take the Chestertown - Fawn Grove - Westminster routing, the aircraft will fly an additional 70 (nautical) miles as compared with System A. |

## TABLE V

## JET PENETRATION SPEEDS

## (TAS IN KNOTS)

| | | | | | |
|---|---|---|---|---|---|
| | Aircraft Category No. | 1 | 2 | 3 | 4 |
| Altitude (Feet MSL) | Representative Type | F104 | DC8 | B707 | T33 |
| | 20,000 | 415 | 330 | 305 | 280 |
| | 15,000 | 410 | 330 | 305 | 280 |
| | 10,000 | 370 | 305 | 285 | 260 |
| | 5,000 | 320 | 260 | 240 | 215 |
| | (approach) 2,000 | 180 | 180 | 170 | 150 |

TABLE VI

RADAR SPACING CHART

| AIRCRAFT SEQUENCE NO. 1 | NO. 2 | GATE SEPARATION (MILES) |
|---|---|---|
| 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 | SMF | 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 |

TABLE VII

AREAS OF TSO HOLDING AIRSPACE
RESERVATIONS, IN SQUARE MILES

| Altitude MSL | Pattern Length | |
|---|---|---|
| | One-Minute | Two-Minute |
| 30,000 and above | 1030 | 1245* |
| 29,000 to 20,000 | 457 | 553 |
| 19,000 and below | 114 | 138 |

*For purposes of comparison, the area of the state of Rhode Island is 1248 square miles.

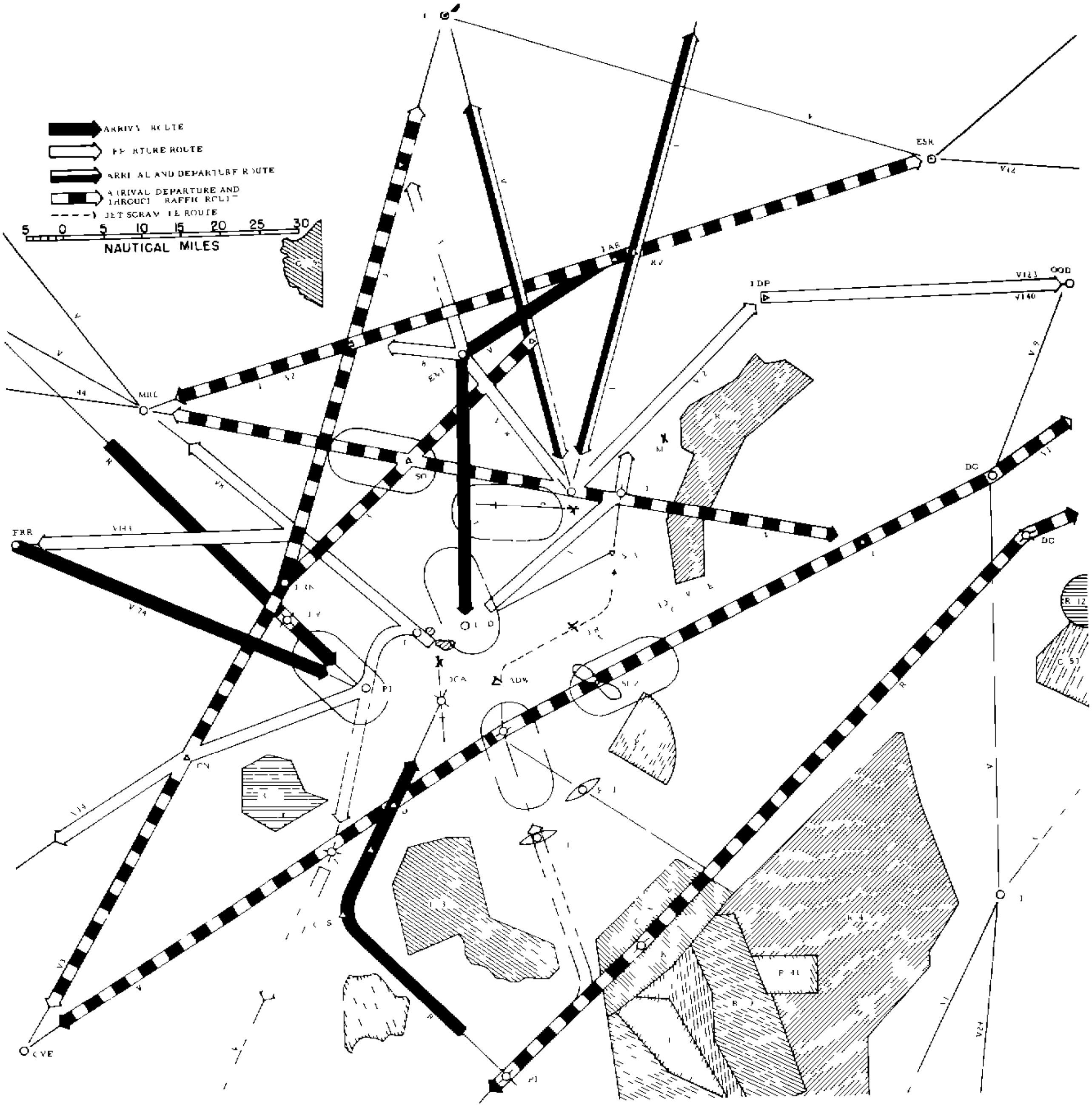



FIG I PRESENT ROUTE STRUCTURE

CAA TECHNICAL DEVELOPMENT CENTER INDIANAPOLIS INDIANA

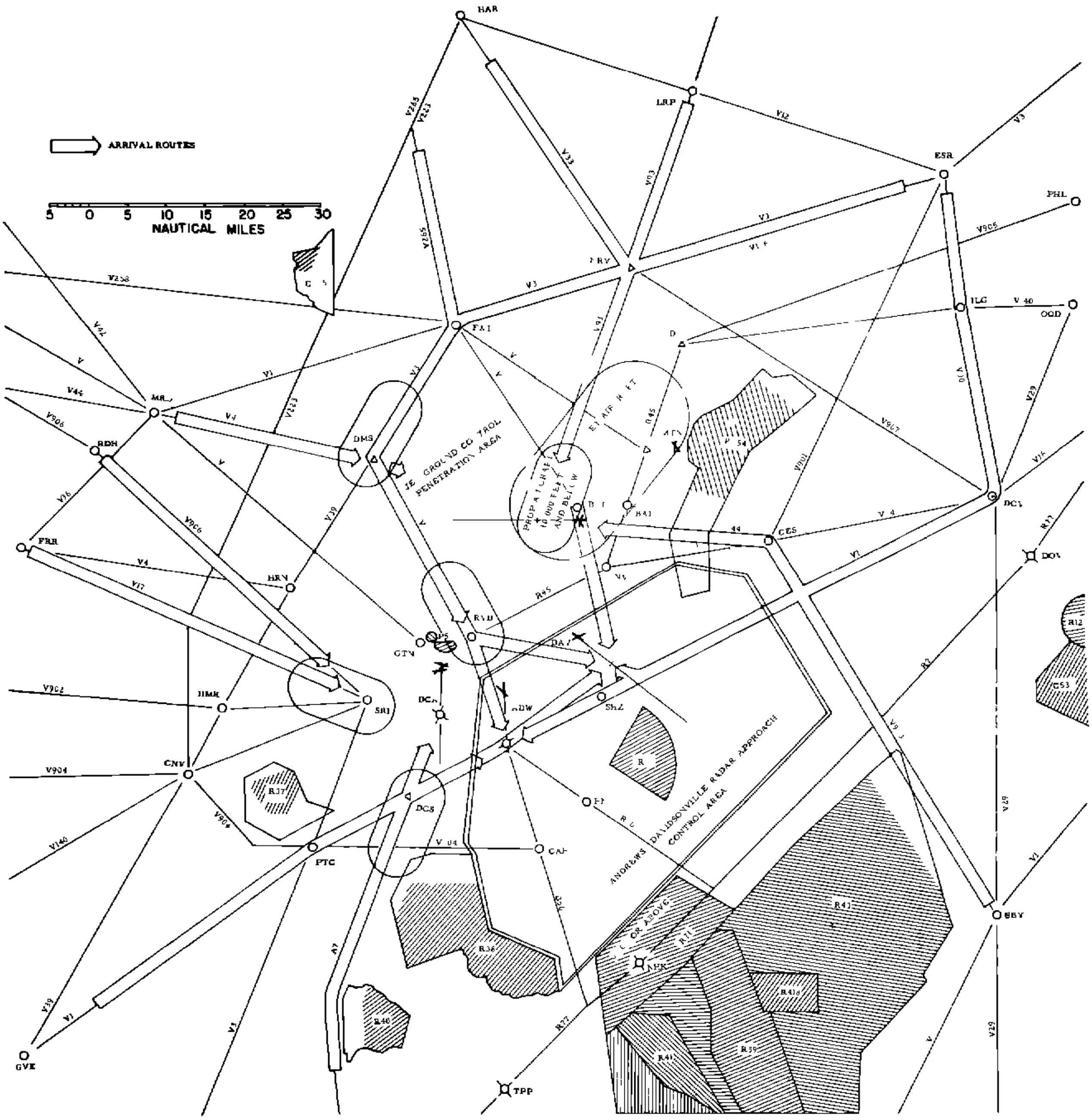


FIG 2 ARRIVAL ROUTES — MODIFIED SYSTEM A - EAST LANDING

CAA TECHNICAL
DEVELOPMENT CENTER
INDIANAPOLIS INDIANA

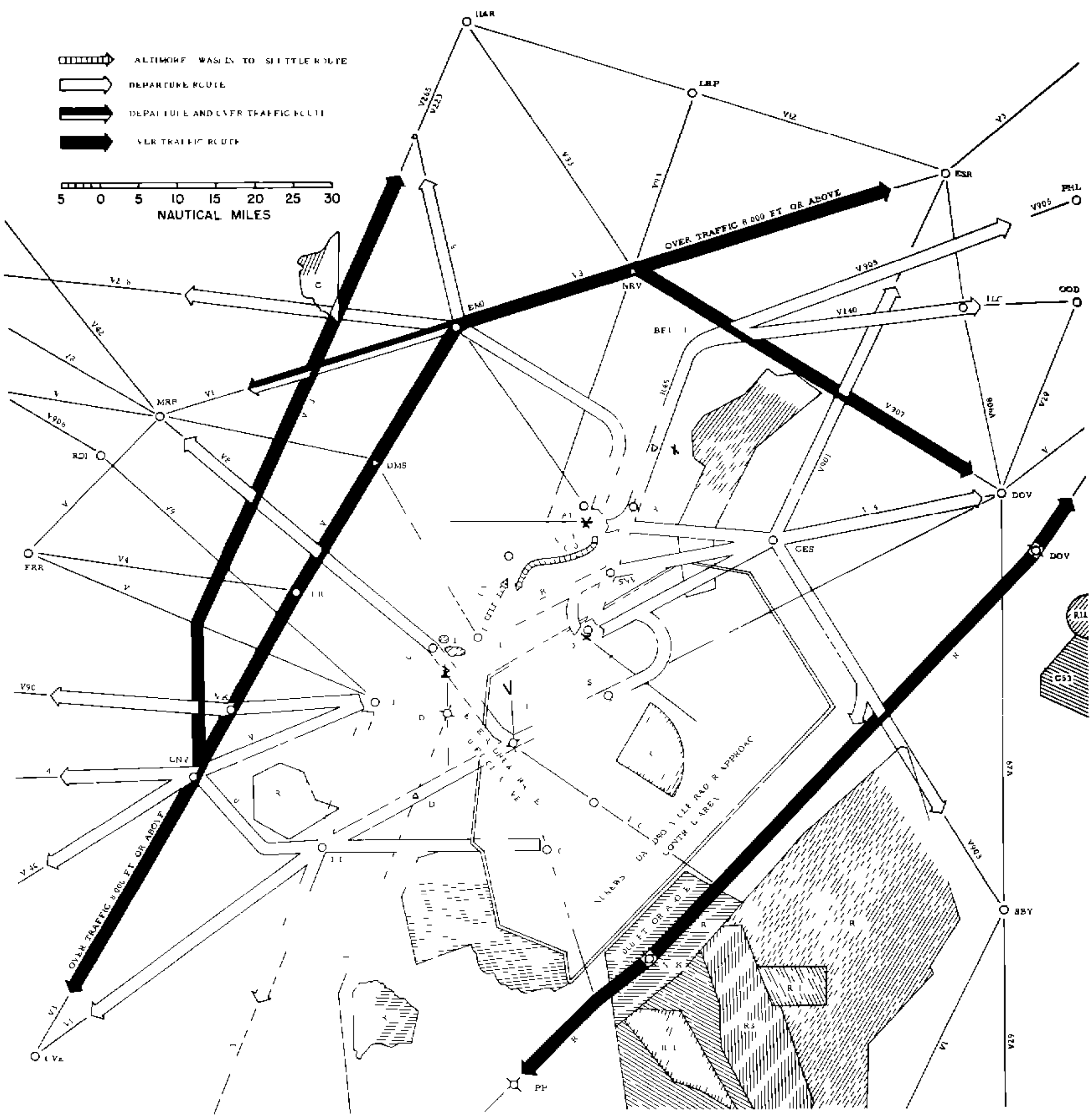



FIG 3 DEPARTURE ROUTES – SYSTEM A – EAST LANDING

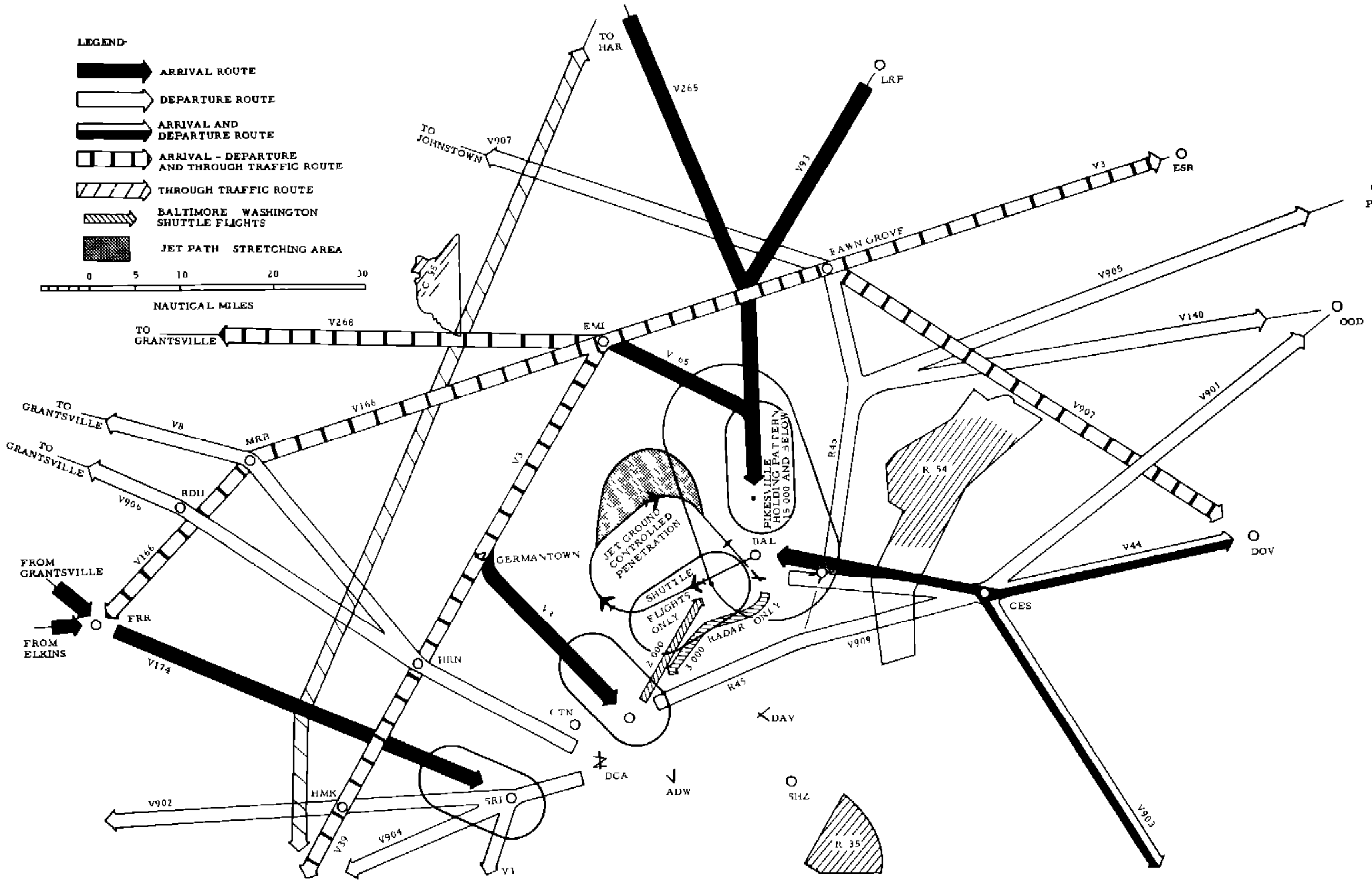



FIG 4 MODIFIED SYSTEM B — SOUTHEAST LANDING

CAA TECHNICAL DEVELOPMENT CENTER INDIANAPOLIS INDIANA

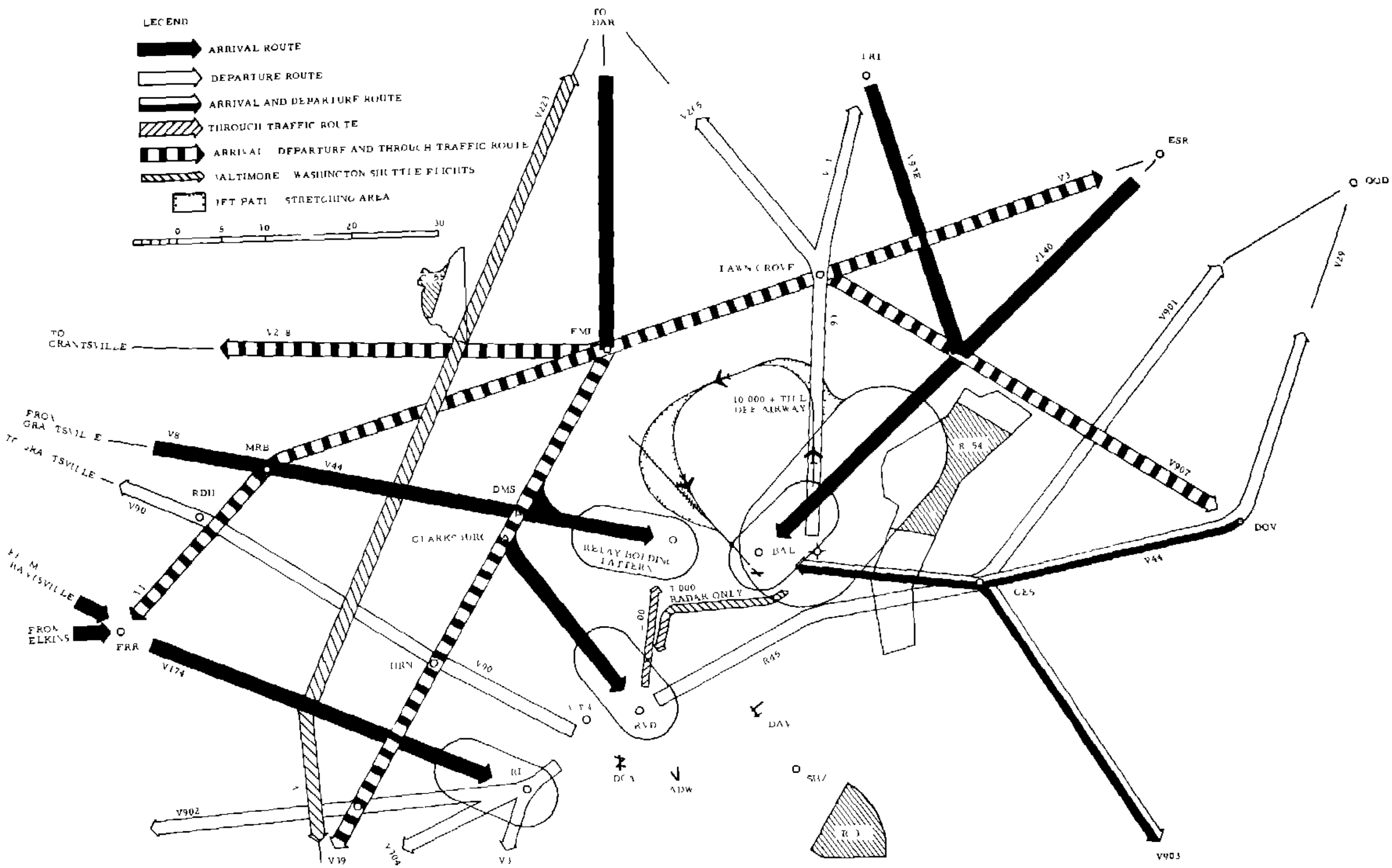



FIG 5 MODIFIED SYSTEM C-SOUTHEAST LANDING

CAA TECHNICAL DEVELOPMENT CENTER INDIANAPOLIS INDIANA

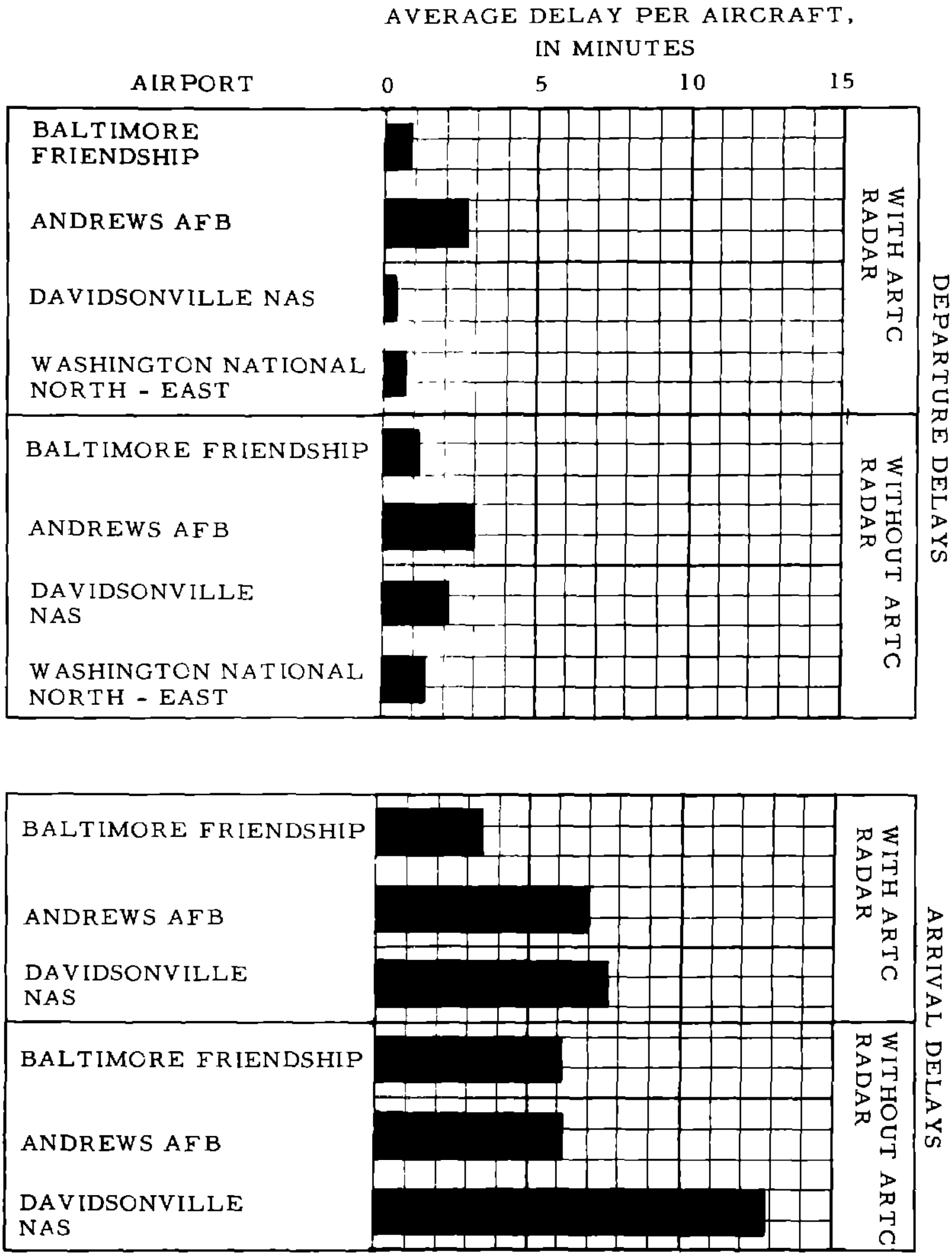



FIG. 6 -- AIRCRAFT DELAYS--MODIFIED AIR ROUTE SYSTEM A

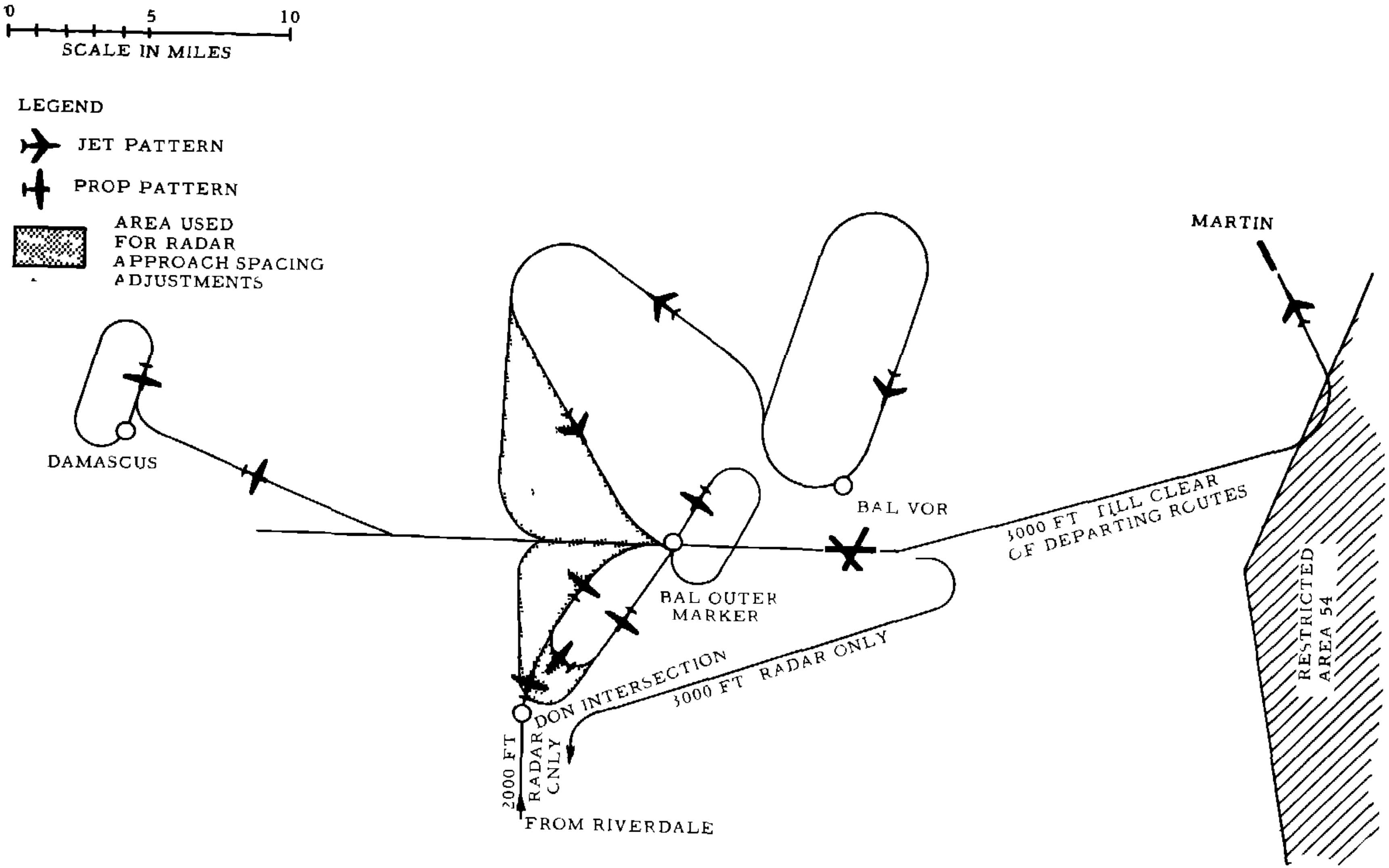



FIG 7 APPROACH SYSTEM 1 — EAST LANDING

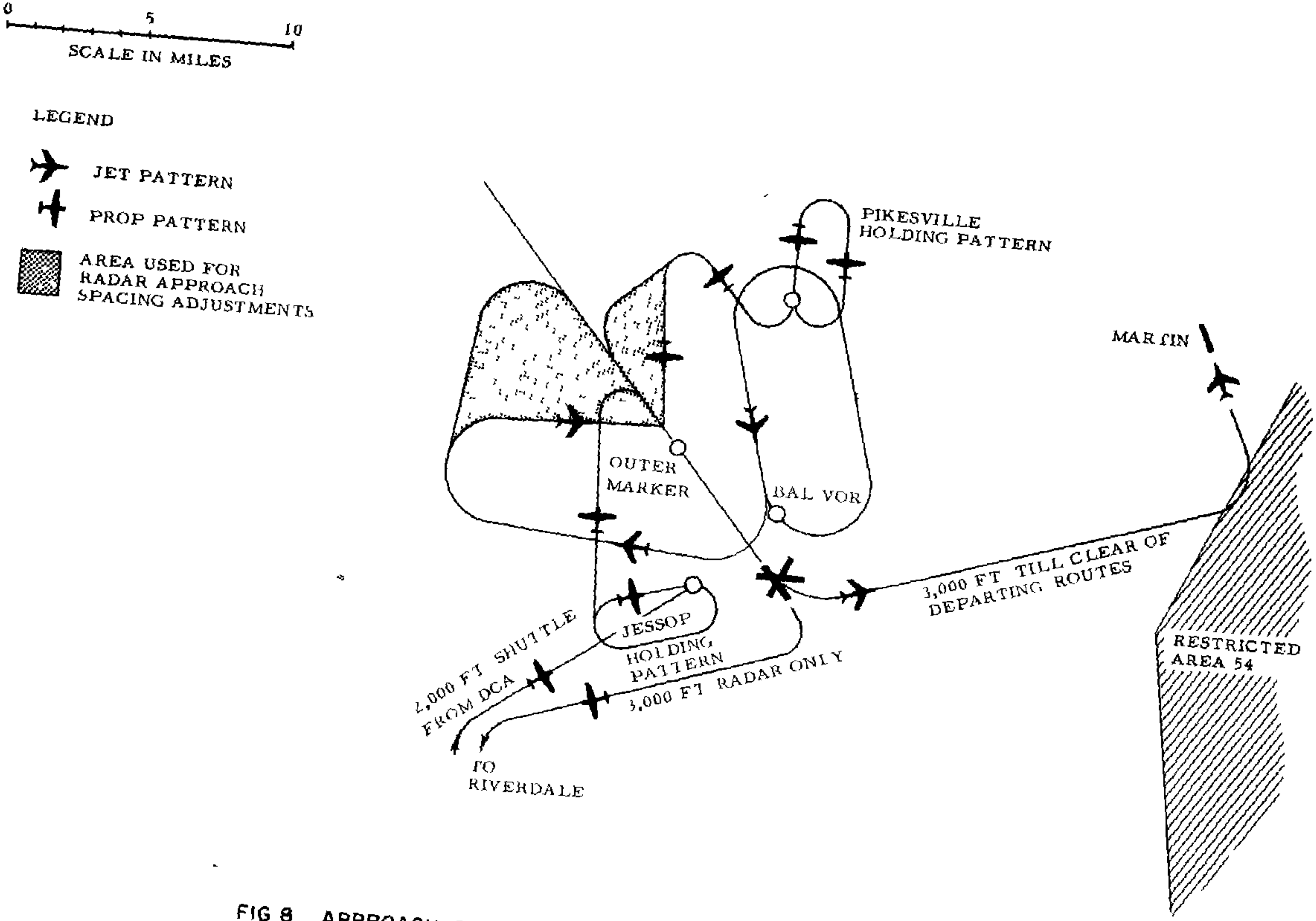



FIG 8 APPROACH SYSTEM 2 - SOUTHEAST LANDING

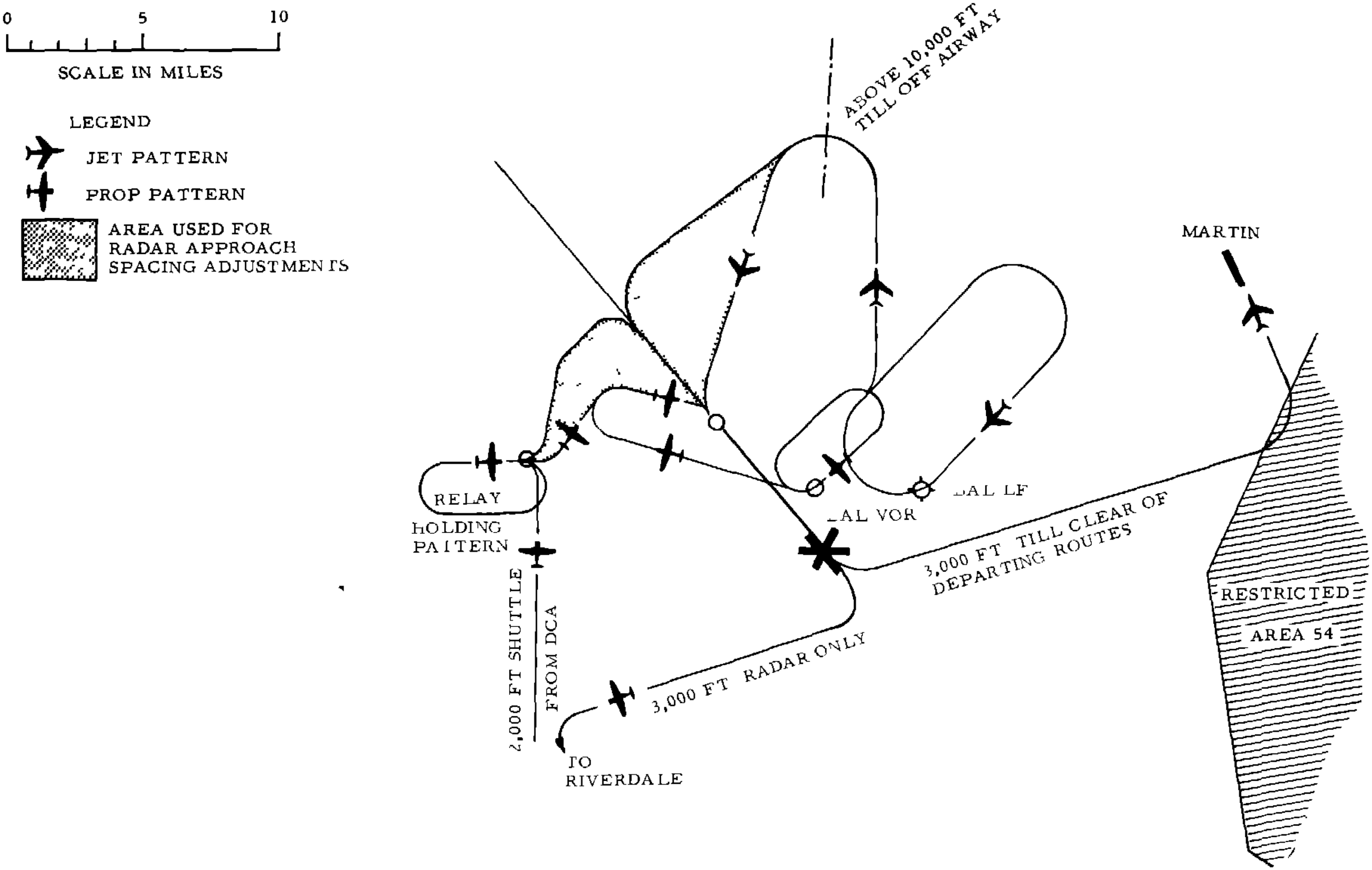



FIG 9 APPROACH SYSTEM 3-SOUTHEAST LANDING

CAA TECHNICAL
DEVELOPMENT CENTER
INDIANAPOLIS INDIANA

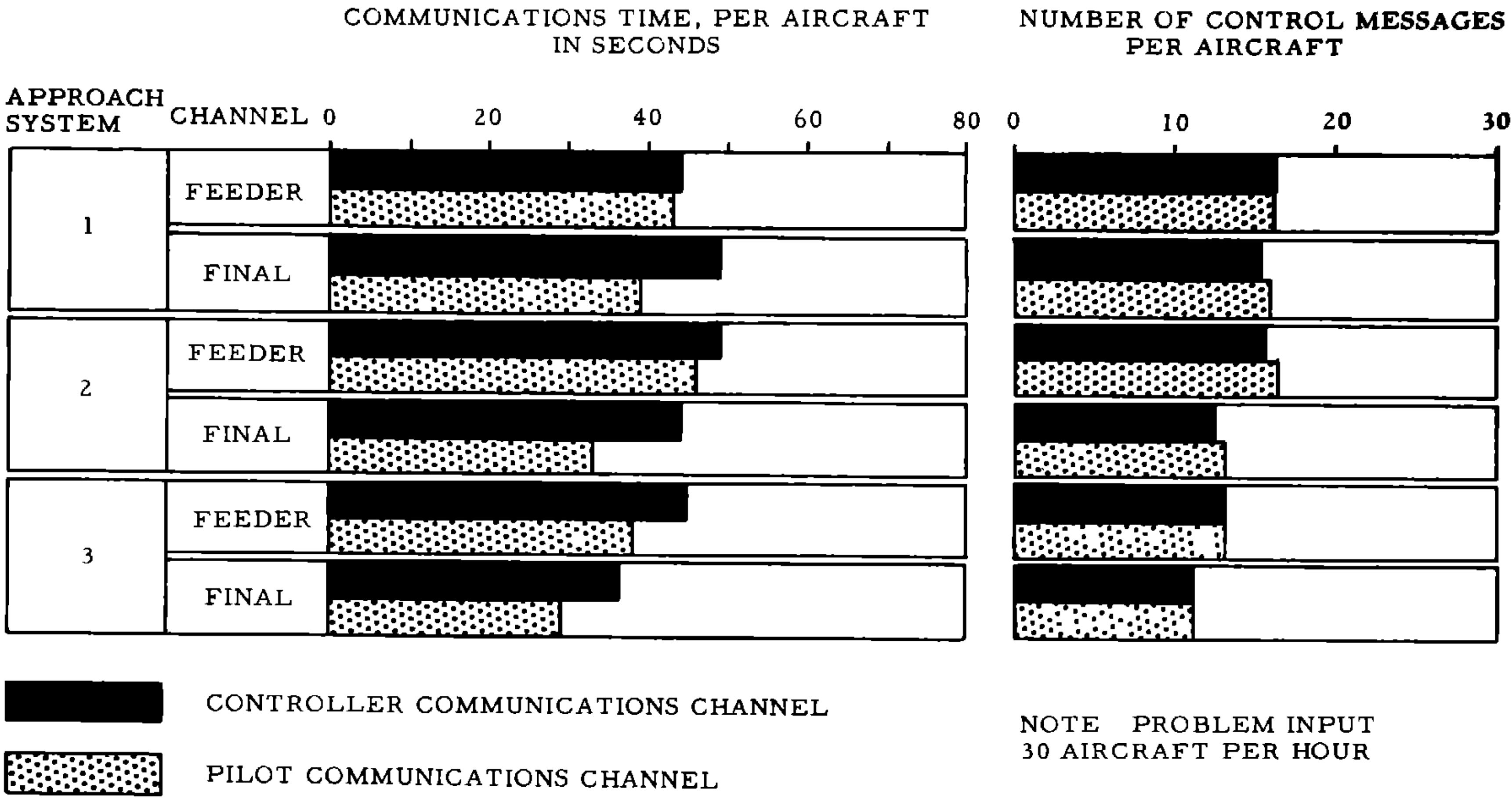



FIG 10 COMMUNICATIONS DATA - TERMINAL AREA TESTS

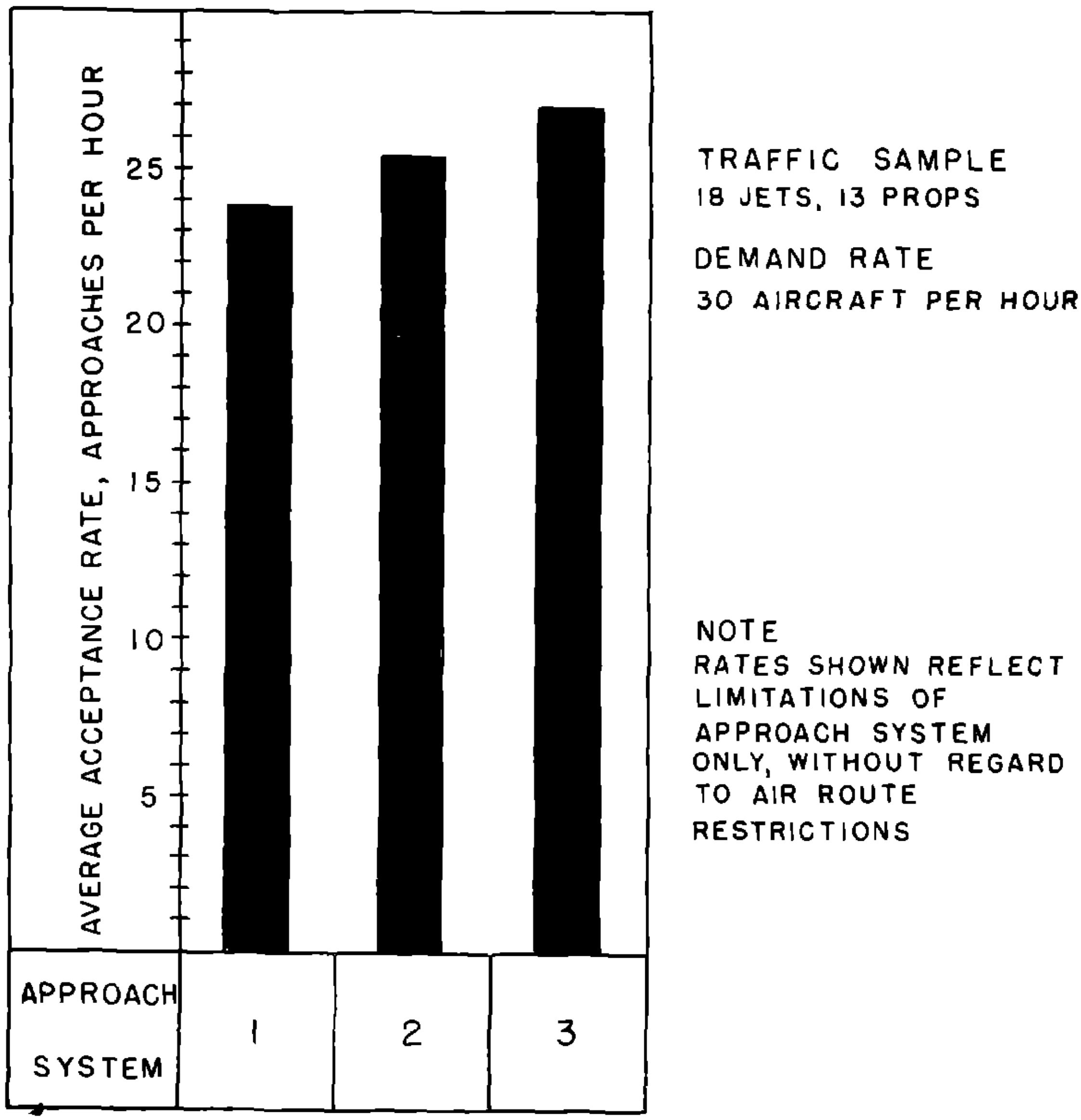



FIG 11 BALTIMORE FRIENDSHIP AIRPORT ACCEPTANCE RATES ATTAINED IN TERMINAL AREA TEST PHASE

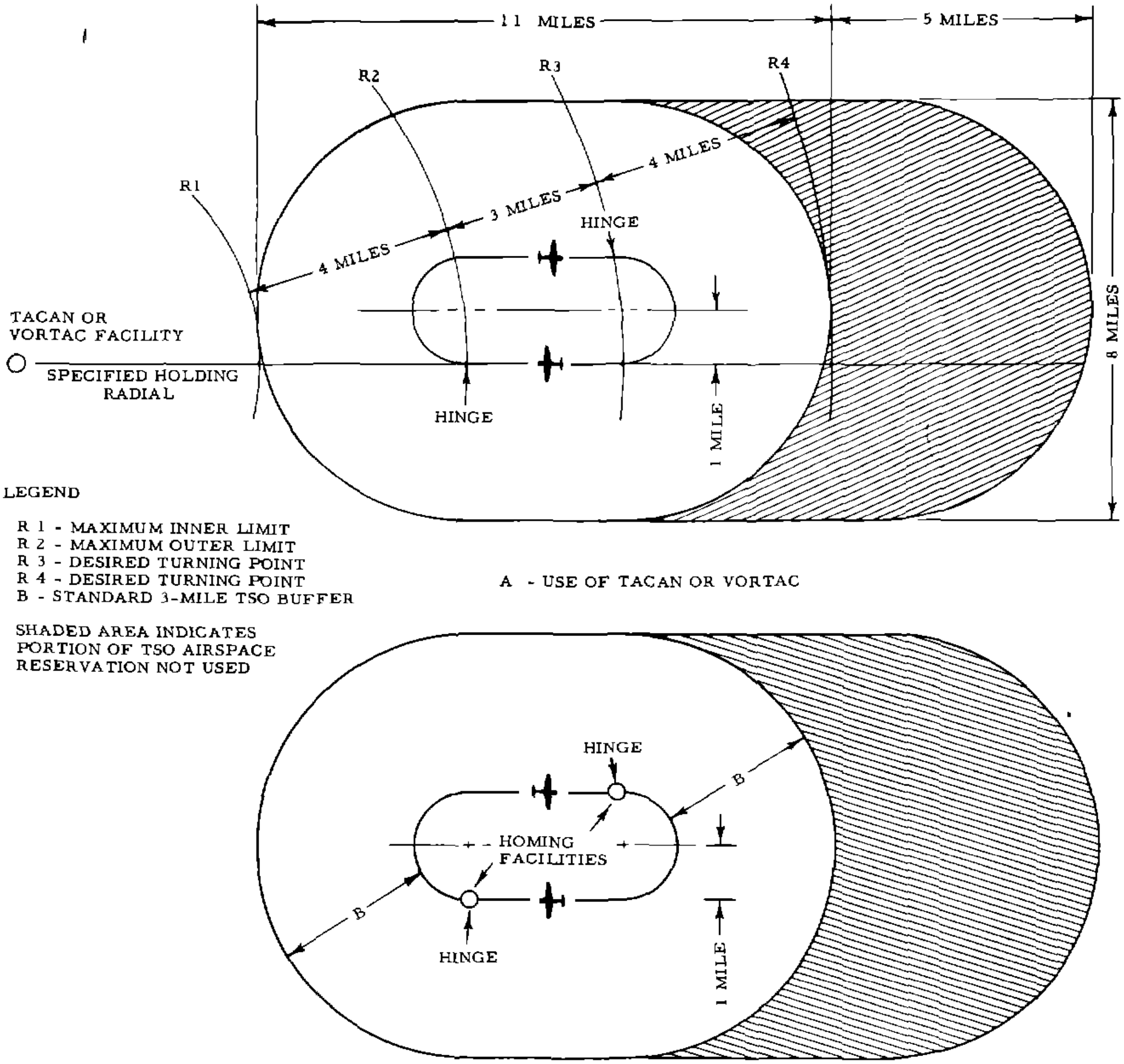
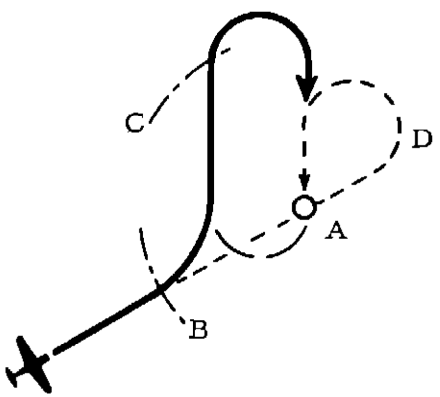


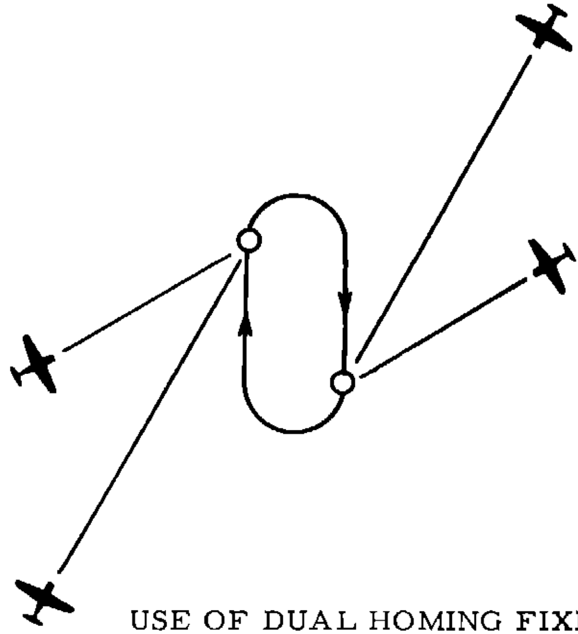

FIG 12 DUAL-HINGE HOLDING PATTERNS




USE OF DISTANCE INFORMATION
TO PERMIT TANGENTIAL ENTRY
TO HOLDING PATTERN OVER TACAN
OR VORTAC STATION

A - RADIO FIX
B - DISTANCE AT WHICH PILOT STARTS TURN TO OUTBOUND HEADING
C - DESIRED TURNING LINE
D - CONVENTIONAL ENTRY PATH

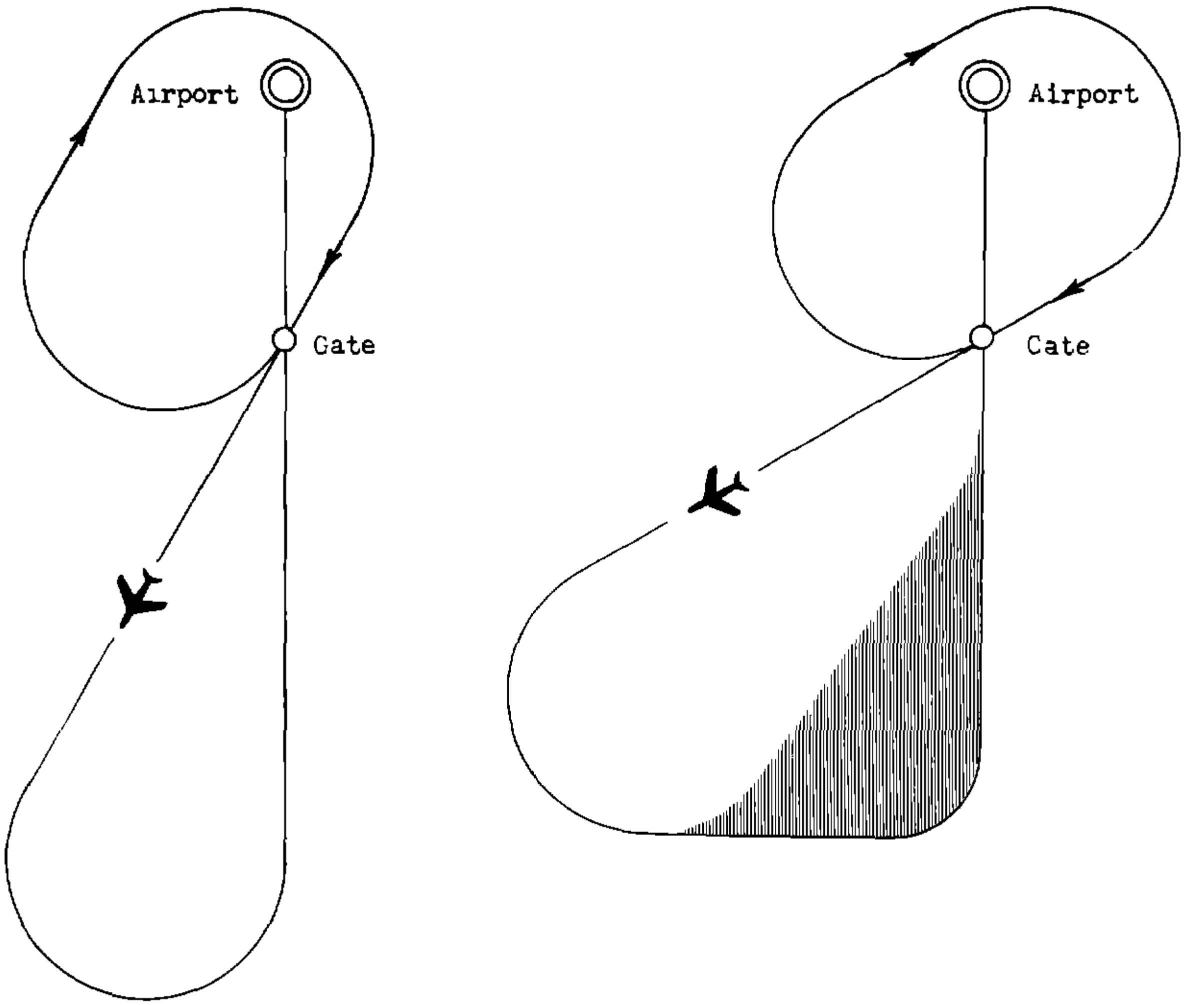
A



USE OF DUAL HOMING FIXES
TO PERMIT TANGENTIAL ENTRY

B

FIG 13 TANGENTIAL ENTRY PROCEDURES




A Conventional
Jet Penetration

B Triangular
Jet Penetration

Shading Indicates Area Available
For Path Stretching

FIG. 14 PENETRATIONS FROM OVERHEAD HOLDING PATTERNS