TECHNICAL DEVELOPMENT REPORT NO. 237

DYNAMIC-SIMULATION TESTS OF SEVERAL PROPOSED DUAL-AIRPORT TRAFFIC CONTROL SYSTEMS FOR WASHINGTON TERMINAL AREA

FOR LIMITED DISTRIBUTION

ADMINISTRATIVELY RESTRICTED

by

Clair M. Anderson
and
Tirey K. Vickers

Navigational Aids Evaluation Division

May 1954

CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS, INDIANA

DYNAMIC SIMULATION TESTS OF SEVERAL PROPOSED DUAL-AIRPORT TRAFFIC CONTROL SYSTEMS FOR THE WASHINGTON TERMINAL AREA

SUMMARY

This report describes the evaluation of several proposed methods of increasing the traffic capacity of the Washington terminal area. Specifically, these methods were aimed at developing the capacity of the two existing airports (Washington National and Andrews), rather than at investigating the possibilities for any additional airports in this area. The evaluation was conducted through the use of the Technical Development and Evaluation Center dynamic air traffic simulator.

Simulation tests showed that relatively simple changes in navigational facilities, routings, and procedures could provide at reasonable cost an immediate increase in the capacity of Andrews Field to approximately one-half that of Washington National Airport. Further changes, which could be made when needed, should increase the capacity of Andrews Field to equal the present capacity of Washington National Airport. Tests indicated that the use of independent segregated routes to and from each airport, with the entire area controlled from a centralized radar control room, should make these increases possible with very little effect on the present capacity of Washington National Airport.

Some of the principles learned in previous TDEC simulation studies were applied in modifying the facility layout for Washington National Airport. Tests indicated that these changes would increase the traffic capacity of this airport and would simultaneously reduce the controller workload per aircraft. Subsequent changes in the terminal area facility layout were made in order to maintain high traffic capacity for both airports under wind conditions which require that take-offs and landings be made in a southerly direction.

The flow characteristics of all systems tested were hampered somewhat by the four large danger areas and by the two small prohibited areas which now exist in the Washington terminal area. It was also found that Washington National Airport and Andrews Field are too close together to permit completely independent operations. Tests showed that these restrictions could be alleviated to some extent through the use of a northwest, instead of a north, landing approach system at Andrews Field.

INTRODUCTION

Background.

During the past few years, considerable study has been given to methods for increasing the traffic capacity of the Washington terminal area. In 1952, the Office of Federal Airways requested this Center to evaluate a number of procedures relating to the possible operation of a proposed supplementary airport at Burke, Virginia. The results of these tests[1] indicated that the addition of a third major airport at the proposed location in the Washington terminal area would complicate arrival and departure routes to a large extent and, in particular, would tend to restrict the traffic capacity of the Washington National Airport.

Development of the Andrews Air Force Base as a supplementary civil airport was then advocated, since it appeared quite feasible and somewhat less expensive than the construction of an entirely new airport. Accordingly, in June 1953, the Office of Federal Airways requested that a study be undertaken to determine how terminal area traffic could be handled to the best advantage in the event that it should ultimately be decided to supplement the Washington National Airport in this manner.

In gathering the necessary background material for this project, personnel from this Center spent several days at Washington visiting the various traffic control agencies and conferring with representatives of the Office of Federal Airways and CAA Region One. Coordination with the First Region was maintained throughout the subsequent simulation tests. Several representatives of the Washington Air Route Traffic Control (ARTC) Center assisted in planning the proposed facility layouts. In addition, personnel from several First Region control towers participated in many of the simulation tests.

Objectives.

Since much previous TDEC simulation work has been concerned with the development of procedures to improve traffic flow at Washington National Airport, the primary emphasis of this project was pointed toward the improvement of traffic flow at Andrews Field, with the added stipulation that the changes required to accomplish this end must not result in any reduction in the traffic capacity of Washington National Airport. The detailed objectives of this program were:

1. The development of an initial system, with as few facility changes as possible, to enable Andrews Field to handle approximately one-half the present traffic demand of the Washington National Airport.
2. Expansion of this system to a point where both airports could handle an equal volume of traffic.

---

[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," CAA Technical Development Report No. 187, November 1952.

3. Although designed primarily for northerly take-offs and landings, traffic systems should be capable of maintaining operations without appreciable reduction in acceptance rates under wind conditions which require that take-offs and landings be made in a southerly direction.

4. Insofar as possible, systems should provide independent, segregated arrival routes to each airport.

5. Systems should provide for adequate and simple procedures for jet operations in and out of Andrews Field.

6. Systems should provide departure paths from each airport independent of traffic flow on the arrival routes within the terminal area.

7. Systems should provide clean-cut sector jurisdiction to permit satisfactory division of work load under heavy traffic conditions.

EVALUATION METHODS

Traffic Samples.

To obtain comparative measurements on the operating characteristics of the various systems, it was necessary first to develop traffic samples representative of the types and distributions of traffic which might be expected to use the terminal area. No official estimates were available for the possible future distribution of aircraft types; therefore, two different samples were made up, as summarized in Table I. One consideration in setting up the laboratory tests was to obtain a maximum amount of significant information about the flow characteristics of the various systems in a minimum number of working hours. Since potential system bottlenecks are not as apparent in light traffic conditions, the traffic samples set up for the tests had somewhat higher flow rates than might be expected in actual operations in the terminal area during the next few years.

It will be noted that Sample 2 had a larger proportion of jet and fast-type aircraft than Sample 1. In both samples, all jet aircraft landed at Andrews rather than Washington. This consideration was due to the presumption that if both airports were available, (a) the high noise level of jet operations would cause less of a public nuisance at the more remote airport, and (b) the absence of close-in obstructions at Andrews should provide greater safety for jet operations.

TABLE I

SUMMARY OF ARRIVAL SAMPLES

SAMPLE NUMBER		1		2	
AIRPORT		Andrews	Washington	Andrews	Washington
NUMBER	Jet	5	0	12	0
	Fast	10	8	15	5
OF	Medium	9	15	13	13
	Slow	6	7	0	23
AIRCRAFT	Total	30	30	40	41
Arrival Rate Per Hour	Per Airport	19.7	19.5	20.3	20.5
	Terminal Area Total	39.2		40.8	

The traffic samples, which included two arrival problems and one departure problem, were assembled through the use of techniques developed by Franklin Institute. The techniques are described in another report.[2] Basic inputs of the traffic samples are given in Table II. General characteristics of the various aircraft types simulated in this problem are listed in Table III.

TABLE II

BASIC INPUT OF TRAFFIC SAMPLES

LEGEND

A - Andrews Field
B - Beltsville
C - Charlotte Hall
D - Washington National Airport
F - Fast
G - Gordonsville
I - Raleigh
J - Jet
K - Meekins Neck
L - Clifton
M - Medium
N - Doncaster
O - Coles Point
P - Pittsburgh
Q - Quantico
R - Riverdale
S - Slow
T - Baltimore
V - Arcola
W - New York
X - Norfolk
Z - Shadyside

[2] "Analytical and Simulation Studies of Several Radar-Vectoring Procedures in the Washington, D. C. Terminal Area," by S. M. Berkowitz, Franklin Institute, Philadelphia, Penna., CAA Technical Development Report No. 222, not yet published.

TABLE II (Cont'd)

Sample 1 - Arrivals

Entry No.	Type	Estimated Fix	Over Time	Enroute to
1	M	R	0120	D
2	M	R	20	D
3	M	N	18	D
4	M	C	19	D
5	M	R	22	D
6	M	V	25	D
7	F	R	29	D
8	F	Q	25	A
9	M	R	29	D
10	F	Z	37	A
11	F	B	32	A
12	S	N	32	D
13	S	V	32	D
14	M	Z	38	A
15	F	N	43	D
16	J	K	37	A
17	S	N	41	D
18	M	V	46	D
19	F	Q	46	A
20	J	K	47	A
21	F	Q	50	A
22	S	B	46	A
23	F	R	58	D
24	F	Q	57	A
25	J	K	56	A
26	M	R	57	D
27	M	B	58	A
28	F	V	0205	D
29	M	Z	02	A
30	J	K	00	A
31	S	R	05	D
32	M	Z	12	A
33	M	Z	15	A
34	M	B	07	A
35	M	V	14	D
36	S	V	13	D
37	F	V	18	D
38	M	B	14	A
39	F	R	25	D
40	M	R	24	D
41	F	B	0221	A
42	M	R	25	D
43	S	N	24	D
44	M	N	30	D
45	J	K	31	A
46	F	B	31	A
47	M	B	31	A
48	S	R	36	D
49	S	Z	43	A
50	S	Z	43	A
51	M	C	44	D
52	M	C	47	A
53	M	C	45	D
54	S	B	39	A
55	S	Q	40	A
56	F	R	33	D
57	F	Z	55	A
58	F	V	54	D
59	S	Q	48	A
60	F	Z	0303	A

TABLE II (Cont'd)

Sample 2 - Arrivals

Entry No.	Type	Estimated Fix	Over Time	Enroute to	Entry No.	Type	Estimated Fix	Over Time	Enroute to
1	S	V	0054	D	41	S	R	0205	D
2	F	Z	0103	A	42	S	R	05	D
3	S	R	03	D	43	S	N	05	D
4	F	Q	03	A	44	S	N	06	D
5	M	N	13	D	45	M	B	06	A
6	F	Q	11	A	46	S	R	08	D
7	M	B	17	A	47	M	R	10	D
8	S	V	14	D	48	F	C	12	A
9	F	N	19	D	49	S	R	10	D
10	F	Z	20	A	50	F	Q	09	A
11	M	R	20	D	51	S	R	14	D
12	M	B	19	A	52	F	Q	13	A
13	J	O	17	A	53	J	O	14	A
14	S	R	25	D	54	M	R	21	D
15	S	R	27	D	55	M	Z	21	A
16	F	B	28	A	56	M	C	20	A
17	J	O	27	A	57	S	R	24	D
18	J	O	28	A	58	S	R	26	D
19	F	Q	31	A	59	F	N	27	D
20	M	B	35	A	60	J	O	28	A
21	M	C	37	A	61	F	V	35	D
22	F	V	38	D	62	J	O	32	A
23	F	Z	41	A	63	M	R	39	D
24	J	O	37	A	64	F	Z	41	A
25	S	R	42	D	65	F	C	41	A
26	M	C	43	A	66	M	V	39	D
27	J	O	39	A	67	M	N	44	D
28	F	C	44	A	68	F	Z	45	A
29	M	V	42	D	69	S	N	44	D
30	M	V	42	D	70	F	V	44	D
31	S	N	44	D	71	M	B	44	A
32	M	B	44	A	72	F	C	48	A
33	S	R	47	D	73	J	O	43	A
34	S	V	45	D	74	M	N	49	D
35	M	B	50	A	75	J	O	47	A
36	S	R	51	D	76	M	R	54	D
37	M	B	50	A	77	M	V	52	D
38	S	N	55	D	78	M	V	54	D
39	M	B	55	A	79	S	N	56	D
40	S	N	59	D	80	F	B	57	A
					81	F	B	59	A

TABLE II (Cont'd)

Sample 3 - Departures

Entry	Proposed Dptr. Time	Type	From Airport	To or Over	Desired * Alt.	Entry	Proposed Dptr. Time	Type	From Airport	To or Over	Desired * Alt.
1	0122	F	A	W	12	31	0213	J	A	P	24
2	24	S	A	W	6	32	17	M	A	W	11
3	25	F	D	I	8	33	20	F	D	T	4
4	27	F	A	P	16	34	21	M	A	W	9
5	27	F	D	P	18	35	23	M	D	W	12
6	32	S	A	W	7	36	24	J	A	W	25
7	33	S	A	G	6	37	26	F	A	P	16
8	34	M	A	W	12	38	28	F	D	I	8
9	36	M	A	W	9	39	29	S	A	W	6
10	37	M	D	I	8	40	29	F	A	X	10
11	38	S	A	W	5	41	30	J	A	W	25
12	40	S	A	W	7	42	34	F	A	W	9
13	41	S	D	W	6	43	36	M	D	I	6
14	43	M	A	W	9	44	37	S	D	G	6
15	46	F	A	W	12	45	40	J	A	I	28
16	46	J	A	P	30	46	42	F	D	P	14
17	47	M	D	P	10	47	47	M	A	W	9
18	49	S	D	W	7	48	49	S	A	T	3
19	54	M	D	W	10	49	52	S	D	I	4
20	55	F	A	P	18	50	53	F	A	W	11
21	56	M	D	G	8	51	54	F	A	W	7
22	58	F	A	T	4	52	57	M	D	T	4
23	0202	M	A	P	10	53	59	F	A	X	8
24	04	F	D	W	12	54	0300	F	D	P	12
25	05	S	A	T	3	55	00	M	D	Y	8
26	06	M	D	T	4	56	01	M	D	T	3
27	10	M	A	P	8	57	02	M	D	I	8
28	11	M	A	W	9	58	04	M	D	G	10
29	11	M	A	W	11	59	05	M	D	I	6
30	12	S	D	P	6	60	07	M	D	T	4

*in thousands of feet, M.S.L.

TABLE II (Cont'd)

Sample 3 - Summary

Type of Aircraft	Airport Washington	Andrews	Area Total
S	5	8	13
M	14	12	26
F	7	9	16
J	0	5	5
Total	26	34	60
Rate Per Hour	15.2	21.0	36.2

TABLE III

AIRCRAFT TYPE CHARACTERISTICS

TYPE	SPEEDS Cruise (mph)	Intermediate (mph)	Approach (mph)	Climb or Descent Rate (fpm)
JET	400	290	180	3000
FAST	290	220	150	1000
MEDIUM	240	190	140	1000
SLOW	180	150	120	500

Measurements.

1. Delay. The basic problem input data listed for the arrival samples in Table II were projected forward, in each system studied, to furnish a theoretical time at which each aircraft would arrive over the outer marker, assuming that no other aircraft was involved. Through use of a recorder, the simulator pilots recorded the actual arrival time of each aircraft over the approach gate. The theoretical arrival time was then subtracted from the actual arrival time to determine the absolute delay to each aircraft. Absolute delay thus included all delay, whether caused by descent, holding, path-stretching, velocity control, or misjudgments on the part of the controllers.

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

3. Significance of Results. The actual traffic control of the various simulation runs was handled mostly by a group of First Region controllers with widely varying radar experience. All runs were made under the general supervision of TDEC traffic control specialists. Thus, from the standpoint of human performance, the results are believed to be indicative of those which could be expected from a typical group of CAA radar controllers.

Although every effort was made to keep the simulation tests as realistic as possible, it was not practical to reproduce in the laboratory all the complications and distractions which might exist under actual operating conditions. Therefore, in studying the results of these tests it should be realized that the quantitative data may not be exactly duplicated in actual practice. However, the results of tests of the same traffic sample on various systems may be used for qualitative comparisons of one system with the other.

Because only nine simulator targets were available, it was not practical to run the departure and arrival traffic simultaneously during the simulation tests. In order to make allowance for this fact, systems of blocked altitudes were established at crossover points in order to make the arrival routes completely independent of the departure routes. These altitude blocks were rigidly adhered to in all tests.

Because of the shortage of targets, arrival samples had to be run on the basis of one airport at a time. However, full allowance was made for the presence of the aircraft which would have been en route to the other airport at the same time. This was done by setting up the traffic input in the various samples so that individual aircraft had ANC separation from all other aircraft. Such separation was maintained in all cases until after the aircraft had passed the points where traffic routes to the two airports diverged from each other.

Because of close-in convergence of some departure routes from the two airports, it was necessary to operate both airports simultaneously during the departure runs. No measurements of take-off delays were recorded because occasional delays would have been caused by the shortage of simulator targets. The main purpose of the departure tests was to observe the flow characteristics of the various systems under heavy traffic conditions and thus to develop improved routings, control procedures, and sector assignments.

GENERAL CONTROL PROCEDURES

Use of Radar.

In conducting the simulation tests, it was assumed that the terminal area had reliable radar coverage extending from the minimum instrument altitude up to about 10,000 msl. It was also assumed that radar vector procedures would be used for the following:

1. Sequencing of aircraft en route to holding fixes.
2. Guiding arriving aircraft from the holding fixes to the final approach course for subsequent ILS or TVOR approaches.
3. Establishing longitudinal separation between arriving aircraft en route to the final approach gate.
4. Maintaining longitudinal or lateral separation between departing aircraft and other traffic until ANC separation was established.

Aids to Controller Judgment.

1. Spacing Table. The job of establishing optimum separation between successive aircraft on the final approach path was simplified considerably through the use of the spacing table shown in Fig. 1. This table, which was posted at each arrival radar control position, was based on the establishment of a three-mile minimum separation between any two airborne aircraft. The three-mile standard was increased to allow for the speed differential in cases where a faster aircraft followed a slower aircraft in the landing sequence. In all cases, an additional allowance was made to compensate for normal variations from the desired approach speeds. Use of this table enabled approach intervals to be reduced to the minimums consistent with adequate safety.

2. Reference Lines. Accuracy of spacing aircraft on the final approach path was increased through use of the simple spacing reference shown in Fig. 2. This reference, which was marked on the radar map overlays for each approach system, consisted of three concentric arcs spaced on radii of three, four, and five miles from the outer marker. The arcs formed a ready reference for the controller in establishing the separations specified in the spacing table.

3. Orbiting Technique. The circular arcs made possible the use of a precise technique for obtaining proper separation between aircraft at the outer marker. For path adjustment the No. 2 aircraft was turned to a heading which was essentially tangential to the outer marker. As shown

in Fig. 3, this orbiting technique kept the No. 2 aircraft at an almost constant distance from the outer marker while the No. 1 aircraft was proceeding inbound. As soon as sufficient separation was established (making due allowance for an extra one-half mile of separation which would accrue during the turn) the controller turned the No. 2 aircraft directly toward the localizer turn-on point.

DEPARTURE TESTS

General Flow Patterns.

Although minor changes had to be made in adapting departure routes to the various facility layouts tested, the general configuration of airport runways, danger areas, and prohibited areas tended to channelize departure paths into two basic patterns; one for northerly take-off operations and one for southerly take-off operations. Detailed diagrams of departure routes for the various systems are discussed later in this report.

Division of Control.

In order to simplify control procedures and to minimize the amount of coordination required between departure and arrival controllers, a prime objective in setting up departure routes was to make them as independent of arrival routes as possible. Because of the proximity of Andrews Field to Washington National Airport, close-in crossovers of departure paths were inevitable. Therefore, considerable coordination between departure controllers had to be conducted in handling the departure traffic from the two airports.

The first departure control arrangement made use of three radar controllers, presumably one at each airport radar facility and another at the Washington ARTC. In this arrangement, each airport radar controller released departures at his location and transferred control to ARTC radar approximately five miles after take-off. Although this procedure worked satisfactorily when traffic at one airport was very light, it became unsafe when departures reached a rate of about 15 per hour from each airport. This was because of the burden which was placed on the ARTC position in accepting, identifying, and providing separation between aircraft on several different routes simultaneously.

The second arrangement assumed that all radar departure controllers were at a central location, with the area divided into three sectors as follows:

1. Sector 1 handled Washington departures and retained control of all westbound, southbound, and southwestbound aircraft until ANC separation was established. Northwestbound and northeastbound aircraft were released to sector 3 control as soon as practicable after take-off.
2. Sector 2 handled Andrews departures and retained control of all aircraft proceeding via Shadyside on eastbound or southeastbound routes

until ANC separation was established. Northwestbound or northeastbound aircraft were released to sector 3 control as soon as practicable after take-off.

3. Sector 3 assumed control of all northwestbound and northeastbound aircraft and provided separation between such crossing traffic from the two airports, as well as radar separation of these routes until ANC separation was established.

Although this control arrangement was somewhat better than the first, it still permitted too many departures to be cleared in close succession on the northwest and northeast routes. Immediate transfer to sector 3 control was required in order to prevent conflictions at the close-in crossover points.

In order to eliminate these disadvantages, a third arrangement was tried. This arrangement assumed that all departure controllers were at a central location, with control jurisdiction as follows:

1. Sector 1 controlled departures from both airports and thus could regulate the interval at which aircraft headed for common or crossing routes could depart from either airport. At first a two-minute minimum interval between successive take-offs was used. Later, this rule was found to be unnecessary. Instead, a simple flow-control arrangement was adopted, with take-offs regulated only enough to keep from exceeding a comfortable work load for either of the two other sectors. Departures were kept under sector 1 control until past the close-in crossover points. Control was then transferred to sector 2 or 3, depending upon flight direction.

2. At designated transfer points, sector 2 took over control of all departures en route toward the northwest, west, or southwest and provided radar separation for such aircraft until ANC separation was established.

3. Sector 3 performed the same duties as sector 2 for departures en route toward the northeast, east, or southeast.

This arrangement, which is shown on all departure route maps in this report, functioned very well during the simulation tests. It appeared much more practical and positive than either of the other two sector arrangements tested.

ARRIVAL TESTS

Phase A (Present System).

1. Object. The purpose of this phase was to observe the performance of the present system of navigational aids and control procedures under conditions when Andrews Field had to accept a heavy traffic load.

2. Control Procedures (North Landings at Both Airports). Present control procedures, as outlined in Washington National Airport Traffic Control Tower Operations Letter No. 5 and Washington Air Route Traffic

Control Center Operations Letter No. 2, were used. These procedures are shown in Fig. 4. Procedures included the use of the present Andrews jet letdown.

3. Results and Observations. One dry run (without measurements) revealed that the present system would be unworkable with any appreciable volume of traffic at Andrews Field. The chief difficulties were:

a. Andrews arrivals shared common routes with Washington arrivals. As a result, entry altitudes in the terminal area built up to high levels. Many delays were due to long descents from these altitudes.

b. The Andrews arrival clearance limits of Shadyside and Charlotte Hall were much too far away from the Andrews approach gate for efficient spacing operations. Use of the Andrews spacing area by Washington arrivals proceeding to Andrews range complicated the radar picture and added to the difficulty of target identification.

c. Andrews approaches had to be made across and underneath the area used by Washington arrivals holding at the Andrews range. The resulting complications in the radar display made the establishment of radar separation between Andrews arrivals very difficult.

As a result of these observations, no further tests were made of the present system. Instead, immediate efforts were made to improve the system.

Phase B (Modified Present System).

1. Object. As a result of the tests of Phase A, minor changes in procedures rather than in facilities were made to determine whether the present basic navigational layout could be expected to handle an increased traffic load at Andrews Field. The modified system, known as Phase B, is illustrated in Fig. 5.

2. Control Procedures.

a. Washington (Runway 36). In order to eliminate some of the difficulties encountered by the Andrews radar controller in Phase A, the Riverdale H facility was designated as the clearance limit for east-west sector arrivals destined for Washington National Airport. This eliminated the holding stack at Andrews range, thus simplifying the Andrews radar display. No other changes were made in the routes used by Washington arrivals.

b. Andrews (Runway 32). The following changes in the Andrews facility layout were assumed:

(1) An ILS was installed to line up with runway 32. This arrangement placed the outer marker closer to Shadyside, the primary clearance limit for Andrews arrivals.

(2) The jet approach procedure was changed so that jet aircraft normally started their descent from Meekins Neck at 20,000 msl and were cleared to the Huntingtown H facility at 6,000 msl or above. As these aircraft crossed Huntingtown they would normally be cleared for straight-in approach across the outer marker. If any delay was involved, such aircraft were held at Huntingtown until the radar controller could fit them into the final approach sequence.

3. Results and Observations. Delay and communications measurements are listed in Tables IV and V for Andrews and Washington, respectively.

TABLE IV

SUMMARY OF ARRIVAL RUNS - ANDREWS FIELD

SAMPLE 1:

Phase	Landing Runway	Holding Fixes	Absolute Delay Avg. Per Aircraft (min/sec)	Absolute Delay Maximum (min/sec)	Avg. Communications Per Aircraft Messages	Avg. Communications Per Aircraft Comm. Time (min/sec)
B	32	Shadyside	11:00	25:00	46.2	2:36
C	1	Croom	4:38	12:01	40.1	2:39
D	1	Croom	2:50	11:39	44.2	2:27
F	1	Croom/Waldorf	4:22	13:23	31.1	1:41
G-H	32	Columbia/Cedarville	2:24	9:31	30.7	1:46

SAMPLE 2:

Phase	Landing Runway	Holding Fixes	Absolute Delay Avg. Per Aircraft (min/sec)	Absolute Delay Maximum (min/sec)	Avg. Communications Per Aircraft Messages	Avg. Communications Per Aircraft Comm. Time (min/sec)
D	1	Croom	3:19	14:12	30.0	1:36
E	1	Croom	4:00	14:51	32.2	1:46
E	19	Croom	6:07	16.44	43.4	2:12
F	1	Croom/Waldorf	3:10	13:01	34.1	1:58
G-H	32	Columbia/Cedarville	3:26	12:29	30.9	1:42
H	19	Largo/Riverdale	5:24	16:49	47.0	2:35

TABLE V

SUMMARY OF ARRIVAL RUNS - WASHINGTON NATIONAL AIRPORT

SAMPLE 1:

Phase	Landing Runway	Holding Fixes	Absolute Delay Avg. Per Aircraft (min/sec)	Absolute Delay Maximum (min/sec)	Avg. Communications Per Aircraft Messages	Avg. Communications Per Aircraft Comm. Time (min/sec)
B	36	Springfield/ Riverdale	5:34	14:50	29.5	1:50
C	36	Alexandria/Hyde	4:13	10:50	34.5	2:35
D	36	Alexandria/Hyde	4:20	10:43	32.4	1:57
F	36	Alexandria/Hyde	4:09	10:31	29.7	1:41
G-H	36	Alexandria/Hyde*	2:55	9:26	32.4	1.53

*Relocated 1-1/2 miles south.

SAMPLE 2:

Phase	Landing Runway	Holding Fixes	Absolute Delay Avg. Per Aircraft (min/sec)	Absolute Delay Maximum (min/sec)	Avg. Communications Per Aircraft Messages	Avg. Communications Per Aircraft Comm. Time (min/sec)
E	36	Springfield/ Riverdale	7:38	20:53	M	M
E	15	McLean/Riverdale	4:32	14:47	M	M
G-H	36	Alexandria/Hyde*	6:07	21:09	38.2	2:09
G	15	Alexandria/ Riverdale	6:46	17:42	34.7	1:55
H	15	McLean/Kensington	5:37	16:12	41.5	2:34

*Relocated 1-1/2 miles south.
M - Missing because of failure of recording equipment.

a. Holding fixes were too far away from both the Andrews and the Washington outer markers to permit efficient radar spacing operations on the final approach. As a result, delays were still rather high.

b. The straight-in jet approach was simple from the pilot's standpoint but was not very efficient from the radar controller's viewpoint because it allowed very little flexibility in stretching the flight path of the jet to adjust the approach interval behind a preceding aircraft. As a result, jets usually arrived with too much spacing behind other aircraft. This factor contributed to the high delays of this phase.

c. Because many of the arrival routes were still shared by aircraft en route to Washington or Andrews, entry altitudes were high and many delays were due to the long descents required. This was particularly true of traffic arriving at Riverdale, because Andrews arrivals did not diverge from Washington arrivals until reaching Beltsville.

d. Traffic en route to Washington from the east and southeast still crossed the Andrews radar area, complicating the radar display and creating additional work load for the Andrews radar controller.

Phase C.

1. Object. The purpose of this phase was to investigate possible improvements in traffic flow through the use of a single close-in holding stack at Andrews and dual close-in holding stacks at Washington. This system, known as Phase C, is shown in Fig. 6.

2. Control Procedures.

a. Washington (Runway 36). To establish a cleaner division between the Washington and Andrews sectors, the old Washington arrival route over Shadyside was abolished. All Washington arrivals from the northeast now entered the terminal area over Beltsville. This change left the Shadyside area free for exclusive use of Andrews arrival and departure traffic and thus simplified the Andrews radar display.

To eliminate the long radar vector patterns associated with previous Washington approach systems, a close-in holding fix was established on either side of the ILS outer marker and offset four miles from the localizer course. The east holding fix, Hyde, was assumed to be a new TVOR facility. The west holding fix, Alexandria, was assumed to be the old Georgetown H facility moved to a new site on the south radial of a TVOR facility installed near Chain Bridge. The Chain Bridge TVOR was assumed to be the old Washington National Airport TVOR relocated so that it would furnish an outer fix plus course guidance for southeast approaches to runway 15 at Washington National Airport. Functional advantages of the close-in twin-stack layout are detailed in another publication.[3]

b. Andrews (Runway 1). In order to set up a system capable of handling approximately one-half the traffic load presently handled by Washington National Airport, a close-in holding fix was established at Croom, about five miles east of the approach course to runway 1. It was assumed that this fix was an H facility located on the northeast course of the Camp Springs LF range.

---

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

For final approach guidance, it was assumed that an ILS was installed for approach to runway 1, with landings made in a northerly direction. This landing direction is preferred by certain Andrews Air Force personnel, who desire to reserve the northwest runway (No. 32) exclusively for jet scramble operations.

To provide a secondary holding pattern clear of the Croom pattern, the Shadyside H facility and fan marker were relocated to a site on the shore line near Cedarhurst.

The same jet letdown procedure used in the Phase B tests was employed. However, the use of runway 1 for landings permitted adequate flexibility of the jet approach path from Huntingtown. Jets could leave Huntingtown on base leg if desired by the radar controller, and could then be turned toward the outer marker as soon as proper separation from the preceding aircraft was established.

3. Results and Observations.

Delay and communications measurements are listed in Tables IV and V for Andrews and Washington, respectively.

a. Because of the elimination of the Shadyside route, more Washington arrivals were concentrated on the Beltsville route. As this route was still shared with Andrews arrivals, entry altitudes over Beltsville built up to even higher levels, thus increasing delays due to descent time.
b. Use of the close-in holding fixes at both airports reduced controller work load and made possible more efficient spacing of aircraft on the final approach paths. This improvement had the effect of reducing aircraft delays at both airports. It was particularly noticeable during the Andrews tests. Andrews delays in this phase averaged less than one-half of those recorded in the previous system.
c. Employment of the jet base-leg pattern from Huntingtown enabled jet approach intervals to be adjusted much more accurately than on previous systems tested. This feature greatly simplified the job of the Andrews radar controller and also contributed to the general reduction in aircraft delays.

Phase D.

1. Object. In order to reduce descent delays caused by congestion on the heavily traveled arrival route over Beltsville, it was decided to split this traffic load by establishing a different routing for Washington arrivals. This segregation was accomplished by realigning the north course of the Camp Springs range to provide course guidance from Lisbon and

Riverdale. In addition, the Croom H facility was replaced by a TVOR. The southwestbound traffic flow was now divided at Lancaster. Andrews arrivals followed the former route over Loch Raven, Relay, and Beltsville, while Washington arrivals proceeded over Westminister and Lisbon to Riverdale. Use of a TVOR at Croom permitted realignment of the holding pattern on a north-south axis. This system is shown in Fig. 7.

2. Control Procedures.

   a. Washington (Runway 36). No changes were made from the procedures used in Phase C.
   b. Andrews (Runway 1). Realignment of the Croom holding pattern made possible the use of short, close-in, trombone-type, radar vectoring patterns. Other procedures remained the same as those used in Phase C.

3. Results and Observations.

Delay and communications measurements are listed in Tables IV and V for Andrews and Washington, respectively.

   a. Reduction in traffic congestion on the Beltsville route enabled arrivals to enter the terminal area at lower levels than were possible in previous systems tested. The consequent reduction in descent time may have contributed to the over-all reduction in Andrews delays. However, this change had little effect on traffic delay at Washington.
   b. Realignment of the Croom pattern to utilize a trombone traffic pattern was the most important improvement in the Andrews approach system. Average delays to Andrews traffic decreased 40 per cent from those recorded in Phase C, largely as a result of the attainment of consistently better approach intervals.

Phase E.

1. Object. From the lessons learned on tests of Phases C and D, it was believed that an interim system could be developed which would provide many of the advantages of these systems at lower cost. The object of this new system, Phase E, was to increase the traffic capacity of the terminal area primarily through improvement of facilities at Andrews Field. This system is shown in Figs. 8, 9, 10, 11, 12, and 13.

2. Arrival Control Procedures--North landings.

   a. Washington (Runway 36). The facility layout reverted to the one described in Phase B, with the exception that the north course of the Camp Springs range was realigned to pass over Riverdale and thus form the arrival route from Lisbon to Riverdale. Springfield and Riverdale were used as the primary holding fixes in this system. The Washington arrival route from Coles Point via Charlotte Hall was eliminated, primarily to simplify the traffic situation in the Andrews radar vectoring area. Washington arrivals which formerly used this route were now cleared via Clifton and Doncaster to Springfield.

b. Andrews (Runway 1). The facility layout was the same as described in Phase C. Arrival routes remained the same, except for the route from the north. This route now proceeded from Relay directly to the Friendship outer locator, thence directly to Croom, utilizing ADF guidance.

3. Arrival Control Procedures--Southerly Landings.

a. Washington (Runway 15). During simulation tests of southeast landing operations it was found advantageous to reverse the normal one-way traffic flow on Red Airways 20 and 61. Congestion between arrival, holding, and departure patterns in the vicinity of Springfield was eliminated by establishing southeastbound traffic flow on Red 20 from Martinsburg to McLean and northwestbound traffic flow on Red 61 between Springfield and DeHaven.

In tests of this phase, it was assumed that an H facility was established at McLean to form the primary holding fix for the west sector. Riverdale was used as the east sector primary holding fix. Traffic was vectored off these two fixes for TVOR approaches over Georgetown to runway 15 at Washington National Airport.

b. Andrews (Runway 19). Croom was used as the primary holding fix. All aircraft were vectored into position for back-course ILS approaches to runway 19 at Andrews Field. It was assumed that a compass locator or fan marker was established about 5.3 miles north of the airport to form an outer locator for the approach system.

4. Results and observations.

Delay and communications measurements are listed in Tables IV and V for Andrews and Washington, respectively.

a. Rearrangement of the arrival routes from the northeast to form segregated routes to each airport reduced descent delays by enabling aircraft to enter the terminal area at lower altitudes than they could in the previous systems tested.

b. Establishment of the holding fix at McLean shortened the radar-vector paths for southeast approaches to Washington. Reversal of the traffic flow on Red 20 and Red 61 during southeast approach operations simplified traffic flow in the vicinity of Springfield and thus reduced possible confusion on the radar display.

c. The air space reservation for the McLean holding pattern extended into Red Airway 33 in the vicinity of Herndon. It appeared desirable that this airway should be moved westward a few miles. This change has been under consideration by the Washington ARTC Center for some time.
d. The radar vector pattern for a south landing at Andrews was excessively long. As a result, delays were much higher than those recorded for north landing operations. However, it appeared that this factor would not become critical as long as the traffic demand rate for Andrews did not exceed 15 approaches per hour.
e. Tests of south landing operations at Andrews pointed out the necessity for a secondary or "stopper" fix on the arrival route from the north. With such a fix it would have been easier to integrate arrivals from the north with jet arrivals which crossed Croom northbound in descent from high altitude levels. This difficulty was corrected on later phases tested by the designation of a VOR intersection as a secondary fix in the vicinity of Bowie.

Phase F.

1. Object. The next system was a further development of the Phase D system. It represented an attempt to expand the Andrews approach system to a twin-stack layout for high traffic demand rates, with approaches to runway 1 or with a proposed parallel north-south runway. This system shown in Figs. 14 and 15.

2. Arrival Control Procedures--North Landings.

a. Washington (Runway 36). Facilities and procedures were the same as those described in the Phase D tests, with the exception that Doncaster could not be used as a secondary holding fix because of the proximity of the west sector Andrews holding fix established at Waldorf.
b. Andrews (Runway 1). An H facility was established at Waldorf to provide a second holding fix for Andrews traffic. This holding pattern was aligned with a radial from the Croom TVOR and was extended southwest from Waldorf. The jet approach pattern was relocated to provide an additional departure route over Huntingtown to Meekins Neck. Jet arrivals normally crossed Coles Point at 20,000 msl, or above, descending on a straight-in approach to cross Charlotte Hall at about 6,000 msl, from which point they were guided into the final approach path by radar. Piston-engine aircraft using the route from Coles Point to Charlotte Hall crossed the latter fix not above 5,000 msl, from which point they could be routed to either Waldorf or Croom

as desired. As the east sector normally controlled more piston-engine traffic than the west sector, most jet aircraft were placed under west sector control in order to equalize the work load.

3. Arrival Control Procedures--Southerly Landings.

   a. Washington (Runway 15). Alexandria and Riverdale were used as holding fixes for feeding the approach to runway 15.
   b. Andrews (Runway 19). Because the Riverdale holding pattern was being used for Washington traffic, it was not possible to maintain a twin-stack operation for Andrews under conditions when approaches had to be made to the south. Therefore, under these conditions the Andrews approach system reverted to a single-stack operation using Croom as the primary holding fix. Waldorf was used only as a secondary holding fix in this case.

4. Results and Observations.

Delay and communication measurements are listed in Tables IV and V for Andrews and Washington, respectively. Although several wind-shift tests were made in switching landing operations from north to south and from south to north at Andrews, no comparative delay and communications measurements were made of south operations at Andrews.

5. a. No special problems were encountered in making the shifts mentioned in the preceding paragraph.
   b. In order to miss the Dahlgren Danger Area (D-38) and also to provide clearance from the Hyde radar vectoring area, the Waldorf holding pattern could not be located and aligned in a manner which would permit the use of the most efficient radar techniques for spacing aircraft on the final approach path. As a result of this configuration, the addition of the Waldorf stack did not produce an appreciable reduction in aircraft delays at Andrews. In most comparative tests of Sample 1, aircraft delays with the Waldorf system were actually higher than those measured in tests of the Phase D single-stack system.
   c. The most important advantage of the second stack at Andrews was the reduction in the communications and radar vectoring work load of the Croom sector controller. However, as the largest proportion of arrivals enters the Washington terminal area from the northeast, the Waldorf sector could not carry its share of the work load.
   d. Tests of the Washington approach system for southeast approaches showed that the use of Alexandria as the west sector holding fix produced long radar vector patterns and a high work load. In this respect the only advantage in the use of Alexandria was that departures could clear the holding pattern and start climbing sooner than they

could when Springfield was used as the holding fix. However, the use of McLean for this purpose, as tested in the Phase E system, produced shorter vector patterns, a cleaner flow of traffic, and 40 per cent lower aircraft delays in the sample tested.

Phase G.

1. Object. Use of runway 32 for approaches to Andrews was reconsidered, primarily as a means of providing additional clearance between east-sector traffic at Washington and west-sector traffic at Andrews. In addition, it was believed that a slightly better arrangement of dual holding fixes for Andrews could be obtained if approaches could be made to the northwest instead of the north. This system is illustrated in Figs. 16, 17, 18, and 19.

2. Arrival Control Procedures--Northerly Landings.

a. Washington (Runway 36). Facilities and procedures were the same as those described in the Phase D tests, except that the Alexandria and Hyde facilities were relocated 1-1/2 miles south of their previous sites in order to keep holding aircraft at a lower average distance from the outer marker at all times.

b. Andrews (Runway 32). It was assumed that the ILS was aligned for approaches to runway 32, with an outer marker about 5.3 miles southeast of the airport. Holding fixes were established at Columbia and Cedarville. It was assumed that the Columbia fix was a TVOR facility. Cedarville was assumed to be an H marker on a southeast radial of the Georgetown TVOR, with the holding pattern aligned on this radial. The Charlotte Hall H facility was relocated about three miles south of its former site to provide adequate clearance between the primary holding pattern at Cedarhurst and a secondary holding pattern at Charlotte Hall. The jet approach procedure consisted of a straight-in descent on the localizer course, crossing Meekins Neck at 20,000 msl and Huntingtown at or below 6,000 msl. The control of the jet aircr ft was assumed by the west-sector controller when the aircraft passed Huntingtown.

3. Arrival Control Procedures--Southerly Landings.

a. Washington (Runway 15). Facilities and procedures were the same as those used in tests of Phase F.

b. Since Riverdale was used for Washington traffic, the Andrews system reverted to a single-stack operation when landings had to be made to the south. Columbia was used as the primary holding fix in this case.

Cedarville functioned as a secondary stack. Radar vector patterns from Columbia were shorter than those which had been necessary on previous systems tested for south landing operations.

4. Pesults and Observations.

Delay and communications measurements are listed in Tables IV and V for Andrews and Washington, respectively.

a. As in Phase B, the use of a straight-in approach, while ideal from the jet pilot's standpoint, made radar spacing operations more difficult than on systems which allowed adequate air space for a base-leg approach. Occasionally, jets were held briefly at Huntingtown through use of a 360° turn to the right. This pattern infringed somewhat on Danger Area D-35. If made to the left, it came close to the Charlotte Hall secondary holding area.

b. The northwest approach procedure at Andrews provided greater clearance between Washington and Andrews aircraft during holding and approach operations. However, any aircraft missing the approach to runway 32 at Andrews was required to make an immediate right turn in order to avoid confliction with the Washington traffic patterns.

c. Relocation of the Alexandria and Hyde fixes 1-1/2 miles south of their previous sites reduced controller work load and delays to the lowest recorded on any tests. The new locations kept holding aircraft at a lower average distance from the approach gate and also produced easier interceptions of the final-approach course by removing the temptation for controllers to "cut the corner" for short turn-ons.

Phase H.

1. Object. To equip the Phase G system with better approach facilities for south operations at each airport, the system was further developed to include two dual-stack systems for each terminal. As this system was assumed to be a long-range development rather than something necessary for the immediate future, full use was made of TVOR facilities for arrival and departure routes. The system is shown in Figs. 20, 21, 22, 23, 24, and 25.

2. Arrival Control Procedures--Northerly Landings.

a. Washington (Runway 36). Arrival routes and procedures remained the same as in Phase G, except that VOR radials were used from Arcola to Alexandria and from Lisbon to Hyde.

b. Andrews (Runway 32). Arrival routes and procedures were the same as those used in Phase G.

3. Arrival Control Procedures--Southerly Landings.

a. Washington (Runway 15). H facilities were installed as holding fixes at McLean and Kensington. Each fix was approximately eight miles from the Chain Bridge VOR. Holding patterns were aligned with radials from the Hyde TVOR. The radial from Hyde to Kensington was extended to form an inbound route from Lisbon.

As in Phase E, the normal traffic flow on Red Airways 20 and 61 was reversed in order to produce a cleaner, smoother flow of traffic in the vicinity of Springfield. Red Airway 20 was used for southeastbound traffic from Martinsburg to McLean, and Red Airway 61 was used for northwestbound traffic from Springfield to DeHaven. Traffic from Doncaster to McLean was routed via the Alexandria TVOR.to allow departures to start their climb sooner after take-off.

b. Andrews (Runway 19). Riverdale was used as the west sector holding fix, with the pattern extending southeast. The holding pattern was aligned with a radial from the Hyde TVOR.

An H facility was installed as the last sector holding fix at Largo. The pattern was aligned with a radial from the Columbia TVOR. ADF courses were used as arrival routes from Fort Meade to Largo and from Shadyside to Largo.

Jets crossed Huntingtown at 8,000 or above and could be cleared to either fix for vectored approaches.

4. Results and Observations.

Delay and communications measurements are listed in Tables IV and V for Andrews and Washington, respectively.

The use of Kensington instead of Riverdale as a holding fix during southerly landing operations at Washington did not directly improve the traffic flow at Washington Airport. However, the release of Riverdale for use as a holding fix for Andrews Field permitted twin-stack operations during southerly landing operations, with a consequent reduction in aircraft delays at this field.

Tests with 30-inch Horizontal Display

The simulation tests previously described in this report were conducted under the assumption that three different agencies, each with separate radar, controlled the air traffic in the Washington Terminal Area. Because the controllers were assumed to be operating from different locations, it was necessary to set up detailed allocations of routes and altitudes, to minimize interference and coordination between agencies.

Several weeks after the other tests were completed, the dynamic simulator was connected to a new type of 30-inch horizontal bright tube radar display. This display was large enough to permit several controllers to function as a team while handling traffic in a comparatively large radar area.

During February, 1954, limited simulation tests were conducted on the Washington-Andrews traffic problem, using the 30-inch horizontal tube as a common display for three controllers. The radar display covered a circular area with a radius of about 32 statute miles, centered just west of Andrews Field. The map scale on the scope face was approximately two and one-fourth miles to the inch.

Identification markers were used to keep track of the various targets on the scope face. Clear plastic markers were used at first, but required the use of a grease pencil for posting pertinent control data on each marker. It was difficult to write small enough with the grease pencil to include the amount of information deemed desirable:

Aircraft Identification
Aircraft type or speed class
Route, if pertinent
Destination or clearance limit
Altitude (current or proposed).

For this reason, the plastic markers were abandoned, and markers of heavy paper stock were used instead. These were approximately one inch by two inches, bluntly pointed at one end to indicate flight direction. Ordinary lead pencils could be used to post flight data. Since the radar display was of the bright-tube type, overhead lighting could be used in the room. Thus, opaque paper markers were thoroughly practical from the standpoint of visibility. They had additional advantages in that various colors could be used for different types of traffic; also, they could be filed easily as permanent records.

Tests showed that the use of the common horizontal display with the associated target markers resulted in an extremely flexible traffic control system which reduced the need for the detailed procedures and altitude allocations previously described in this report. Since all controllers had complete and current information on all IFR traffic below

12,000 M.S.L. in the radar area, they were able to make immediate use of available airspace as soon as such opportunities occurred. The result was a speedup of traffic flow and a considerable reduction in controller work load.

Following is an indication of the effects of this change:

Washington Airport - Phase E - North Landings

Sample 2 - Arrival rate 20.5 aircraft per hour

	Absolute Delay (min/sec)	
	Average	Maximum
Previous tests using separate control agencies and blocked altitudes	7:39*	20:53*
Single test using common horizontal display and target markers	4:12	11:36

* From Table V

Assuming that positive radar coverage and direct air/ground communications could be maintained, there appeared to be little need for independent arrival and departure routes until the traffic density in the terminal area exceeded 45 operations per hour. However, the practice of diverting non-landing en route traffic around the terminal area still appeared desirable in order to allow controllers to give their undivided attention to the progress of departing and arriving traffic.

CONCLUSIONS

1. Because of the proximity of various Danger Areas and Prohibited Areas, the development of an ideal arrangement of inbound and outbound routes is not possible at this time. This factor is particularly critical for the channel between the Quantico and Dahlgren (D-37 and D-38) Danger Areas.

2. The addition of a holding fix at Croom, in conjunction with the other procedural changes incorporated in Phase E, is expected to provide Andrews Field with an IFR traffic capacity equivalent to one-half the present traffic capacity of Washington National Airport, with no appreciable reduction in the latter figure.

3. Use of twin close-in holding fixes for north landings at Washington National Airport, as described in connection with Phases C, D, F, or preferably, in connection with Phase G or H, reduces controller work load and facilitates use of the simple and precise spacing procedures shown in Fig. 3.

4. Tests indicate that runway 32 will be preferable to runway 1 as the primary landing runway at Andrews, if traffic develops to the point where the Andrews approach system must be expanded to a twin-stack operation. Use of runway 32 in this case will provide a better arrangement of holding fixes and greater separation between the east holding fix at Washington and the west holding fix at Andrews. Tests indicate that the usable capacity of an Andrews traffic system utilizing runway 1 for take-offs and a proposed dual parallel north-south runway for landings would be very little if any higher than the capacity of a system utilizing runway 1 for take-offs and runway 32 for landings. Therefore, the construction of the parallel north-south runway is not justified from the standpoint of increased traffic capacity at this time.

5. It appears desirable to restrict all Washington terminal area jet operations to Andrews Field, from the standpoints of noise abatement, traffic safety, and efficiency.

6. The use of centralized radar control is a necessity in the efficient operation of the departure procedures described in these tests. To provide adequate coverage of the area in which departing aircraft are climbing to cruising altitude, it would be desirable for the departure radar to have reliable coverage up to 20,000 feet and out to a range of at least 60 miles.

7. It appears desirable to provide a new traffic route, farther to the west, for aircraft by-passing the Washington area now using the present Red Airway 33. The proposed holding pattern air space reservation areas for McLean and Kensington extend into the present airway; unless this airway could be relocated, altitude separation would have to be used between holding traffic and airway traffic. A possible method of providing a new routing for Red Airway 33 is an ADF route from Allentown LF range to the Harrisburg LF range; an ADF route from Harrisburg to the Martinsburg LF range; via the south course of Martinsburg to the Front Royal LF range; and an ADF route from Front Royal to the Gordonsville LF range.

RECOMMENDATIONS

1. As the first step in increasing the capacity of the Washington terminal area, it is recommended that the facilities and procedures described in Phase E be installed.

2. To decrease controller work load and improve radar-vectoring procedures at Washington National Airport, it is recommended that holding fixes be installed at Alexandria and Hyde as described in connection with Phases G or H.

3. When a single-stack system becomes inadequate to handle Andrews Field traffic, it is recommended that the system described in connection with Phase H be installed for northwesterly landings.

4. In order to maintain a high acceptance rate at each airport under southerly wind conditions, it is recommended that the system be expanded further to include the McLean, Kensington, and Largo facilities described in connection with Phase H.

5. If still further increases in acceptance rate are demanded, it is recommended that efforts be made to secure the use of portions of Danger Areas D-35, D-36, D-37, and D-38 so that a better system of arrival and departure routes utilizing VOR facilities can be developed.

6. The development of Andrews Field as the second major airport for the Washington terminal area is recommended as preferable to the construction of another major airport in the terminal area. The chief reason for this recommendation is that the use of the two present airports provides a more simple arrangement of arrival and departure routes than would be involved if a third major airport were commissioned. Comparative tests also indicate that the use of Andrews Field instead of the proposed Burke Airport may involve less restriction on the potential capacity of Washington National Airport.

7. The use of a large horizontal radar plotting scope as a common display for several air traffic controllers provides the opportunity to simplify the coordination problem. When used with an adequate system of target identification, the common pictorial display enables controllers to make immediate use of available altitudes at route intersections, with a considerable improvement in airspace utilization and a consequent reduction in aircraft delays. Because the advantages of such a system are particularly well adapted to the control of traffic in a complex terminal area, the development and procurement of an operational radar display having these characteristics is recommended as an important step in the solution of the Washington-Andrews traffic problem.

TABLE VI

SUMMARY OF CHANGES IN
AIR NAVIGATION FACILITIES

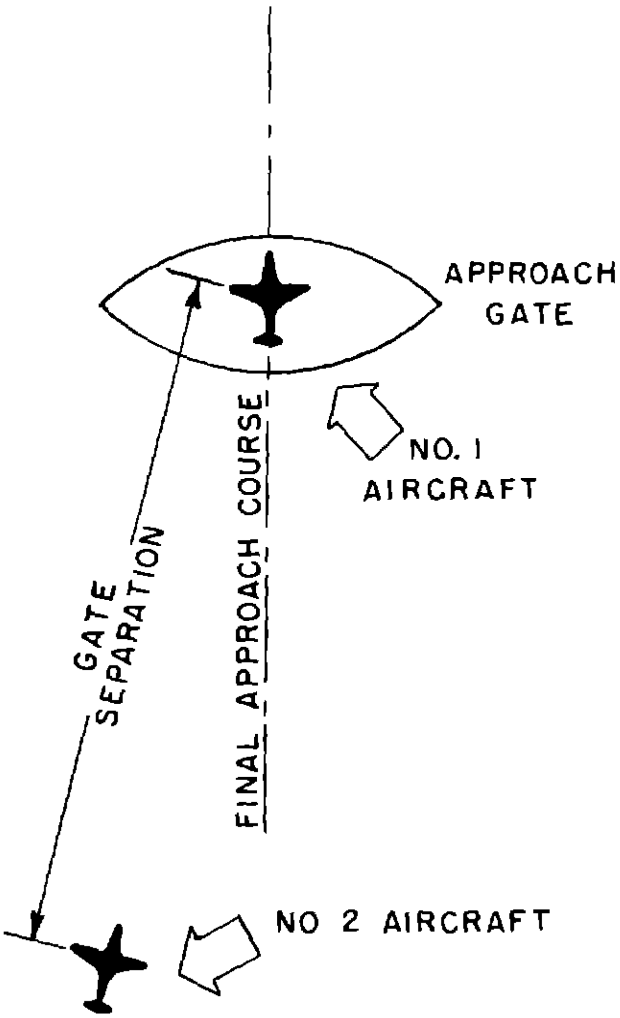
PHASE	ITEM NO.	CHANGE NEW	CHANGE RELOCATE	FACILITY	REASON
B	1	X		ILS for runway 32 at Andrews Field.	Provide precision approach aid.
	2	X		Compass locator 5.3 miles SE of Andrews Field.	Provide approach gate and letdown fix.
	3		X	Move Huntingtown H facility 2 miles NE, on centerline of approach course to runway 32 at Andrews Field.	Provide holding fix and radar identification check point for jet aircraft.
C	4	X		ILS for runway 1 at Andrews Field.	Same as 1.
	5	X		Compass locator 5.3 miles S of Andrews Field.	Same as 2.
	6		X	Move Washington TVOR to Chain Bridge.	Provide approach gate, letdown fix, and course guidance for approaches to runway 15 at Washington. Provide radial for aligning Alexandria holding pattern.
	7		X	Move Georgetown H facility to Alexandria.	Provide close-in holding fix.
	8	X		TVOR at Hyde.	Same as 7.
	9	X		H facility at Croom.	Same as 7.
	10		X	Move Shadyside H facility to Cedarhurst.	Provide secondary holding pattern clear of Croom pattern. Provide new ADF route SE to Red Airway 77.
D	11		X	Realign N course of Camp Springs LF range to cross Riverdale.	Provide independent arrival route for Washington traffic from the north.
	12	X		TVOR at Croom.	Provide shorter trombone-type paths. Provide VHF course guidance from Beltsville and Charlotte Hall.
	4	X		See corresponding items above.	See corresponding items above.
	5	X			
	6		X		
	10		X		

TABLE VI (Cont'd)

PHASE	ITEM NO.	CHANGE NEW	CHANGE RELOCATE	FACILITY	REASON
E	13	X		Compass locator 5.3 miles N of Andrews Field.	Same as 2.
	14	X		H facility at McLean.	Same as 7.
	4	X			
	5	X			
	9	X		See corresponding items above.	See corresponding items above.
	10		X		
	11		X		
F	15	X		H facility at Waldorf.	Same as 7.
	4	X			
	5	X			
	6		X		
	7		X		
	8	X		See corresponding items above.	See corresponding items above.
	10		X		
	11		X		
	12	X			
	13	X			
	14	X			
G	16	X		TVOR at Columbia.	Provide close-in holding fix plus VHF course guidance for routes from N and E.
	17	X		H facility at Cedarville.	Same as 7.
	18		X	Move Charlotte Hall H facility 3 miles south.	Provide secondary holding pattern clear of Columbia pattern.

TABLE VI (Cont'd)

PHASE	ITEM NO.	CHANGE ADD	RELOCATE	FACILITY	REASON
G	1	X			
	2	X			
	3	X			
	6		X	See corresponding items above.	See corresponding items above.
	7		X		
	8	X			
	10	X			
	11		X		
	13	X			
H	19	X		H facility at Kensington.	Same as 7.
	20	X		H facility at Largo.	Same as 7.
	21	-	-	Change designation of Cedarhurst facility to Shadyside.	Avoid confusion between Cedarville and Cedarhurst.
	1	X			
	2	X			
	3		X		
	6		X		
	7		X		
	[illegible]	X		See corresponding items above.	See corresponding items above.
	10		X		
	11		X		
	13	X			
	14	X			
	16	X			
	17	X			
	18	X			



NOTE:
GATE SEPARATION REFERS TO FLIGHT PATH DISTANCE BETWEEN TWO SUCCESSIVE AIRCRAFT AT MOMENT NO 1 AIRCRAFT IS OVER THE APPROACH GATE

OPTIMUM
AIRCRAFT SPACING

ZERO WIND CONDITION
GATE TO RUNWAY 5 3 MI

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	F	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 (MPH)
S	120
M	140
F	150
J	180

FIG. 1 AIRCRAFT SPACING TABLE

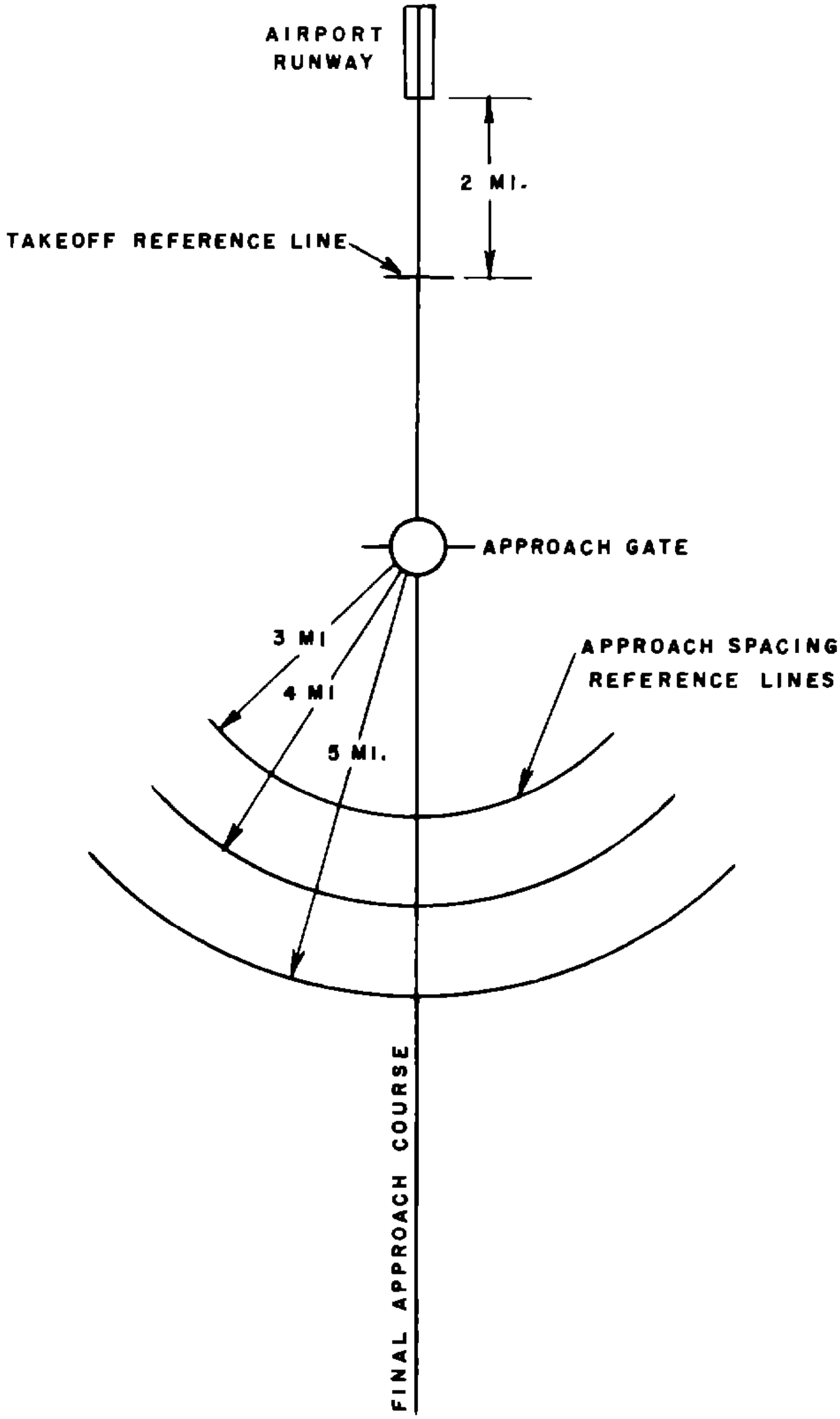


FIG 2 RECOMMENDED SPACING REFERENCE LINES FOR RADAR OVERLAY

CAA TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS INDIANA

EXAMPLE
FIVE MILES SPACING DESIRED BETWEEN AIRCRAFT AT APPROACH GATE

AT A, NO 2 AIRCRAFT IS TURNED TO HEADING WHICH WILL PLACE IT APPROXIMATELY 4 ½ MILES FROM GATE WHEN NO I AIRCRAFT REACHES GATE

AT B, WHEN NO I AIRCRAFT REACHES APPROACH GATE, NO 2 AIRCRAFT IS HEADED DIRECTLY TOWARD TURN-ON POINT

AT C, WHEN NO 2 AIRCRAFT COMPLETES TURN, SEPARATION HAS INCREASED APPROXIMATELY ½ MILE TO THE DESIRED VALUE OF 5 MILES

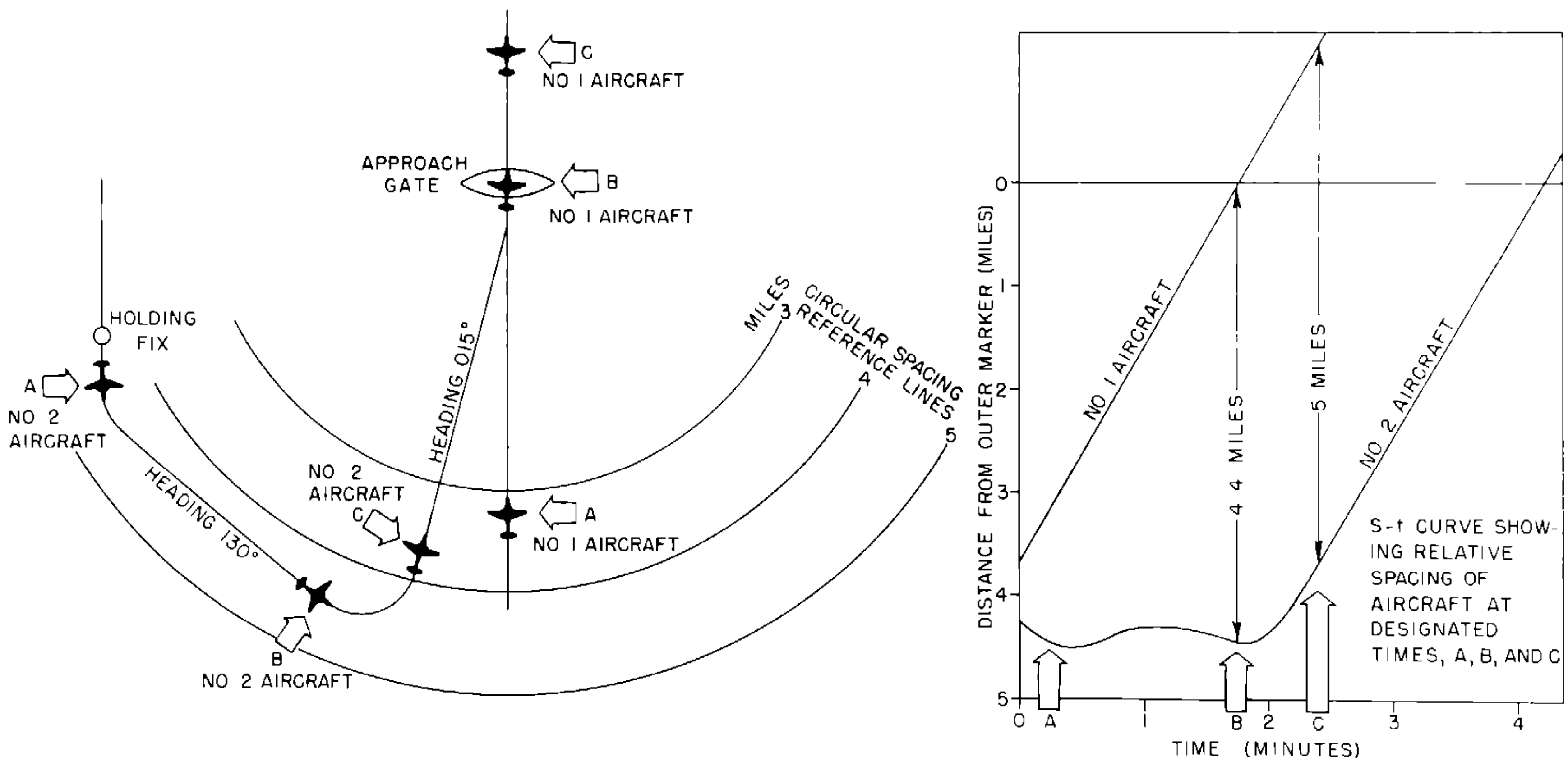
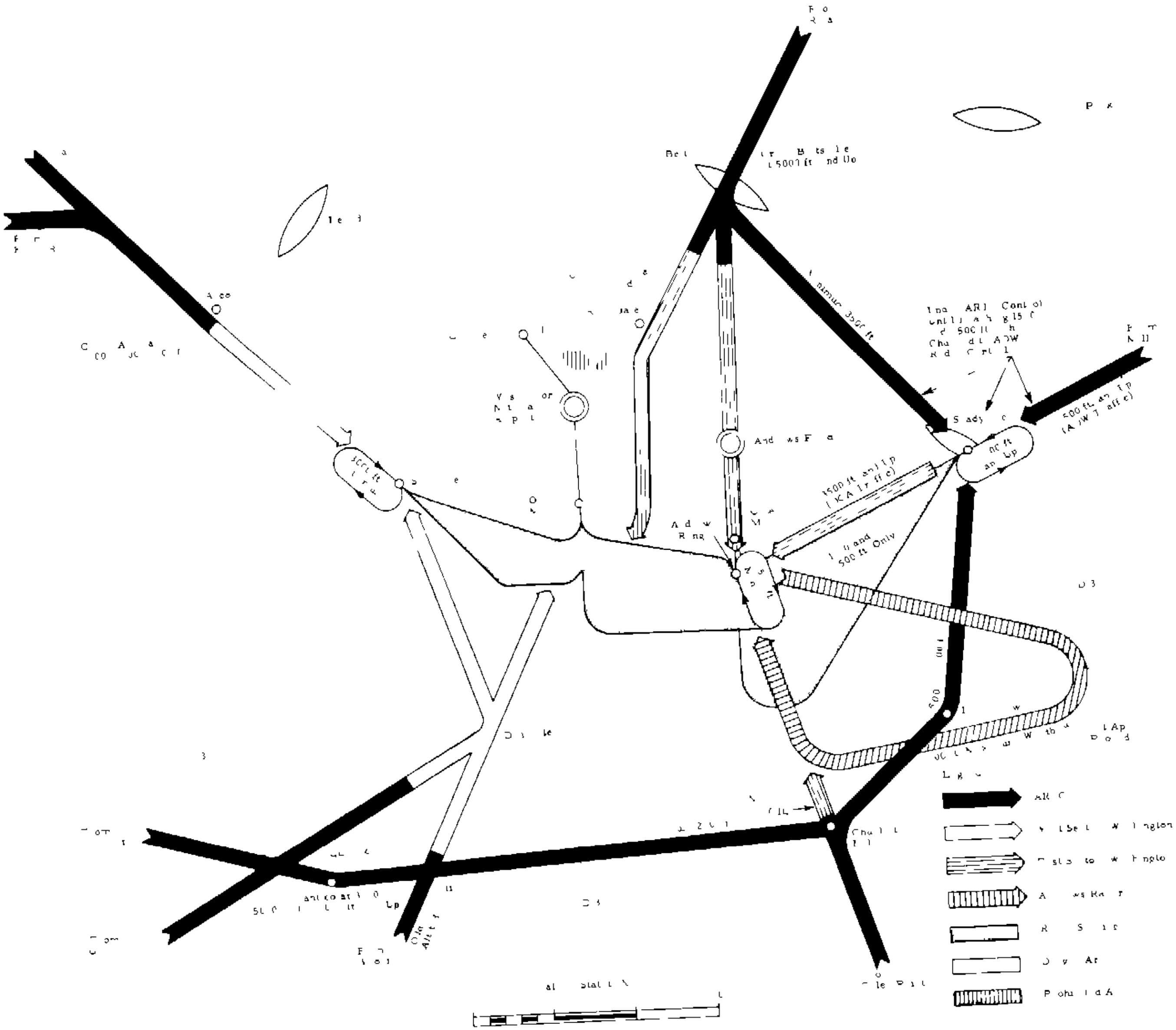
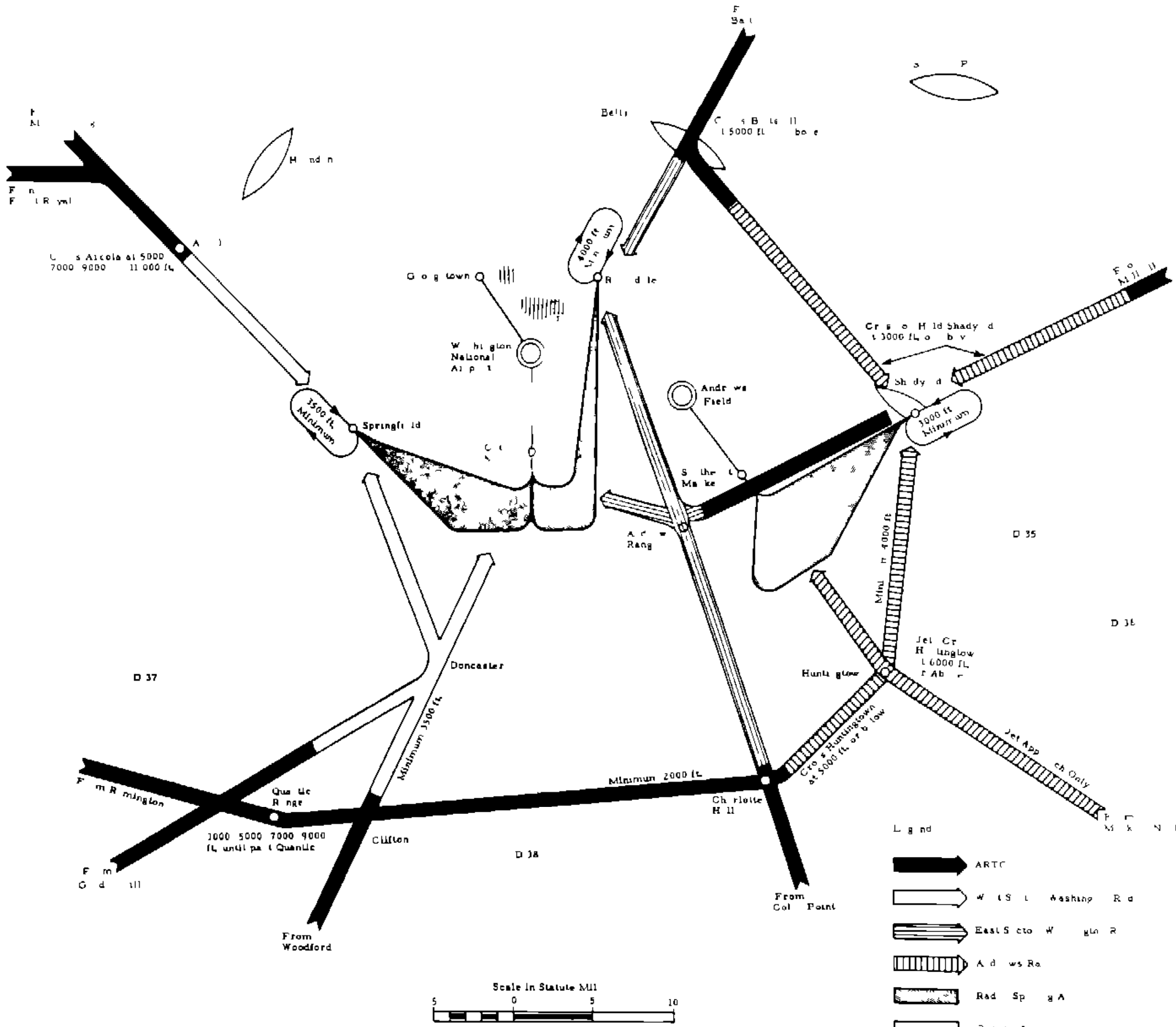


FIG 3 USE OF CIRCULAR SPACING REFERENCE ON RADAR SCOPE





Doncaster
Springfield
Washington National Airport
Andrews Field
Clifton
From Woodford
From Col Point
Charlotte Hall
Huntingtown
Minimum 2000 ft.
Minimum 3500 ft.
3500 ft. Minimum
3000 ft. Minimum
4000 ft. Minimum
3000 5000 7000 9000 ft. until past Quantic
Cross Huntingtown at 5000 ft. or below
Jet Approach Only
D 35
D 37
D 38
Legend
ARTC
Scale in Statute Miles
5
0
5
10

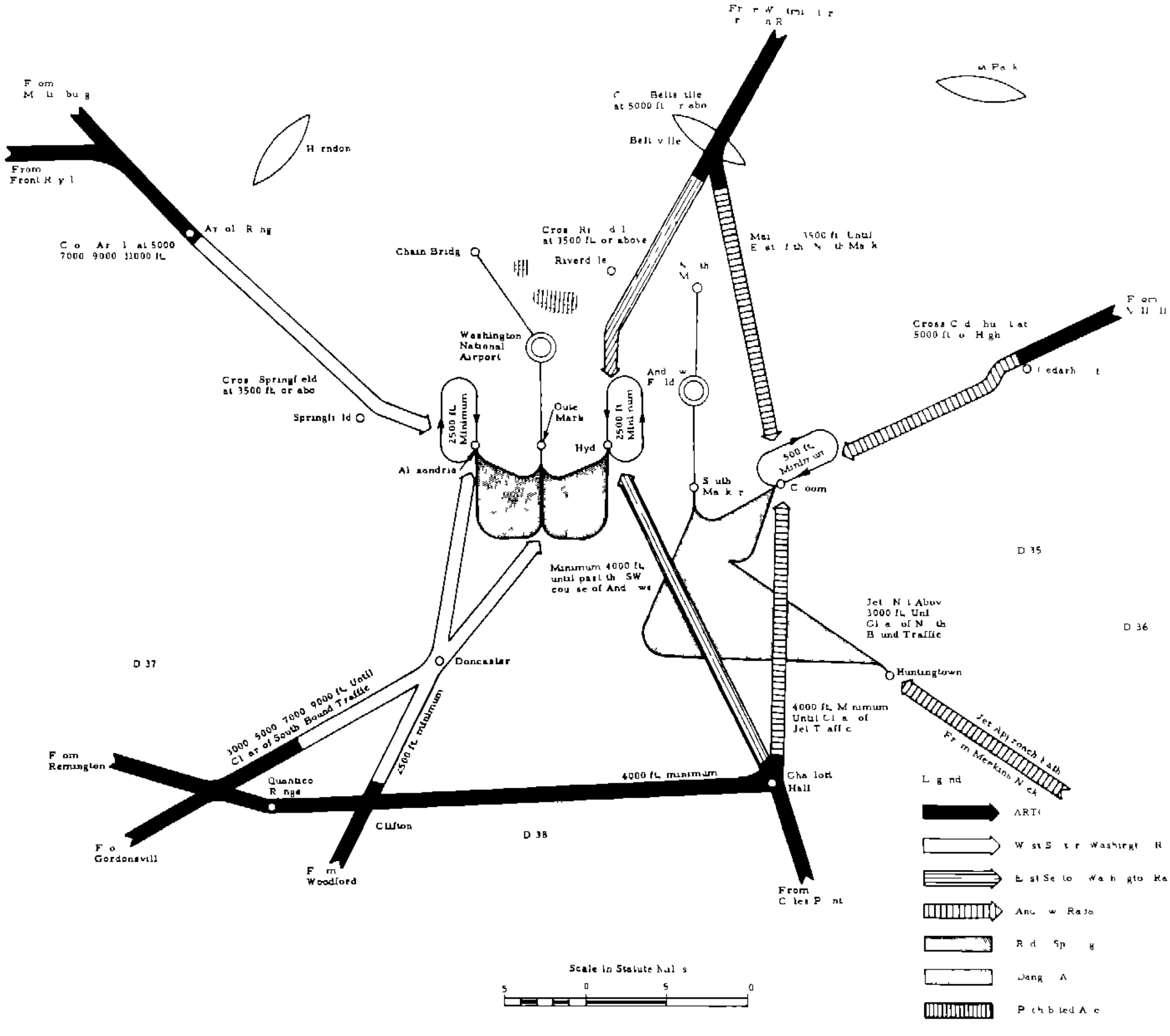


FIG 6 PHASE C ARRIVAL ROUTES NORTH LANDINGS

CAA TECHNICAL DEVELOPMENT AND EVALUATION CENTER INDIANAPOLIS INDIANA

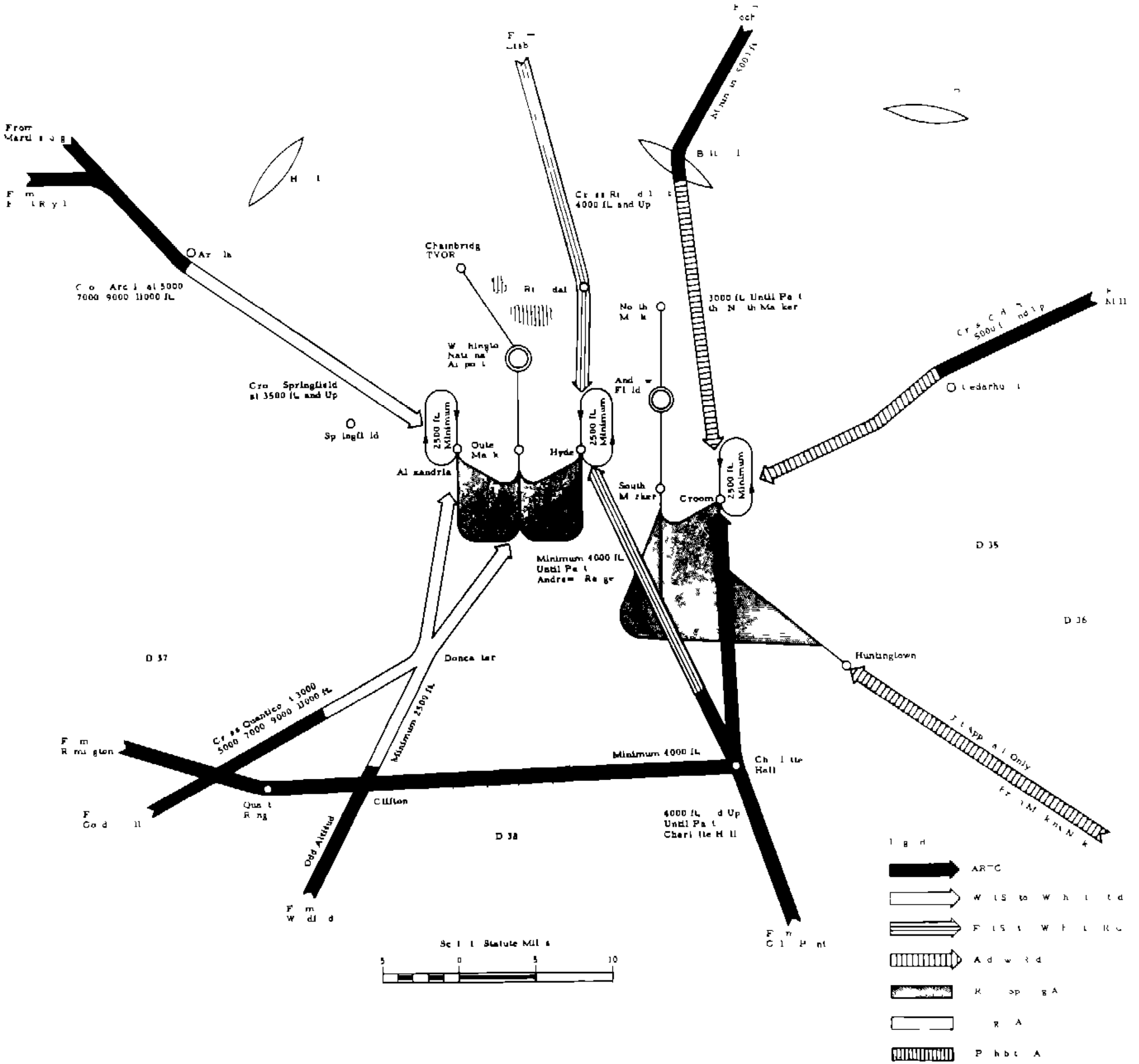


FIG PHASE D ARRIVAL ROLTES NORTH ANTINGS

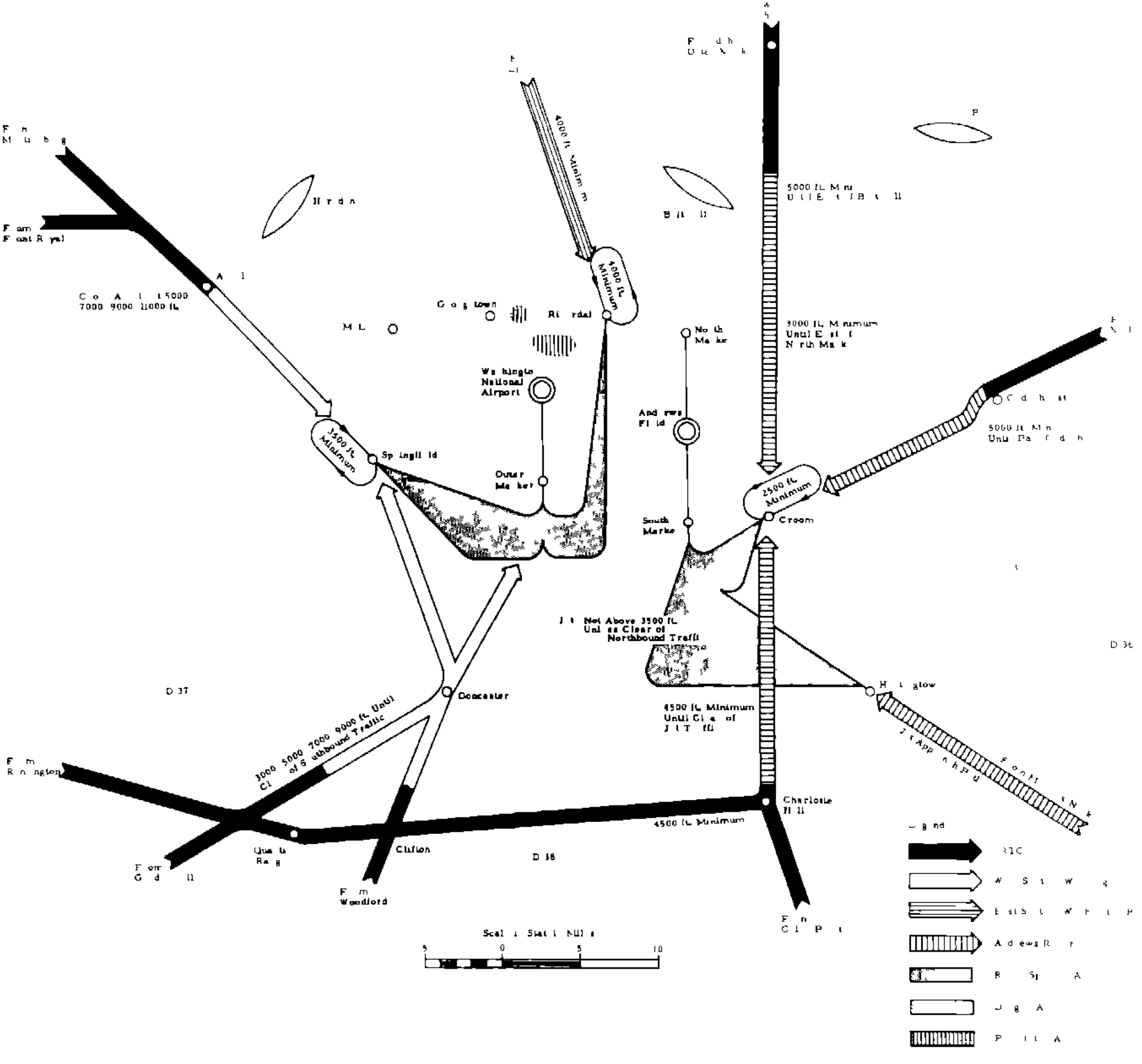
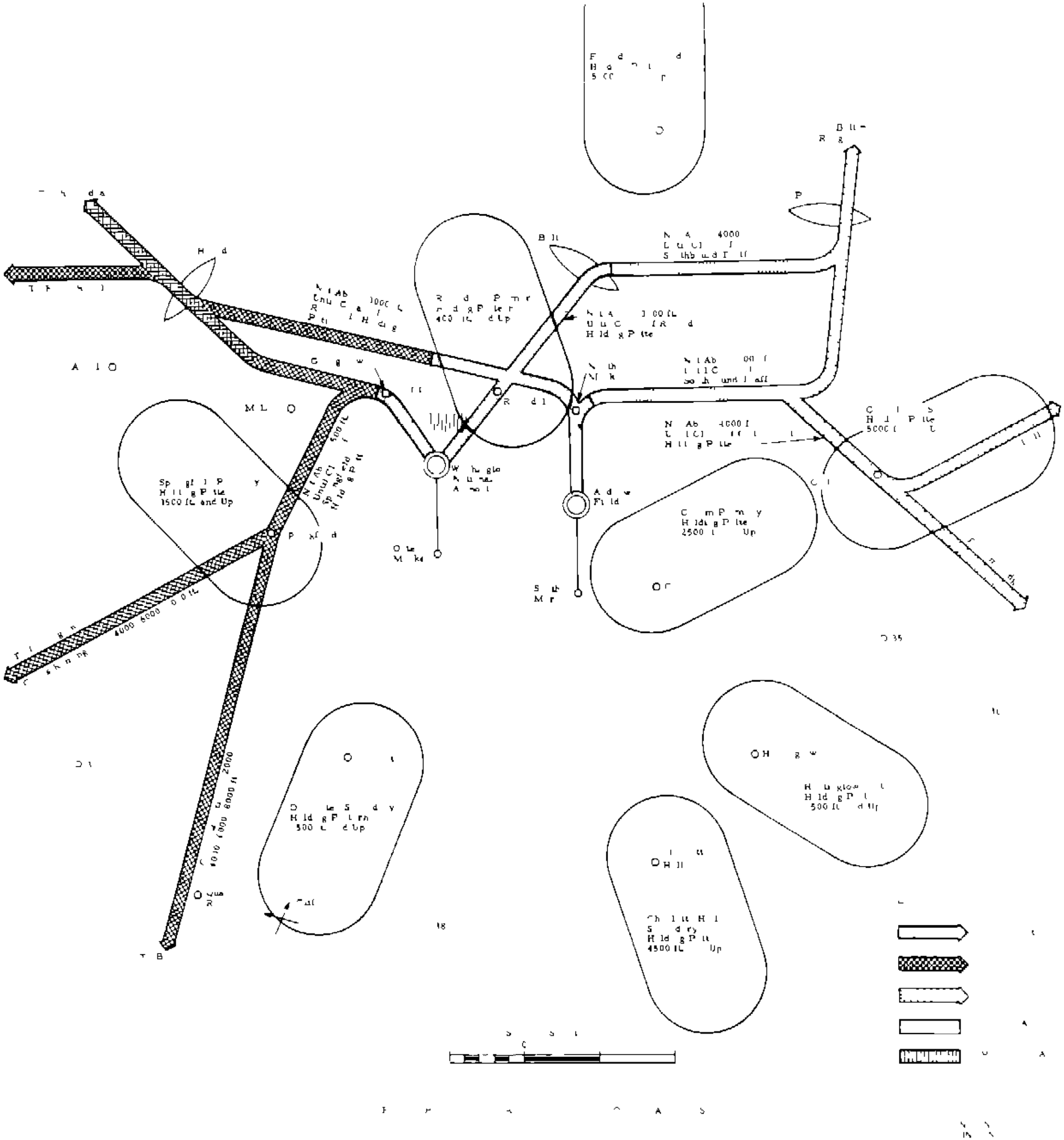


FIG 8 PHASE E ARRIVAL ROUTES NORTH LANDINGS



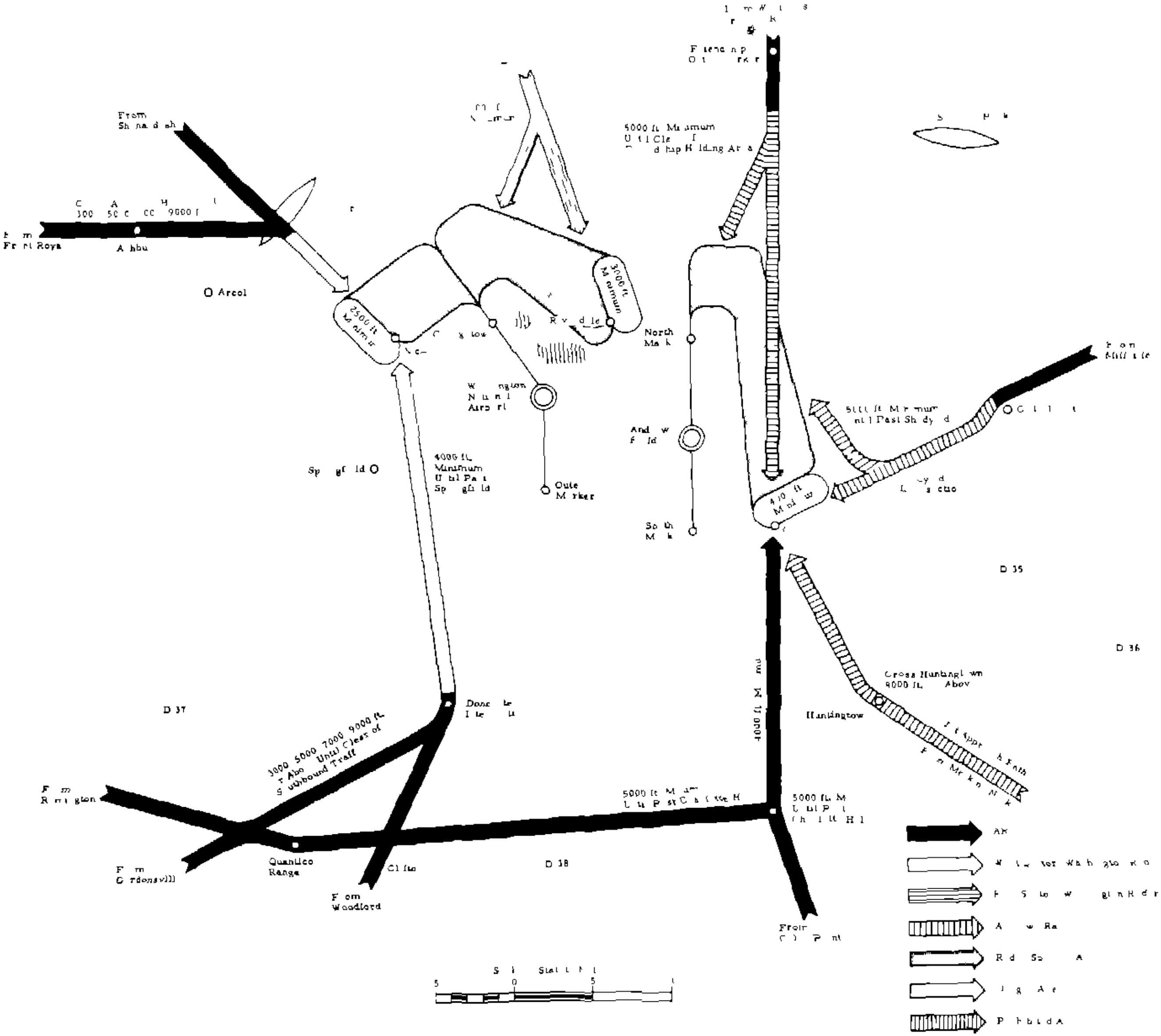


FIG PHASE C ARRIVAL ROUTES SOUTH LANDINGS

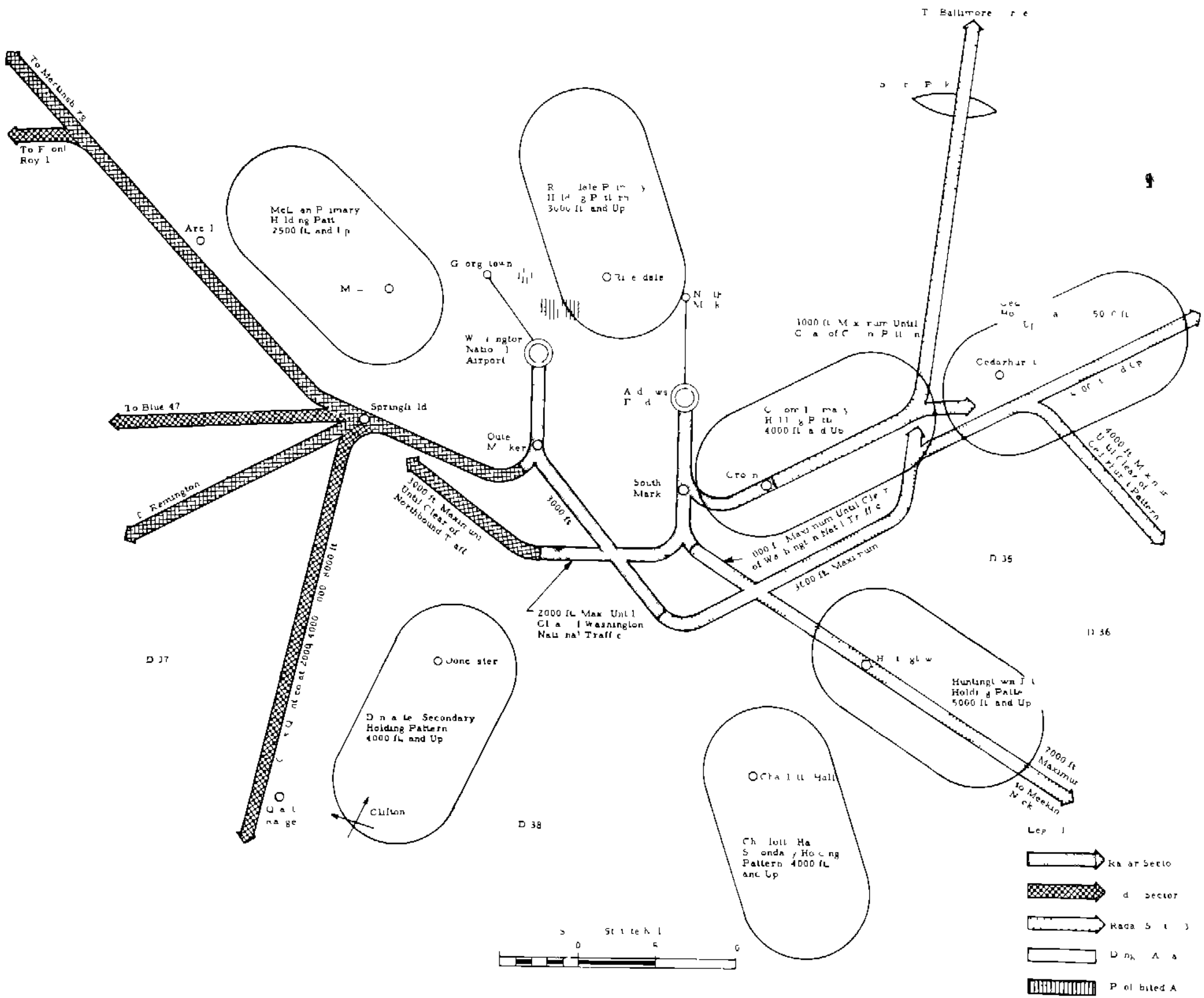
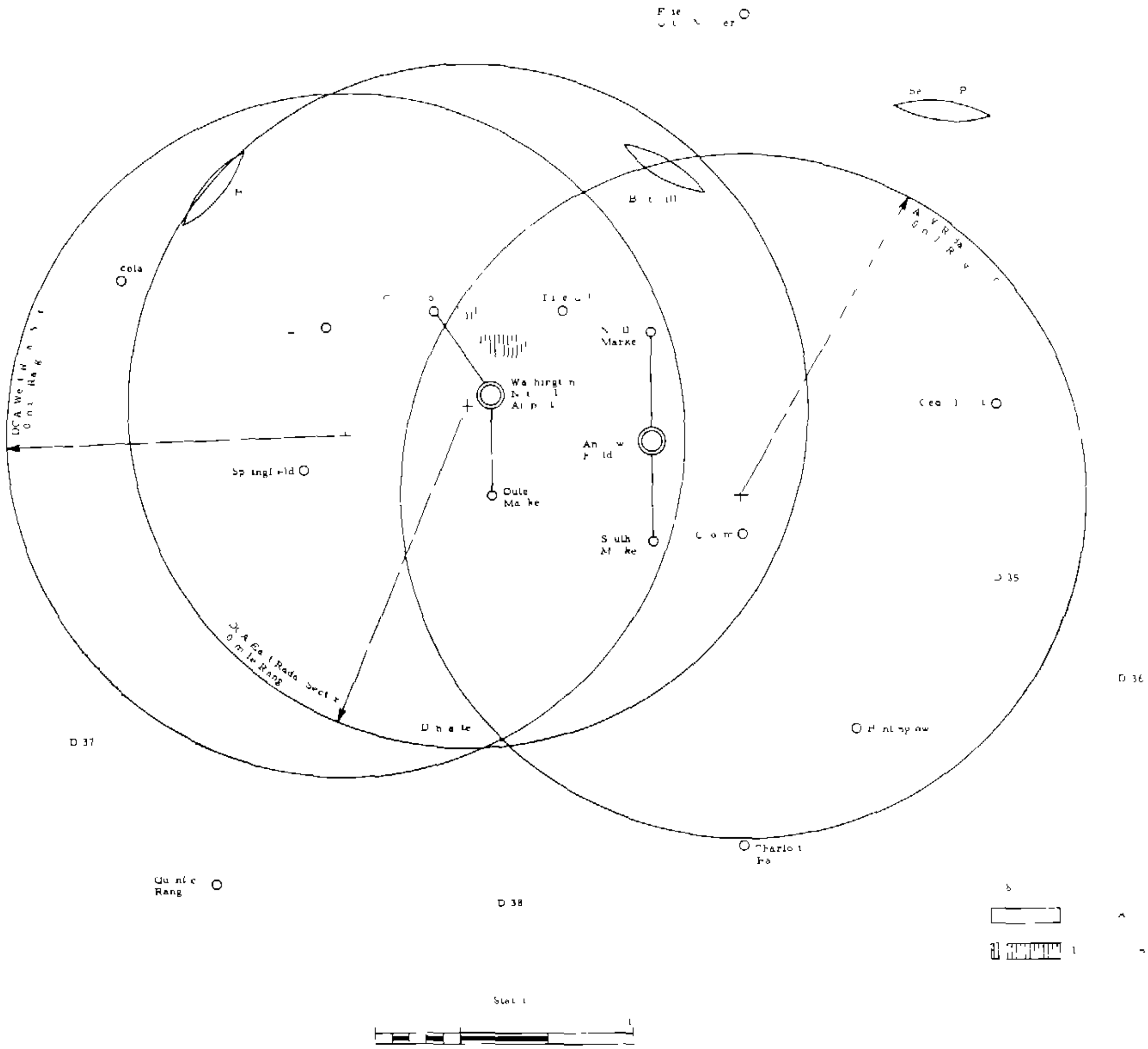


FIG. 11 PHASE E DEPARTURE ROUTES SOUTH TAKEOFFS



L) RED A AR CO ERAGE PHA O TH AND NGS

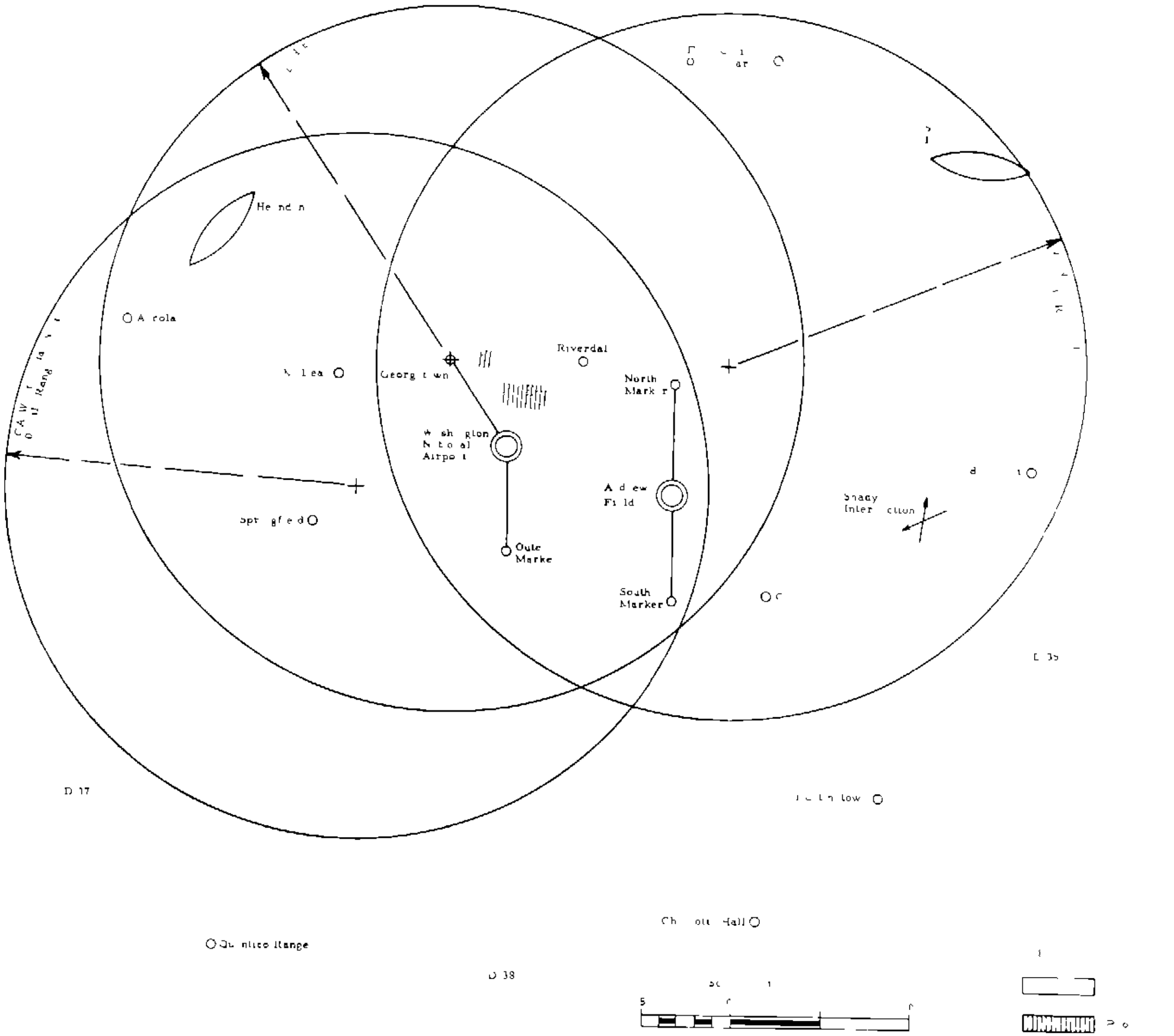


FIG 3 DESIRE A COVERAGE PHAS E S I H

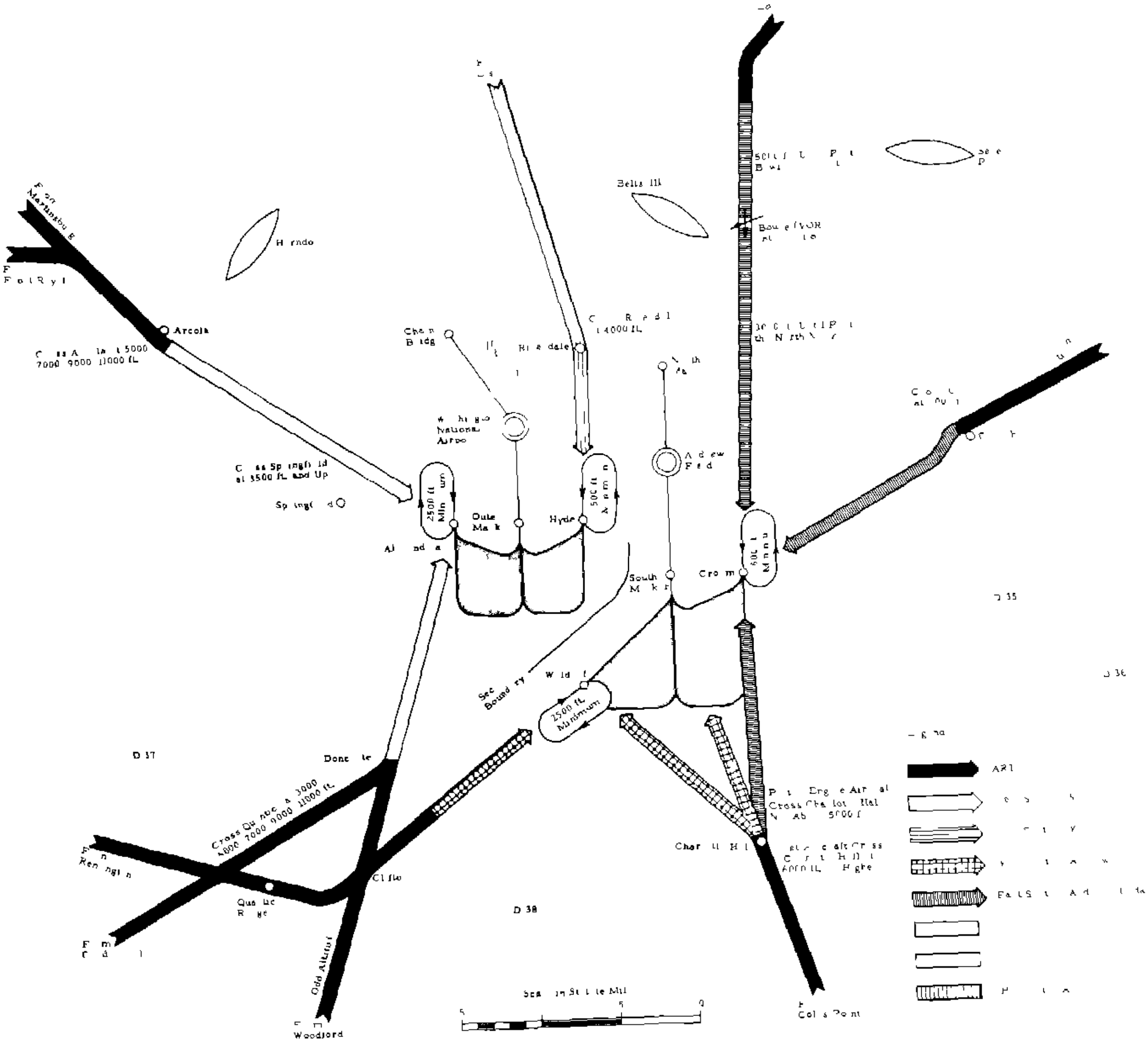
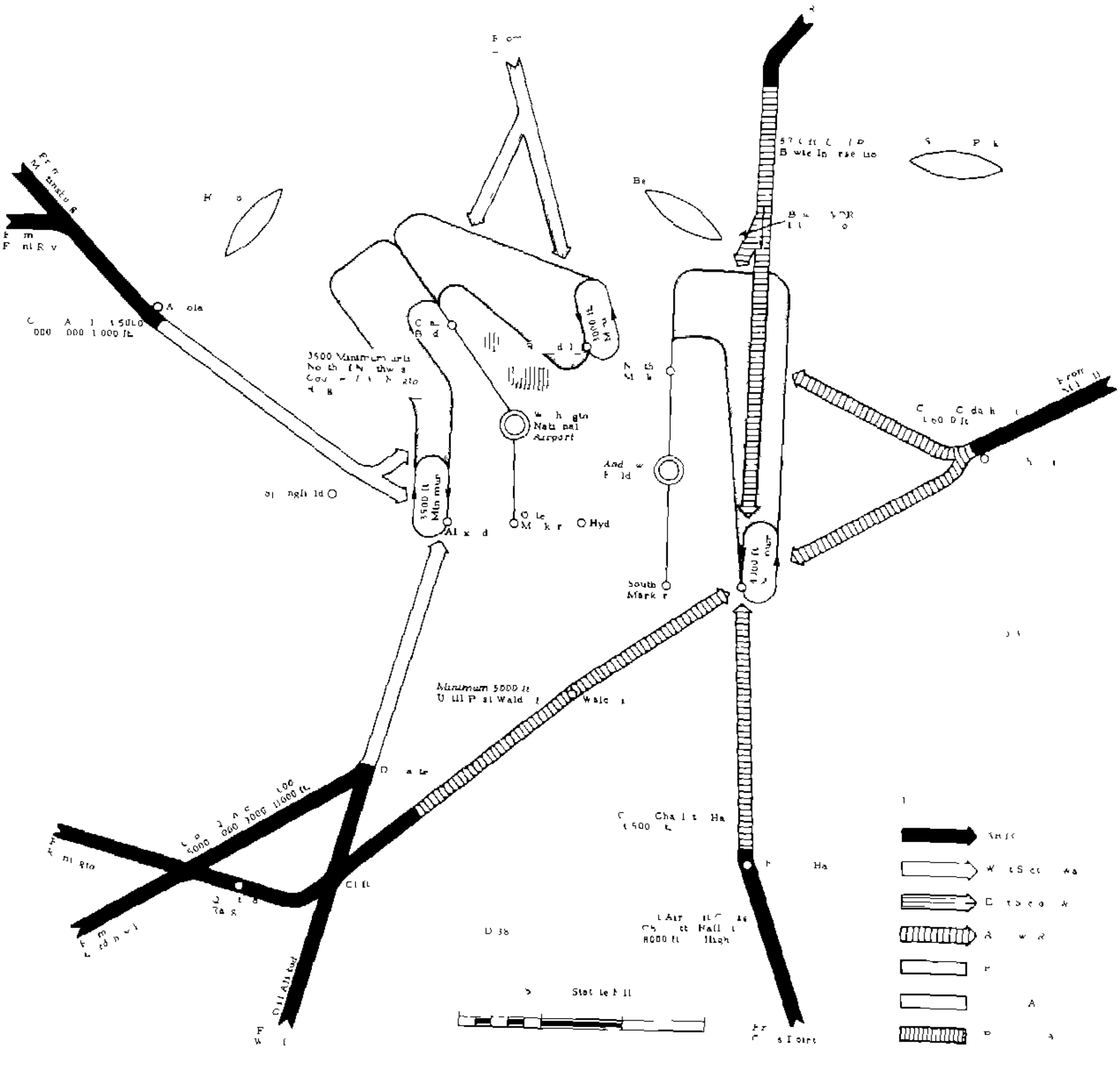
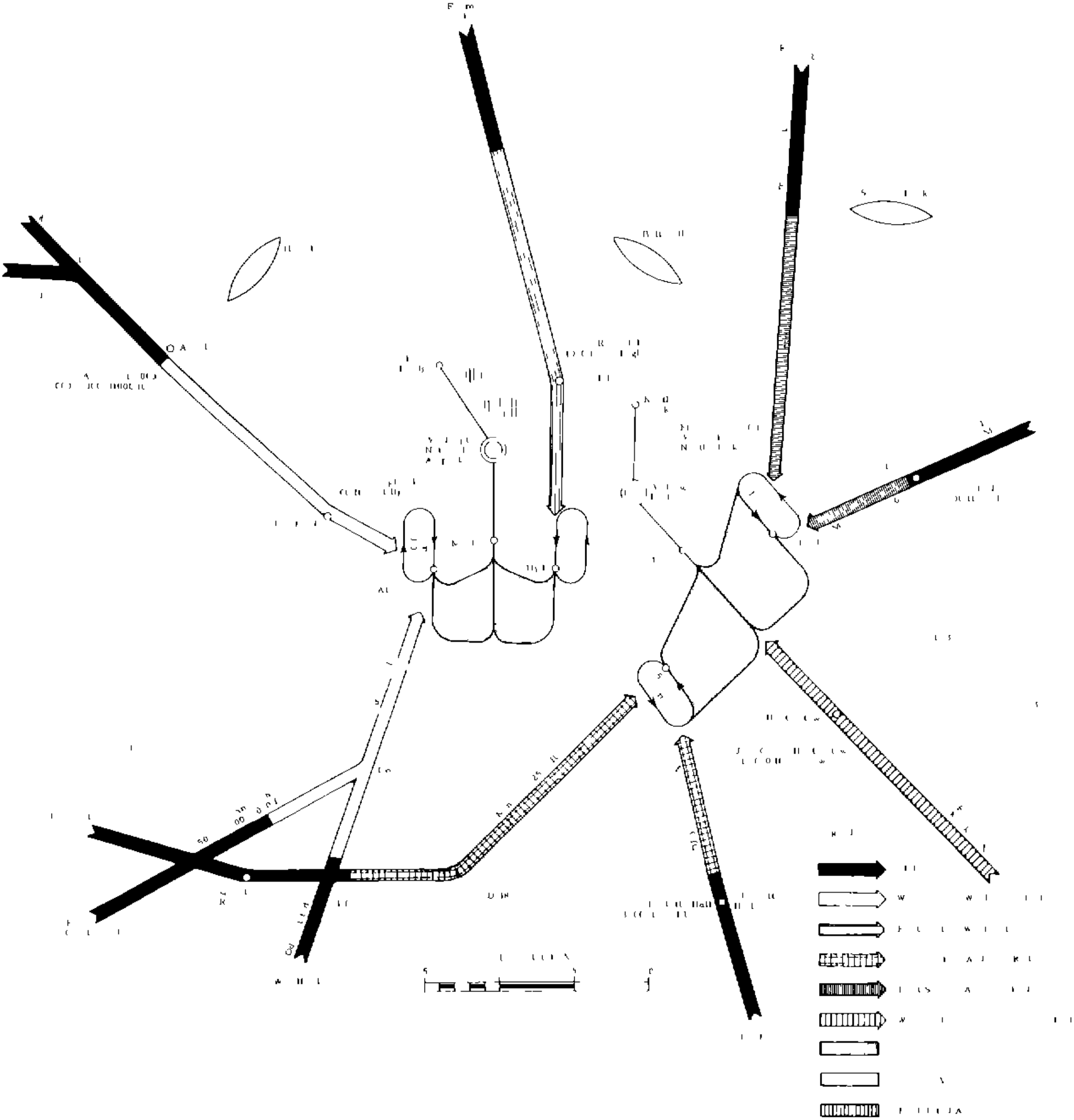


FIG 4 PHASE ARRI A UTES



F C I PHASE I ARR VAL OUT G H A I 70



AA TECHN AL DEVELOPMENT
ANI EVA UATION CENTER
INDIANAPOLIS INDIANA

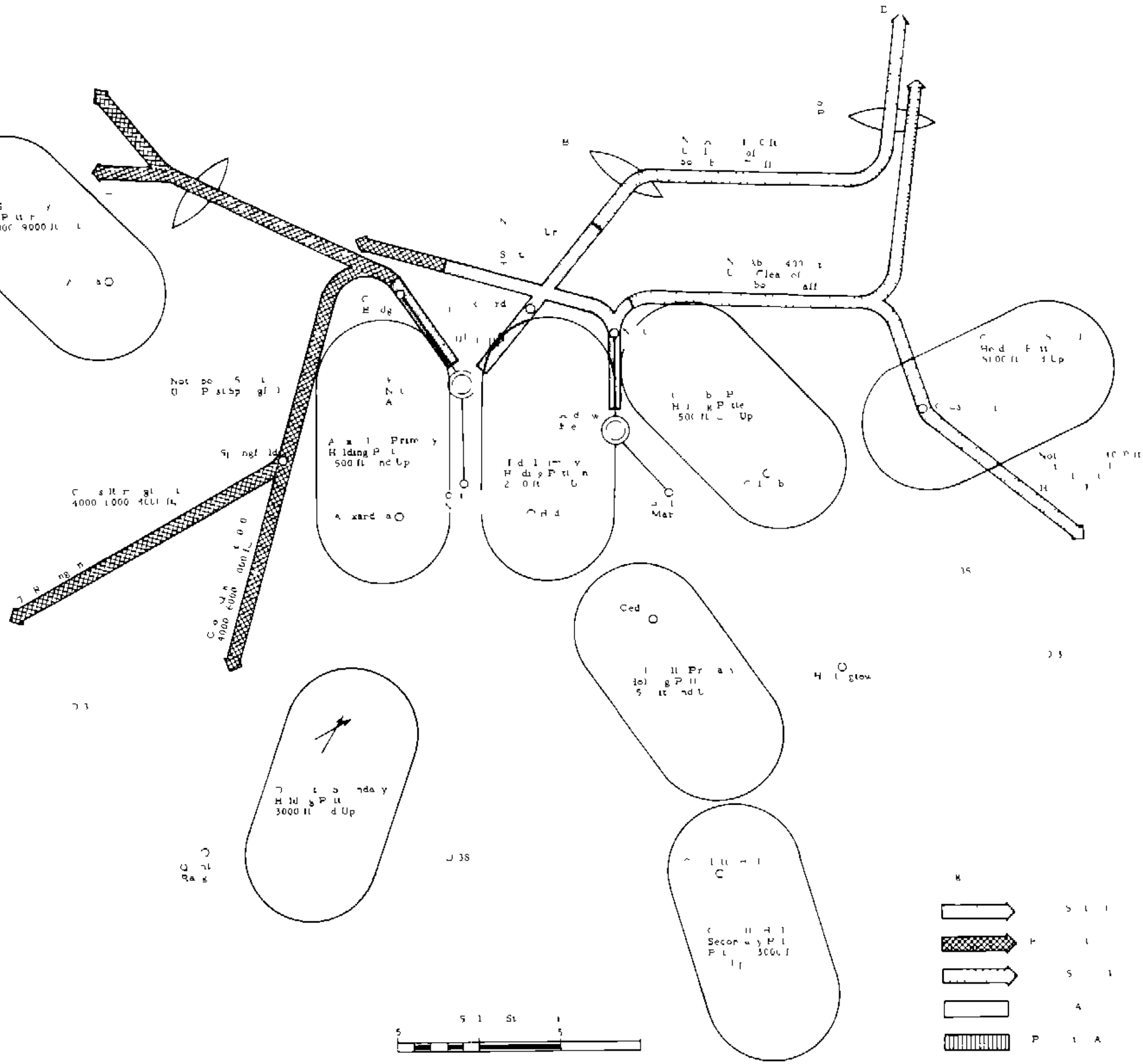
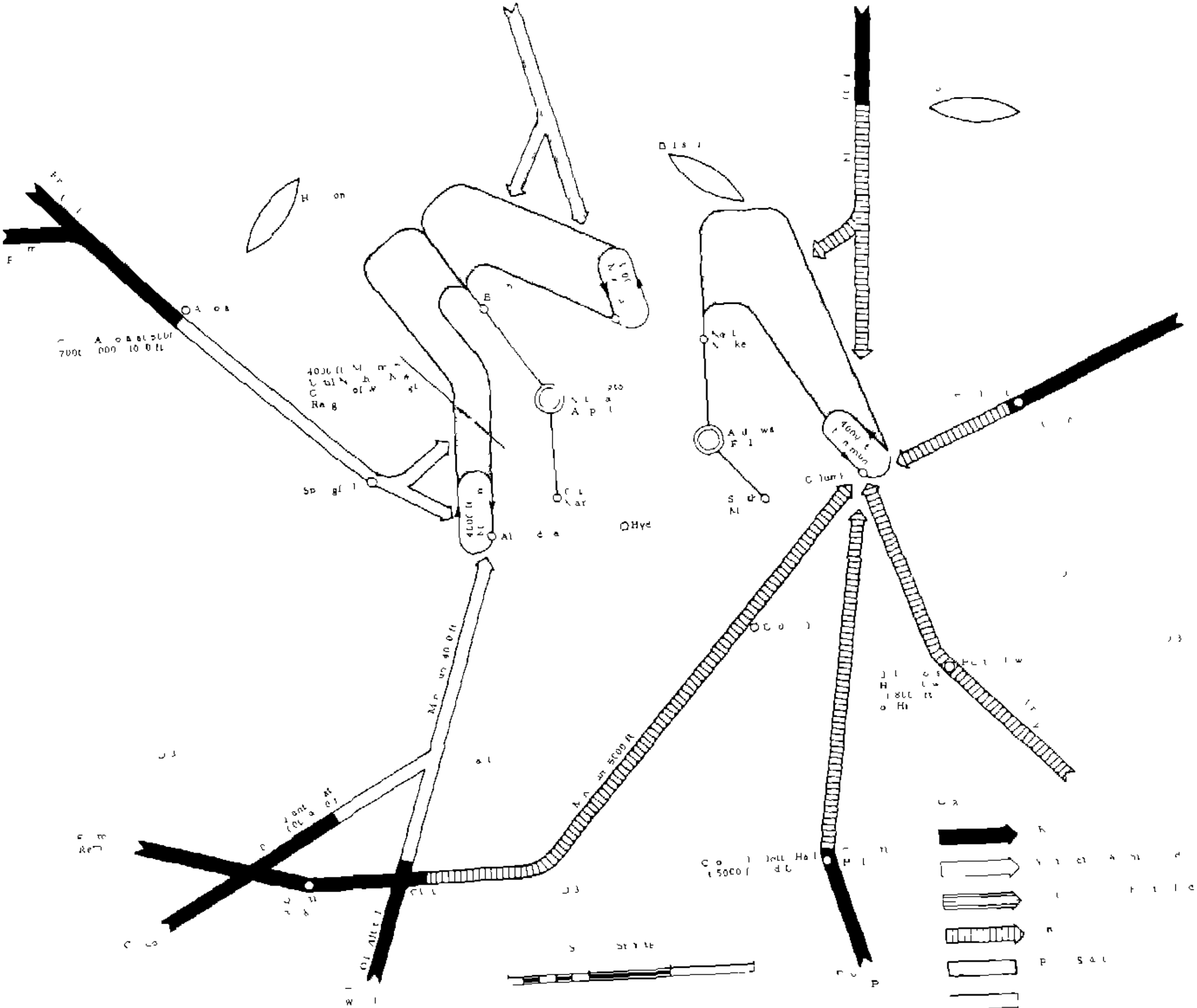
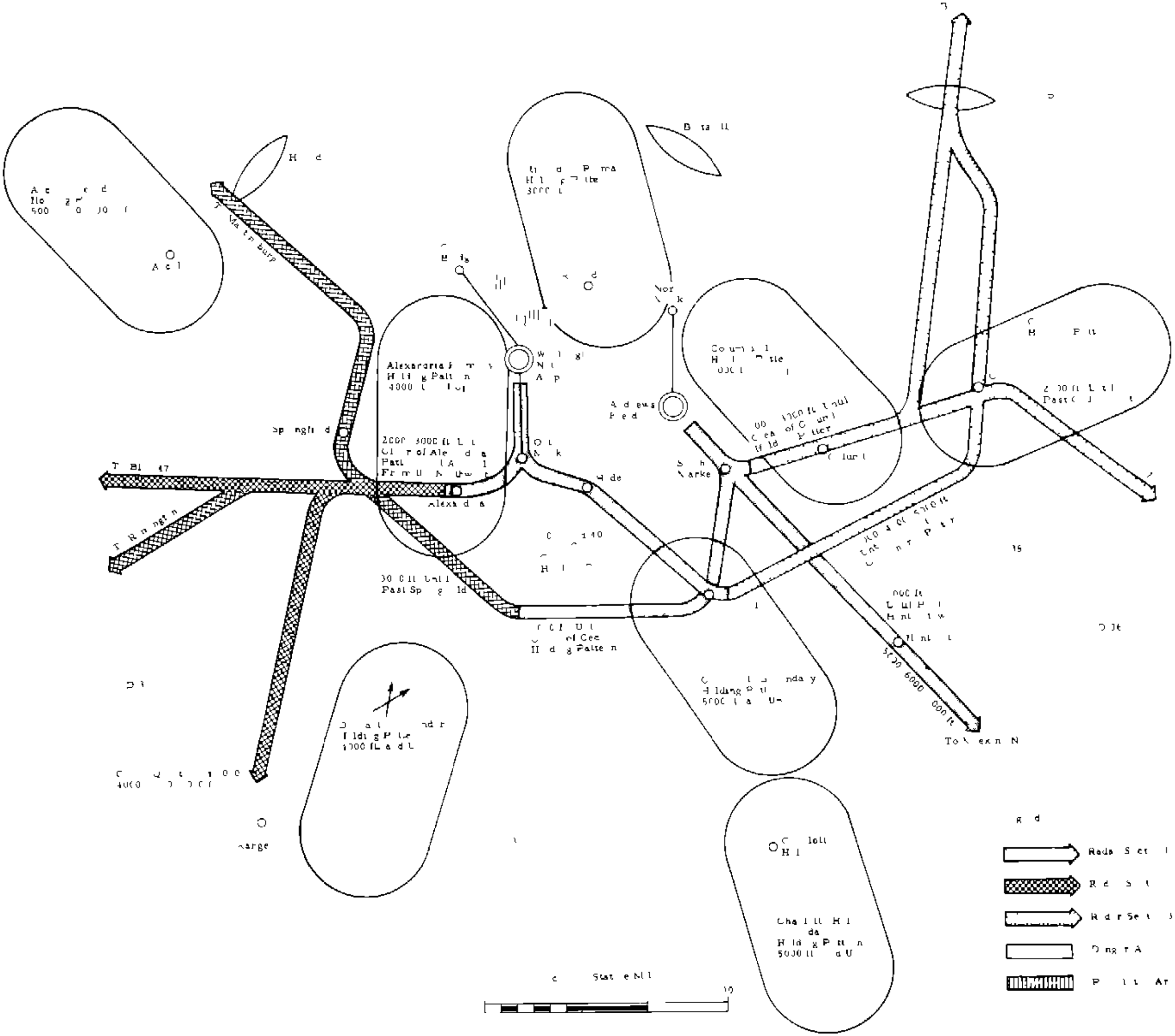


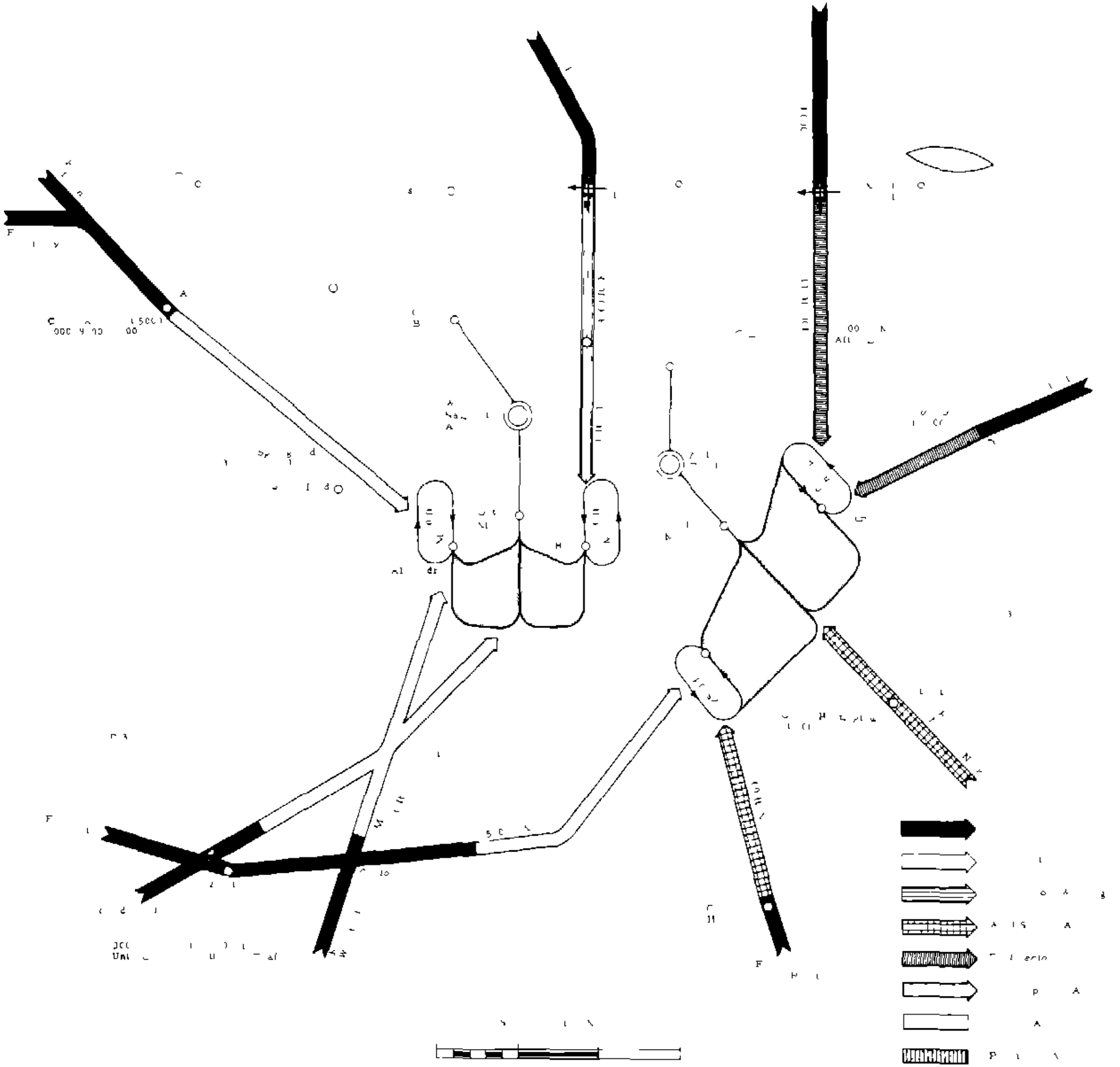
FIG P ASE G) PAR UR ROU NORT A I OR

AA ECHNICAL DEVELOPMENT
AN E ALUATION CENTER
INDIANAPOLIS INDIANA





…NICAL DEVELOPMENT AND EVALUATION CENTER, INDIANAPOLIS, INDIANA



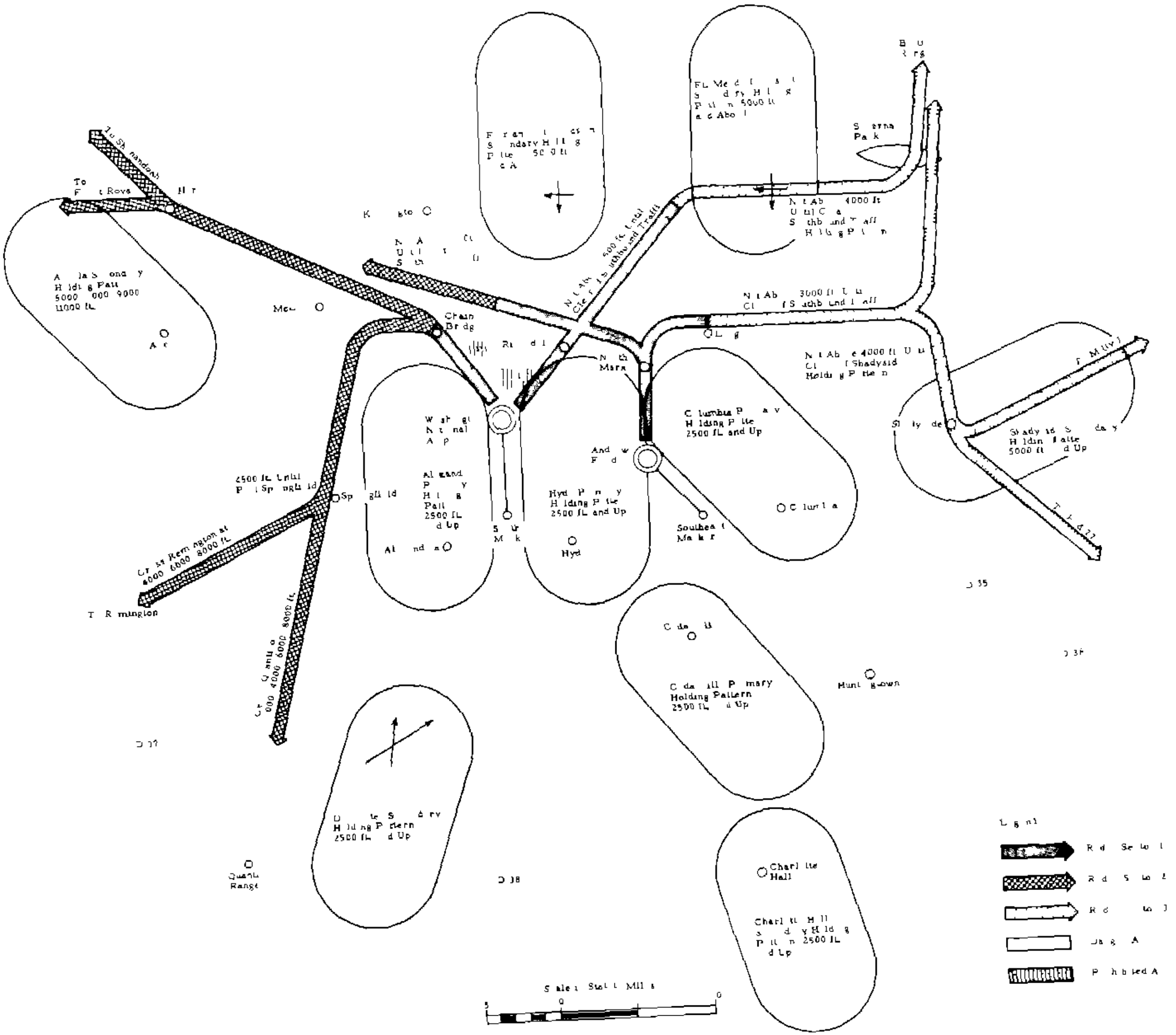


FIG PH SE P EPARTURE ROU ES NORTH TAKEOFF

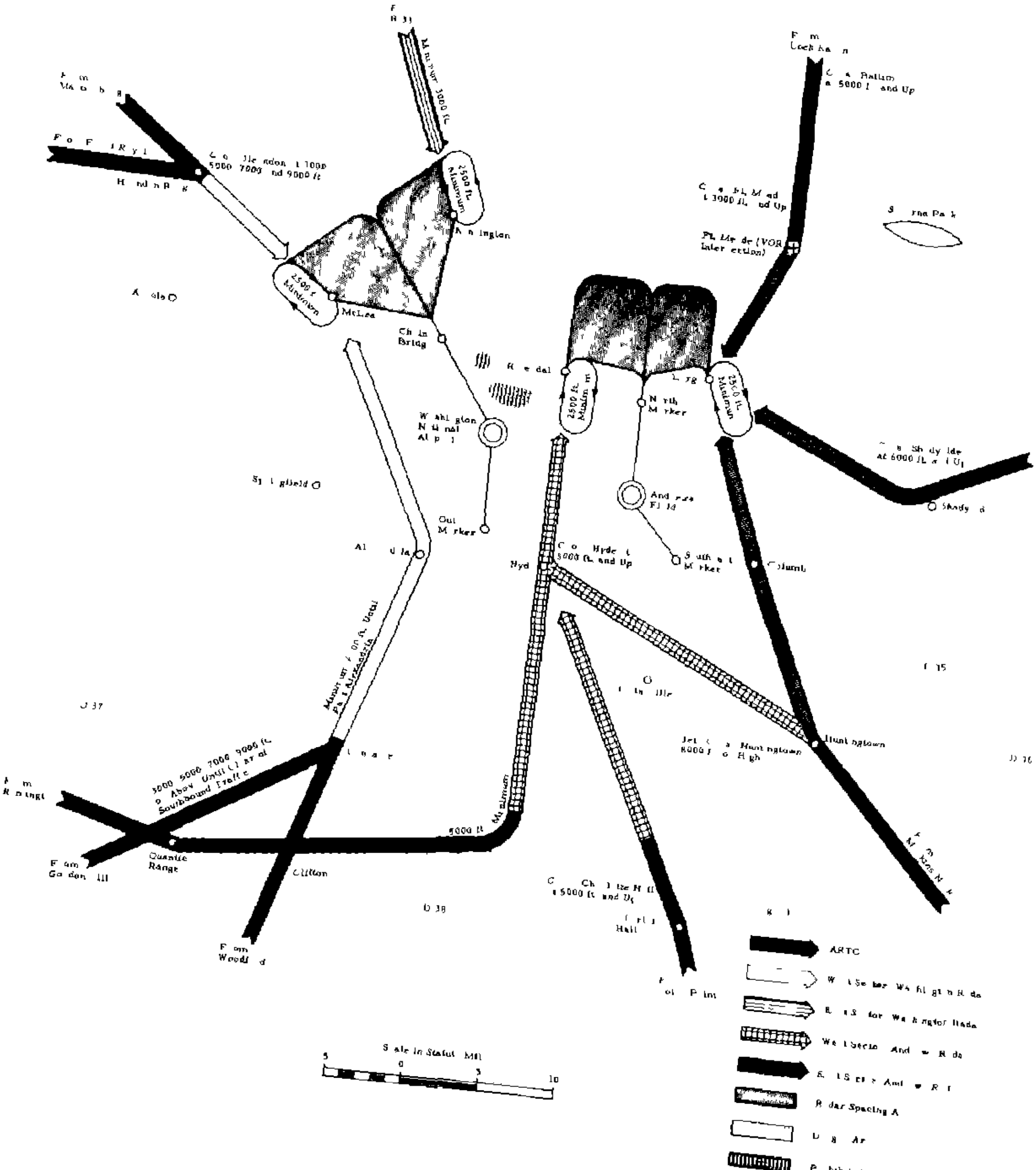


FIG 22 PHASE II ARRIVAL ROUTES SOUTH LANDINGS

A TE HNICAL DEVELOPM NT
AN EVALUATION CENTER
INDIANA OLIS INDIANA

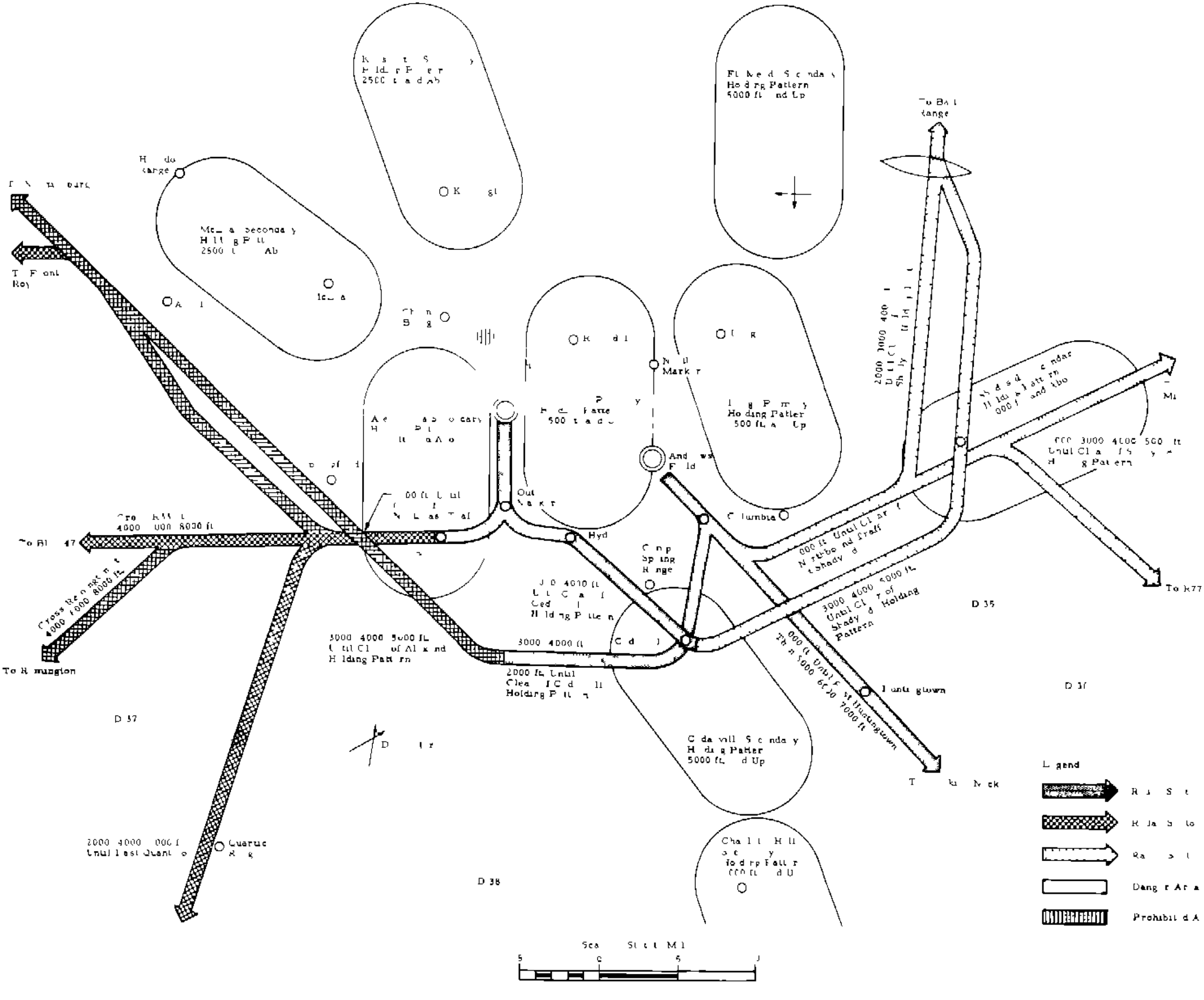


FIG 3 PHASE II DEPARTURE ROUTES — SOUTH TAKEOFFS

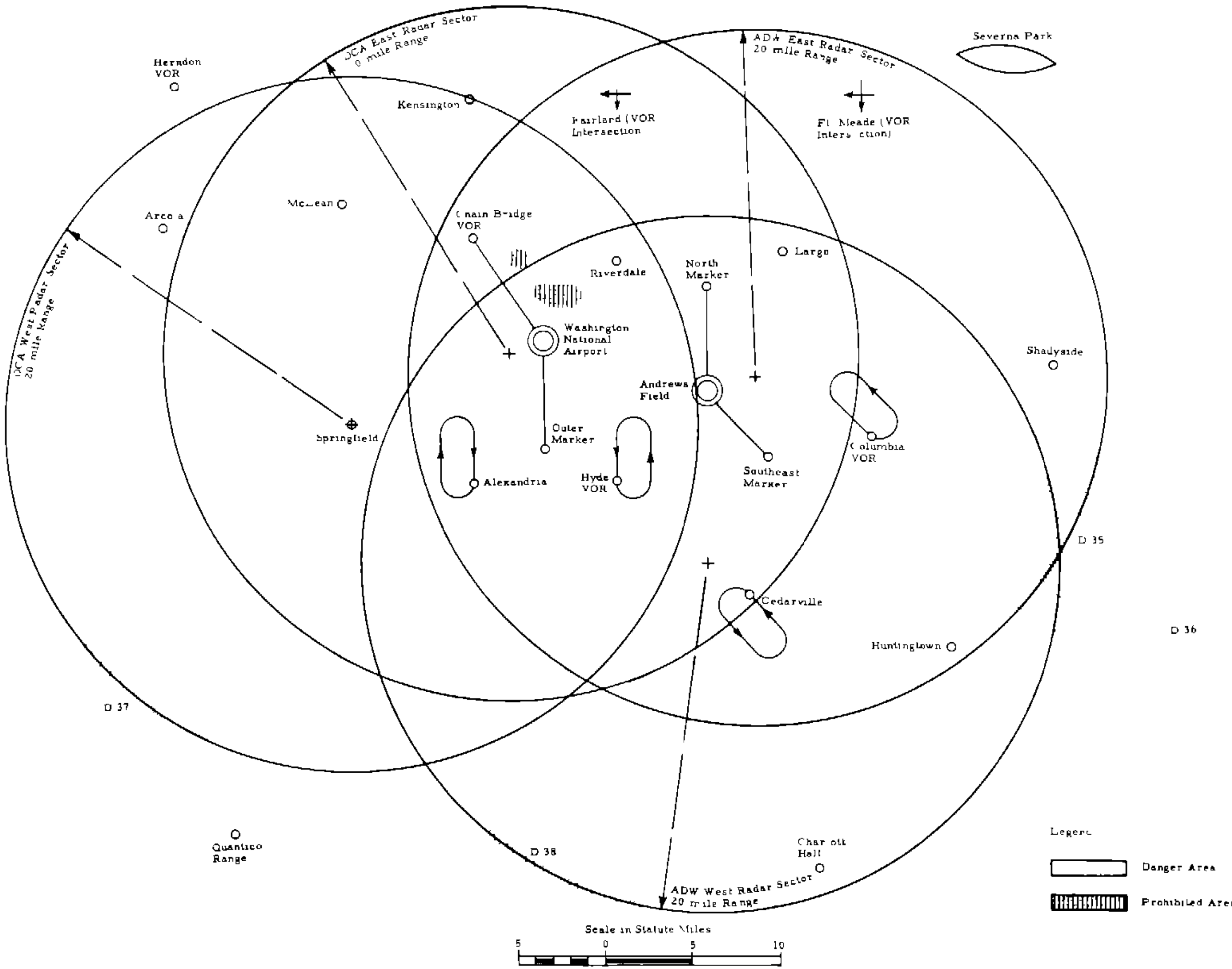


FIG 4 DESIRED RADAR COVERAGE PHASE H NORTH LANDINGS

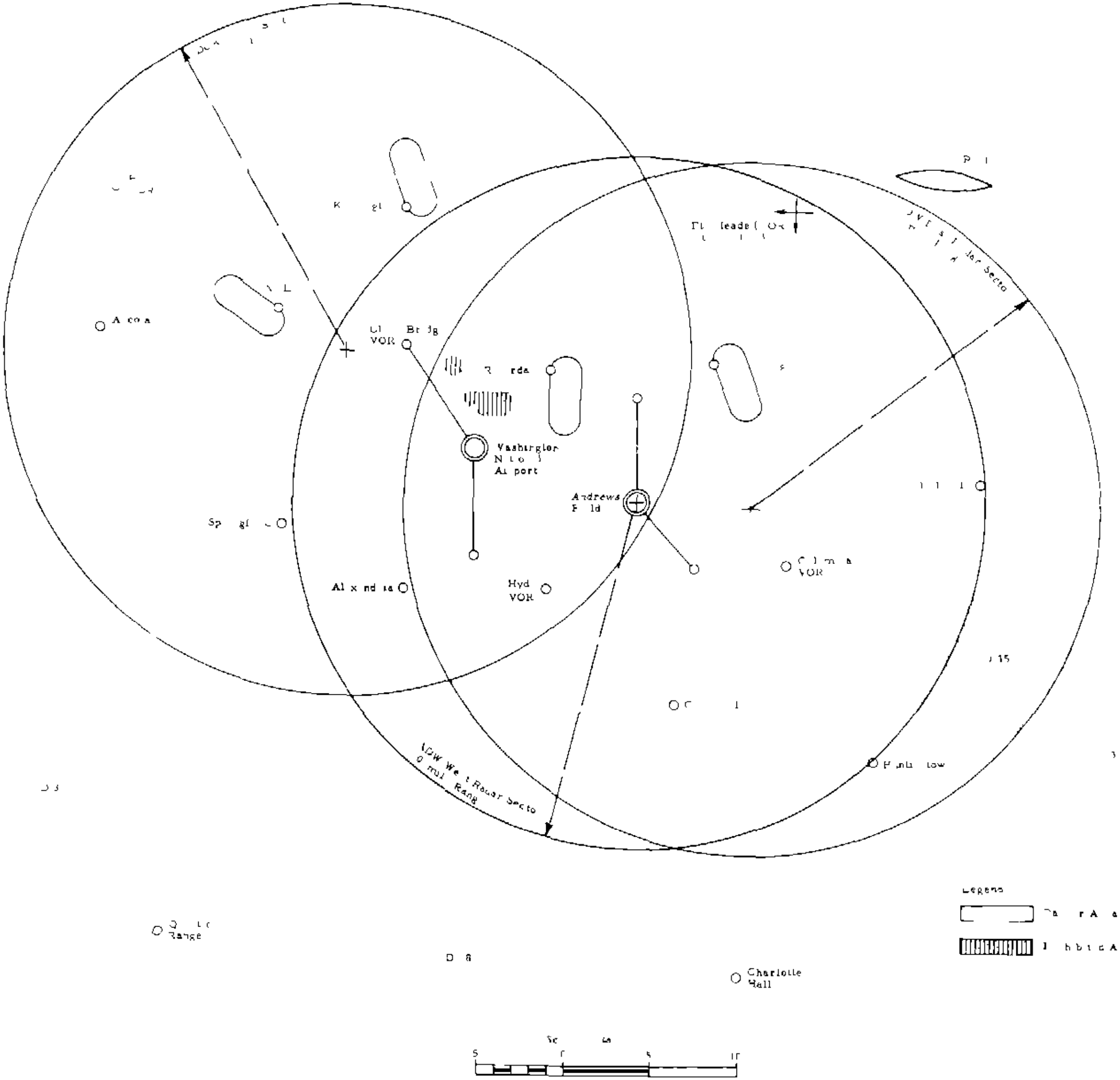


FIG 5 D SIRED RA AR COVERAGE PHASE II SOUTH LANDI GS