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DEVELOPMENT OF TRAFFIC CONTROL PROCEDURES FOR TACTICAL AIRLIFT OPERATIONS

FOR LIMITED DISTRIBUTION

By
Tirey K. Vickers

Navigational Aids Evaluation Division

Prepared for
The Air Navigation Development Board
Under
Project 6.7

by

CIVIL AERONAUTICS ADMINISTRATION
TECHNICAL DEVELOPMENT
AND EVALUATION CENTER
INDIANAPOLIS, INDIANA

April 1954

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F. B. Lee, Administrator
D. M. Stuart, Director, Technical Development and Evaluation Center

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FOREWORD

The Air Navigation Development Board (ANDB) was established by the Departments of Defense and Commerce in 1948 to carry out a unified development program aimed at meeting the stated operational requirements of the common military/civil air navigation and traffic control system. This project, sponsored and financed by the ANDB, is a part of that program. The ANDB is located within the administrative framework of the Civil Aeronautics Administration for housekeeping purposes only. Persons desiring to communicate with ANDB should address the Executive Secretary, Air Navigation Development Board, Civil Aeronautics Administration, W-9, Washington, 25, D. C.

SUMMARY

This report describes the formulation and testing of a number of traffic control and approach techniques which were developed to meet the specialized requirements of tactical military airlift operations. Tests were conducted on the Dynamic Air Traffic Control Simulator at the CAA Technical Development and Evaluation Center (TDEC) at Indianapolis. Some of the principles which were evolved during this study are expected to have a direct application in the control of low-altitude, short-haul, high-density civil airplane and helicopter traffic of the future.

INTRODUCTION

Air mobility is a new military concept which seeks to increase the effectiveness of a ground force by utilizing air transport for the swift mass movement of men and material. This concept makes use of two distinct types of air transportation. One is the strategic airlift which is conducted by large multi-engined aircraft carrying heavy loads over long distances. The other is the tactical airlift which is conducted by helicopters and light cargo aircraft delivering smaller loads into temporary airstrips in or near the actual combat zones.

Extensive military maneuvers are planned for the near future to test the utility of the tactical airlift under conditions approaching all-weather operations. Details of these exercises are summarized in Table I. To prepare for these maneuvers, the Department of the Army recently requested ANDB assistance in analyzing the special problems of tactical airlift operations and in developing suitable traffic control procedures for such missions. It was found that the proposed study lay well within the scope of ANDB Project 6.7, already assigned to TDEC. In carrying out this assignment, TDEC traffic control specialists worked closely with engineering and operational personnel of the Signal Corps Aviation Center. The work was completed during the month of March, 1954.

BASIC REQUIREMENTS

Traffic control procedures developed for tactical airlift systems have to be tailored around a unique combination of operational requirements. A discussion of the more important factors which are involved in this type of military activity follows.

Flow Characteristics.

In logistical support operations, the function of a tactical airlift is similar to that of a moving-bucket conveyor system. Its aircraft may be thought of as a continuous stream of containers which pick up material at one location, carry it to another location, and return for another load as soon as possible. Since this is a closed-loop system, a restriction to traffic flow in one part of the system ultimately slows down traffic flow in the rest of the system. For maximum output, the system should permit continuous traffic flow in both directions simultaneously.

Altitude Limitations.

Existing policy agreements restrict the use of Army tactical support aircraft to the lowest altitude levels available. This simplifies antiaircraft defense activities and leaves the rest of the airspace available for Air Force operations. However, it places a strict limitation on the use of altitude separation between traffic lanes for tactical airlift operations. Also, it virtually precludes the use of vertical stacking procedures for holding such aircraft in flight. Fig. 1 illustrates the flight levels presently contemplated for such operations.

Navigation Aids.

Because of logistical and manpower limitations, navigation aids for tactical airlift systems will normally include only portable types of facilities which can be set up or moved quickly in accordance with military necessity. The number of aids will be limited to the minimum necessary to handle the traffic load.

Separation Standards.

Aircraft separation standards utilized in tactical airlift operations probably will be lower than those in civil use today. It is expected that such standards will be reduced on a calculated-risk basis consistent with the urgency of the mission.

Communications.

A high-density tactical airlift is an important target for enemy attention. Therefore, it is essential that the traffic control system be able to function with a minimum amount of radio communication to avoid furnishing intelligence to the enemy and to reduce the possibility of enemy interception or jamming.

Aircraft Characteristics.

Because of the necessity for flying in and out of small or improvised airstrips, aircraft presently planned for tactical airlift operations will be slow-landing types such as helicopters or single-engined airplanes with relatively light wing loadings. Airplanes of this category will not require large turning radii or long straight-in final approach paths. These characteristics will tend to simplify flight patterns and reduce the amount of airspace and time required in executing instrument approaches.

Although considerable night flying has been accomplished by helicopters, little instrument flight experience has been obtained with these machines, other than climbs or descents through shallow cloud layers. Fortunately, their low flight speeds at the low altitude levels contemplated for tactical airlift operations will enable them to stay within visual contact with the ground most of the time.

It is expected that future improvements in helicopter stability, plus the development of a practical instrument for indicating airspeed in any direction, will some day make instrument operations routine for this type of aircraft. Meanwhile, for the purposes of this study, it has been assumed that such improvements actually exist, and that helicopters will be able to execute cross-wind letdowns, if necessary, turning into the wind only for touchdown after the pilot attains visual contact with the ground.

FORMULATION OF CONTROL PROCEDURES

Theoretical Considerations.

Because of the extremely low altitude levels involved in tactical airlift operations, complete radar coverage of flight routes is not considered feasible at this time. This factor, together with the necessity for minimizing radio communications, makes it desirable to establish, if possible, an airway traffic control system capable of functioning on a semi-automatic basis, without human intervention, between terminal areas. To handle heavy traffic, it is believed that each airway traffic lane would require:

1. A common take-off point.
2. A common flight direction.
3. A common cruising speed.

Assuming that all traffic lanes were independent of each other, it then should be possible to maintain safe separation between en route aircraft by imposing a specific amount of time or distance separation between successive departures in each lane. The amount of separation necessary would depend on the accuracy with which individual pilots could fly the predetermined standard cruising speed.

The theoretical capacity of a single traffic lane may be expressed by

$$C = \frac{V}{S} = \frac{60}{H} \qquad (1)$$

where: C = Capacity, in aircraft per hour
V = Average ground speed of aircraft in miles per hour
S = Separation between successive aircraft, in miles
H = Headway or separation between successive aircraft, in minutes.

As shown in Fig. 2, increased accuracy in following a predetermined speed would permit reduced headway (closer spacing) between aircraft, and thereby increase the theoretical capacity of the traffic lane. This method should work out satisfactorily for short routes. However, as shown in Fig. 3, an increase in route length would require an increase in headway, with a consequent decrease in system capacity, if no other form of control were used. In such a case, the trend of route length versus system capacity could be shown as in Fig. 4.

Fig. 5 illustrates how the capacity or acceptance rate of an approach system can put a ceiling on route capacity. Normally, there would be no point in dispatching departures at a rate higher than the acceptance rate at the other end of the line.

Scheduling Procedure.

A practical procedure for reducing the amount of headway necessary on long routes would include the following:

1. Establishment of additional en route radio fixes to divide the airway into shorter route segments.

2. Establishment of flight schedules based on the desired elapsed time from take-off to each check point. A typical schedule would include some tolerance which would define the limits of the time block assigned to the aircraft at each check point.

The initial schedule could be established by dispatching a pilot flight to fly down the specific route at the assigned cruising air speed. The elapsed flight times to each check point, made good by this aircraft, would then form the master schedule to be made good by subsequent aircraft. Since these elapsed times would include the effects of the prevailing wind, they should form a reasonable schedule which could be maintained by similar aircraft without excessive jockeying of engine power.

In any subsequent flight on this route, it would be the pilot's responsibility to note his actual elapsed times to each check point, making speed adjustments as necessary to stay within his assigned time block. This procedure is shown in Fig. 6. As long as the aircraft remained within its assigned time block, no progress reports or other air/ground traffic control communications would be necessary. Whenever there was a significant change in the prevailing wind conditions over the route, another pilot flight would be dispatched to establish a new master schedule.

Operation at Maximum Capacity.

The capacity of a traffic lane in terms of cargo can be determined from

$$P = \frac{60L}{H} \qquad (2)$$

where: P = Total cargo capacity in pounds per hour of operation
L = Average cargo load per aircraft, in pounds
H = Headway, in minutes.

To deliver cargo at maximum hourly capacity, it is necessary that enough aircraft be available to maintain a continuous, uninterrupted flow of traffic around the circuit. The required number of aircraft can be determined from

$$A = \frac{E}{H} \qquad (3)$$

where: A = Number of aircraft required to provide continuous flow in one traffic circuit
E = Elapsed time, in minutes, for one complete circuit. (This includes total flight time for outbound and inbound routes, plus total turnaround (ground) time at <u>both</u> ends of the system.)
H = Headway, in minutes.

Operation at Reduced Capacity.

Whenever the number of available aircraft is less than that required to provide a continuous flow of traffic in one traffic lane, the minimum headway can be increased somewhat without decreasing the average hourly cargo capacity of these aircraft. For these conditions, the desired headway can be calculated by

$$H = \frac{E}{N} \qquad (4)$$

where: H = Headway, in minutes
E = Elapsed time, in minutes, for one complete circuit (See Eq. 3)
N = Number of aircraft available.

By increasing separation between available aircraft, this procedure tends to provide increased safety in flight and to reduce congestion in loading and unloading areas.

CONTROL PROCEDURES

Departures.

The control agency at the take-off point will have the responsibility for establishing proper separation between aircraft in each departure lane. This can be accomplished by:

1. Insuring that each departing aircraft has been issued the current master flight schedule for the route to be flown.

2. Clearing each departure to the proper lane.

3. Establishing proper headway in each traffic lane by scheduling take-offs as necessary to provide adequate separation from preceding aircraft.

In addition, the control agency will be responsible for providing separation between each departure and all other aircraft in the vicinity until the departure is established on course in its assigned traffic lane.

Arrivals.

It has been noted previously that the altitude restriction on tactical airlift operations practically rules out the use of vertical stacking procedures at destination airports. For this reason, each airway should be organized as a rigidly flow-controlled unit, geared to the capacity of the destination airport. With such a system, no in-flight holding of aircraft should ever be necessary, except under emergency conditions. Normally, traffic should flow toward the destination airport in a steady, orderly sequence, with enough separation that each aircraft will be able to start letdown immediately on arrival at the approach fix. Because of normal speed variations, this type of scheduling may occasionally allow two successive aircraft in the same traffic lane to arrive over the approach fix with less than the desired amount of separation. However, the probability of three successive aircraft arriving in a bunch is very remote indeed. Therefore, the job of providing adequate separation between successive aircraft on the approach path becomes relatively simple. Simulation tests showed that simple velocity-control or path-stretching techniques[1] were sufficient to provide adequate separation between all approaches.

APPROACH PROCEDURES

Tangential Approach Principle.

The tangential approach principle[2] is a very simple approach

[1] C. M. Anderson and T. K. Vickers, "Application of Simulation Techniques in the Study of Terminal Area Air Traffic Control Problems," Technical Development Report No. 192, November, 1953, pp 18-21.

[2] C. M. Anderson, N. R. Smith, T. K. Vickers, and M. H. Yost, "A Preliminary Investigation of the Application of the Tangential Approach Principle to Air Traffic Control," Technical Development Report No. 149, October, 1951.

coupling system which supplies heading corrections to guide an aircraft toward a desired course and to align it on such course headed inbound. Developed in 1950, this principle was given extensive simulation tests in connection with its possible applications for radar, ILS, VOR, and ADF approaches. As illustrated in Fig. 7, all applications utilize the principle of making the correction angle a function of the displacement angle, as expressed by the formula

$$C = Kd \tag{5}$$

where: C = correction angle
K = correction factor
d = displacement angle.

Satisfactory operations have been obtained using various values of K ranging from 2.0 to 5.0. Increasing this value has an effect analogous to narrowing the course.

The tangential approach principle was introduced to engineering and operational personnel at the Signal Corps Aviation Center early in March, 1954. Subsequent flight tests applying this principle to the Ekco radar approach aid and the Decca surveillance radar indicate that the principle offers many advantages in tactical airlift operations. These applications are discussed below.

Ekco Radar Approach Aid.

This equipment consists of a 3-cm pencil beam radar coupled with a VHF DF receiver. The operator tracks targets manually by manipulation of antenna azimuth and elevation controls. The radar display consists of a simple A-scope presentation which indicates the range of the target. This basic information is supplemented by a dial which indicates the azimuth of the target.

The advantages of this radar over other types of radar include low cost, simplicity, and portability. In addition, the fact that it emits only a very narrow directional beam may have a military advantage in decreasing the possibility of its detection by the enemy. Disadvantages include the fact that normally it can handle only one aircraft target at a time. Also, it requires a high controller work load in acquiring and tracking each target. In addition, the very limited display of range and azimuth information requires an extremely high degree of visualization by the controller in determining what heading instructions should be issued to the aircraft.

The capacity of the Ekco radar approach system can be expressed by

$$C_a = \frac{60}{A + B} \qquad (6)$$

where: C_a = Capacity, in approaches per hour

A = Approach time, in minutes. (Time required to bring one aircraft from initial pickup point to a point where the pilot can complete his approach unassisted.)

B = Bogey time, in minutes. (Time required to get equipment set up for next approach, then acquire and identify the target.)

It has been found that approach time can be reduced by keeping the approach path as short as practicable. Tests indicate that bogey time can be reduced by establishing a close-in radio reporting fix which can be used as a convenient pickup point for target acquisition.

The tangential approach principle has been applied to the Ekco approach aid by adding a tangential heading scale to the azimuth dial, with the following effects:

1. The operator's mental workload has been greatly reduced because he is now supplied continuously with the heading information necessary to align the aircraft on the final approach course.

2. The resulting technique eliminates over-correction and bracketing. Instead, the aircraft now spirals gently and precisely into the final approach course.

3. Use of the tangential scale supplies automatic correction for cross-wind components. It also gives the operator more time to take care of his other duties.

Decca Airfield Control Radar.

The capacity of an approach system can be increased through the use of surveillance radar or other equipment which allows more than one aircraft to be on approach simultaneously. The Decca Model 424 radar is now being tested for this purpose. It is a short-range X-band truck-mounted surveillance radar with two receivers and two 12-inch scopes.

The scope display is equipped with the Deccaplot, an optical device which allows plotting to be carried out without parallax errors. This device has been found to be ideally adapted for the application of a tangential approach grid, as illustrated in Fig. 8. Use of the tangential approach grid in conjunction with the Decca radar has resulted in the following advantages for tactical airlift operations:

1. The level of operator skill and judgment required for directing radar approaches has been reduced, as heading corrections are now presented automatically to the operator. This factor is particularly advantageous for an organization which has to train its own radar operators, as the amount of training and experience required to bring an operator to an acceptable working level can be reduced appreciably when the tangential system is used.

2. For the types of aircraft used in tactical airlift operations, use of the tangential approach makes practical a short curved letdown path with a base leg distance only 2-1/2 miles from the airport. Compared to the manual approach procedure previously used, the tangential approach procedure saves up to eight miles flight distance or five minutes of flight time per approach. Pilots have found that the curved approach path produced by the tangential approach system is extremely easy to fly, as all heading changes are normally made in the same direction.

SIMULATION TEST PROCEDURES

Objective.

Using the general operating principles evolved during the preliminary analysis of the tactical airlift problem, the object of the TDEC simulation problem was to set up a number of typical configurations of electronic aids and airstrip facilities, and to determine the general operating characteristics of each configuration under typical traffic loads.

Traffic Samples.

All systems were tested with a basic traffic sample which consisted of 50 aircraft movements for each airstrip during a period of slightly over one hour. In addition, the high-capacity traffic system known as System 6 was tested under a high density sample of 96 operations for a one-hour period. Because of the rigid flow-control procedures used in all systems, steady-state operations were approached quickly and maintained throughout the rest of the operating period. For this reason, it was felt that no particular advantage would be obtained by extending the samples to cover a period over one hour.

Measurements.

In past simulation studies, aircraft delay has been carefully measured as an index of the performance of an air traffic control system. In this program, however, in-flight delays were almost nonexistent, since airway traffie flow was regulated to stay within the capacity of the destination airport. Therefore, no delay measurements were made during these tests. Instead, airport capacity formed the only index of workable traffic systems. This was largely a function of the number of traffic lanes which could be accommodated by the system in use, assuming that a constant spacing of one aircraft per five minutes could be handled in each traffic lane.

Operating Assumptions.

All tests simulated operations under weather conditions of 500-foot ceiling and one-half mile visibility. It was assumed that all configurations tested were based on navigation systems using the facilities listed in Table I. It was further assumed that airport facilities for fixed-wing aircraft consisted of a single airstrip only. Helicopters utilized an adjacent mat or landing pad for terminal operations. To complicate the exercise further, System 5 utilized two landing mats for helicopters, one on each side of the fixed-wing airstrip. System 6 used one landing runway for helicopters; it was assumed that these aircraft taxied over to one of two available loading sites before take-off.

When the Ekco radar was simulated in these tests, it handled helicopter approaches only, while fixed-wing aircraft made VOR or ADF approaches. When Decca radar was simulated, it handled all approaches. Since the Decca is more versatile than the Ekco for approach and traffic control operations, Ekco was not simulated at any site which had a Decca installation.

It was assumed that all flight operations were conducted with a minimum amount of radio communications. Simplification included the following:

1. Briefing of pilots prior to take-off regarding departure routes, cruising, and approach procedures.

2. Elimination of in-flight position reports between terminal areas, except in emergencies.

3. Elimination of routine warnings such as landing cockpit checks, runway length, width, and elevation, and instructions to set gyro.

As a further means of simplifying communications, and also as a means for eliminating the routine transfer of flight data between terminals, each airport was issued a consecutive block of numbers for assignment to successive departures. For example, the first airplane to leave one terminal might be "Beaver 50," to be followed in succession by "Beaver 51," "Beaver 52," etc. A different block of numbers was assigned to the helicopters. Using this system, successive aircraft normally reported in at the destination terminal in the same numerical order. This feature formed an immediate warning to the arrival controller when an aircraft was missing or flying off schedule.

SYSTEM TESTS AND RESULTS

System 1.

Tests were made for northeast operations only. Traffic patterns are shown in Fig. 9. The main function of Ekco in this procedure was to provide a helicopter letdown path clear of the letdown path for airplanes.

Helicopters reporting over Alpha were instructed to leave this fix on a heading of 060° for a tangential Ekco approach. This approach required approximately three minutes under no-wind conditions. During northeast operations, no particular difficulty was encountered in handling about 48 aircraft operations per hour, distributed as follows:

Helicopters - 12 in, 12 out.

Airplanes - 12 in, 12 out.

It was believed that the system would experience greater difficulty in handling southwest operations due to the longer and more complicated approach paths involved.

Systems 2 and 3.

The only difference between these two systems lay in the alignment of the associated airstrip. The use of Decca radar was assumed in all tests. North, south, east, and west operations were tested, as shown in Figs. 10, 11, 12, and 13. The marker facility at Alpha functioned as a reporting point for identification of all arriving aircraft and a convenient point for separating airplane and helicopter traffic patterns. In all directions tested, the systems appeared quite capable of handling 48 operations per hour, distributed as follows:

Helicopters - 12 in, 12 out.

Airplanes - 12 in, 12 out.

System 3A.

This system was tested for north operations to determine the problems of a layout consisting of only one radio navigation facility and no radar. Traffic patterns are shown in Fig. 14. Because of take-off delays caused by arriving aircraft, the system could accommodate only ten helicopter take-offs and ten airplane take-offs per hour. It is expected that this would ultimately limit the flow of traffic to this figure throughout the system.

System 4.

This system was set up to test the operation of a complete ten-mile airlift system under light wind conditions when straight-in approaches could be made to each airstrip. It will be noted that, in this system, helicopters had shorter routes than airplanes. Traffic patterns are shown in Fig. 15. Decca radar was simulated at the airstrip Alpha and Ekco was used at airstrip Delta for helicopter approaches only. Under the conditions tested, the system appeared capable of handling 48 operations per hour, distributed as follows:

Helicopters - 12 in, 12 out.

Airplanes - 12 in, 12 out.

It is expected that this system would become more difficult to operate if wind conditions required the flow of traffic to be reversed at airstrip Delta.

System 5.

This system represents a configuration quite similar to that of airstrip Alpha in System 4, but operating in a wind condition which requires that airplane landings be made toward the VOR or LF facility. Traffic patterns are shown in Fig. 16. Decca radar was simulated. This system required rather long approach and departure paths for airplanes and some controller attention had to be devoted to the insurance of adequate separation between arrivals and departures in the vicinity of Bravo. Otherwise, the system worked out quite satisfactorily and appeared capable of handling 48 operations per hour distributed as follows:

Helicopters - 12 in, 12 out.

Airplanes - 12 in, 12 out.

System 6.

This system was developed to test the capabilities of a high-density airlift terminal, using eight traffic lanes. These lanes might all be connected to a single high-density terminal at the other end of the line or conceivably the simulated airport could be a rear terminal serving as many as four advanced bases with one traffic loop (two independent traffic lanes) apiece. This system was tested for north and south operations, as shown in Figs. 17 and 18. In these tests, traffic was segregated as listed below.

Route	Type of Aircraft	Direction	Altitude Levels (ft.)
W	Helicopters	Inbound	500 & 1,000
X	"	Outbound	500 & 1,000
Y	Airplanes	Outbound	500 & 1,000
Z	"	Inbound	500 & 1,000

One radar controller handled all arrivals on Route W while another radar controller handled all arrivals on Route Z. A third controller handled all departures. When the direction of operation was north, the departure controller's duties were simplified since there were no conflictions between arrivals and departures. When south operations were in progress, this controller had to watch out for possible conflictions between arrivals and departures at the crossover points. For this reason, it was necessary for the departure controller to have access to a surveillance radar display. No unusual difficulty was encountered in handling this operation as long as dependable radar coverage existed. Five-minute spacing was used in each of the eight traffic lanes, giving a normal capacity of 96 operations per hour, distributed as follows:

Helicopters - 24 in, 24 out.

Airplanes - 24 in, 24 out.

Because of the rigid flow-control system, an individual arrival controller seldom had more than two aircraft under simultaneous control, even when the terminal area was operating at the rate of 96 aircraft movements per hour. On rare occasions, it was necessary for an arrival controller to handle a maximum of three aircraft simultaneously.

CONCLUSIONS

1. Simulation tests indicate that the airway scheduling procedure shown in Fig. 6 is a practical method of handling en route control of tactical airlift operations. It may also have an application in future low-altitude civil traffic control systems on certain high-density routes. Terminal control procedures for this type of operation become relatively simple because of the orderly flow of route traffic.

2. Simulation tests at TDEC and flight tests at SCAC indicate that the tangential approach principle is well adapted for use with the Ekco and Decca radars. Its use greatly simplifies the controller's workload in each case, and makes possible a very short and precise method of guiding an aircraft down to a point where the pilot can take over for a visual landing.

3. The various combinations of facilities developed for the simulation tests form a repertoire of possible arrangements which can be used in many different installations, depending on the configuration of the airstrips, airways, and navigational facilities which must be used. It should be pointed out that the system performances during the simulation tests represent reasonable capacities which could be expected providing:

  a. Five-minute spacing could be maintained in all traffic lanes.

  b. Pilot navigational proficiency could be maintained at a high level.

4. Comparisons made between systems which had the VOR or LF homing device located on the airport, as against systems which had the facility located a few miles away, indicated that:

  a. All systems worked well in at least one landing direction.

  b. When airport operations were reversed from the ideal landing directions, systems which had the facility located on the field tended to have less complicated traffic patterns than those which had the facility located elsewhere.

c. When the landing direction was changed to approximately 90° from the ideal direction, an airport-sited facility could still provide guidance for an upwind approach to the runway if one was available. A circling approach would have to be made in this case if the facility were located away from the airport.

d. In many localities, airport sites may represent the only cleared areas available. For military operations, facilities at such sites will usually be easier to maintain and protect than facilities at outlying points.

e. From a navigational standpoint, the airport site offers the advantage of greater navigational precision where it is needed, which is just before landing.

f. Airport-sited omnidirectional facilities can provide guidance for departing flights immediately after take-off. Off-airport facilities cannot always furnish this guidance in a simple manner.

RECOMMENDATIONS

1. It is recommended that the airway scheduling procedure described in this report be tested thoroughly on routes up to 100 miles in length to develop pilot proficiency and to determine what reasonable tolerances should be allowed in spacing aircraft on such routes.

2. The capacity of any closed-loop system is only as great as the capacity of its weakest component. Therefore, in setting up facilities for tactical airlift operations, care should be taken to see that the facilities are distributed so as to maintain an approximately equal traffic capacity at both ends of the system.

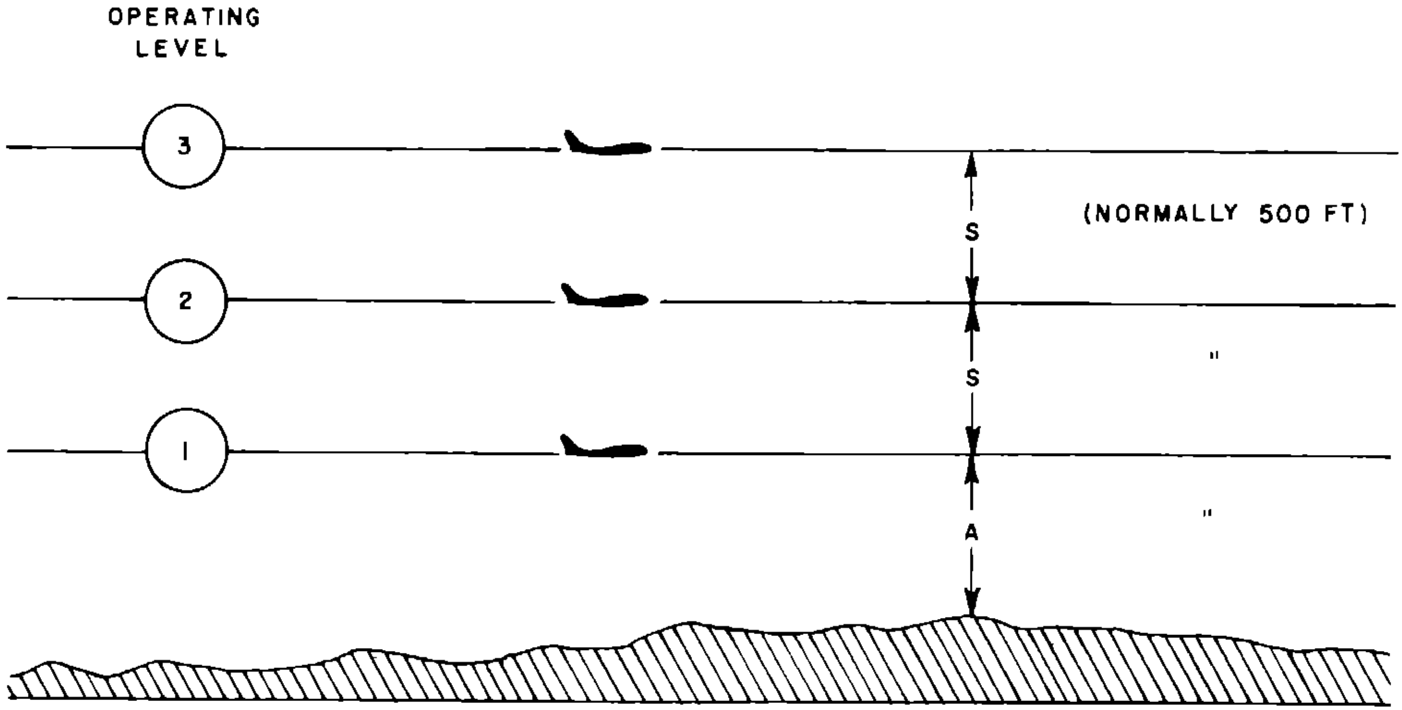
TABLE I

TENTATIVE DETAILS OF PROPOSED TACTICAL AIRLIFT MANEUVERS

Designation:	SKYDROP II.
Location:	Fort Bragg, North Carolina.
Date:	June 1, 1954.
Duration:	Approximately three weeks.
Objectives:	1. To demonstrate the comparative efficiency of the L-20 (DeHavilland Beaver) airplane and the H-19 (Sikorsky) helicopter on logistical support missions of 10, 40, and 100 route miles. 2. To test the relative efficiency of the VOR and the LF ADF navigation systems, considering reliability, ease of operation, and accuracy, under simulated instrument conditions of 500-foot ceiling and one-half mile visibility.

Navigation and Approach Facilities:

Terminal Aids:	2 - Wickes portable airport control towers. 1 - Decca Type 424 surveillance radar. 1 - Ekco Type CE71 radar approach aid.
VOR System:	2 - TVOR's. 1 - AGA talking beacon. 4 to 8 - heterodyne marker beacons.
ADF System:	4 - 50-watt LF non-directional homing beacons.
Aircraft:	14 - L-20 airplanes. 14 - H-19 helicopters.



A = DESIRED CLEARANCE OVER HIGHEST OBSTRUCTION ON ROUTE SEGMENT

S = DESIRED CLEARANCE BETWEEN ADJACENT TRAFFIC LANES

NOTE

LEVEL 3 MAY BE USED ONLY AS AN EMERGENCY ALTITUDE, OR TO PROVIDE SEPARATION AT CROSSOVERS

FIG I OPERATING LEVELS

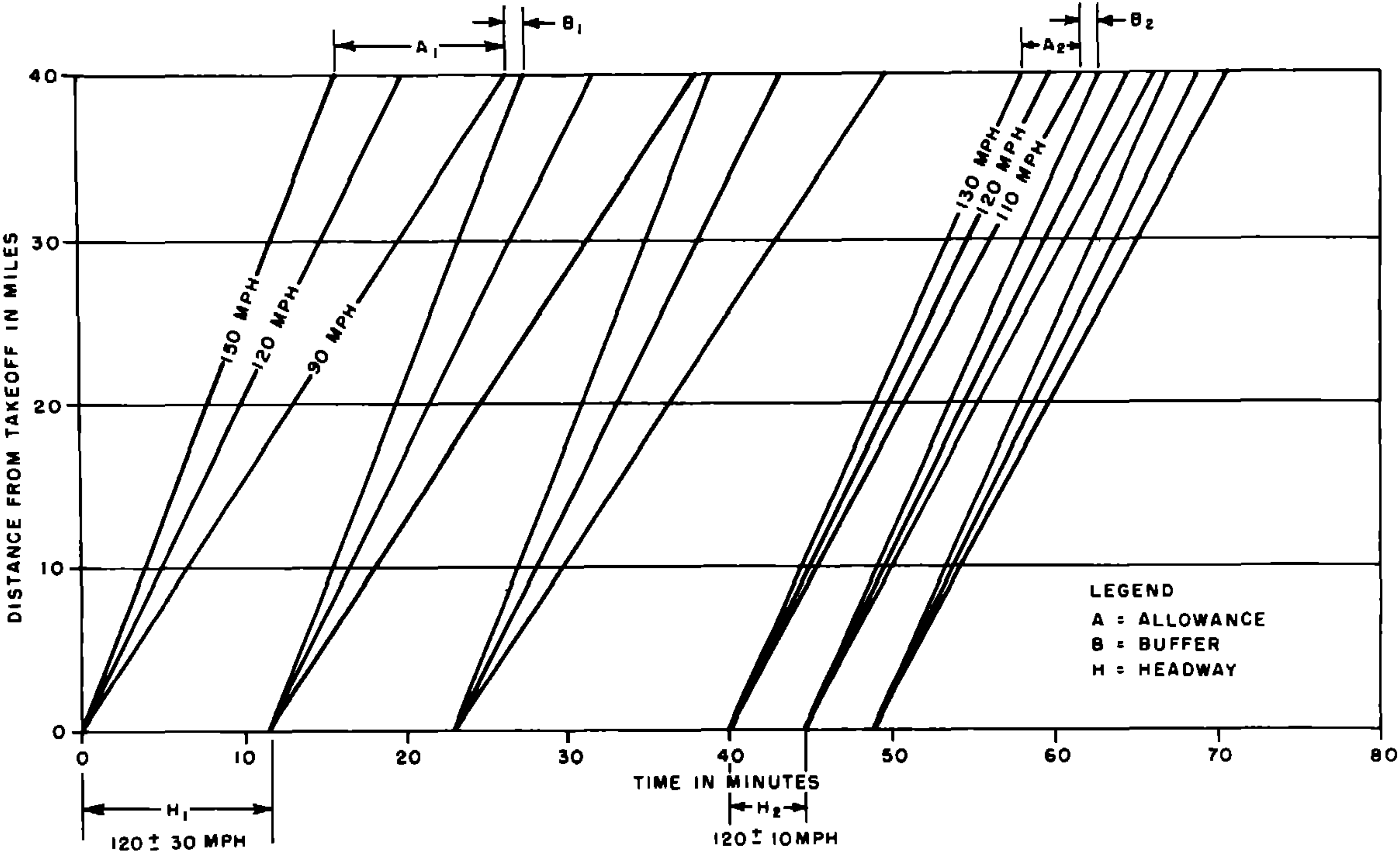


FIG 2 EFFECT OF VARIATIONS IN GROUND SPEED

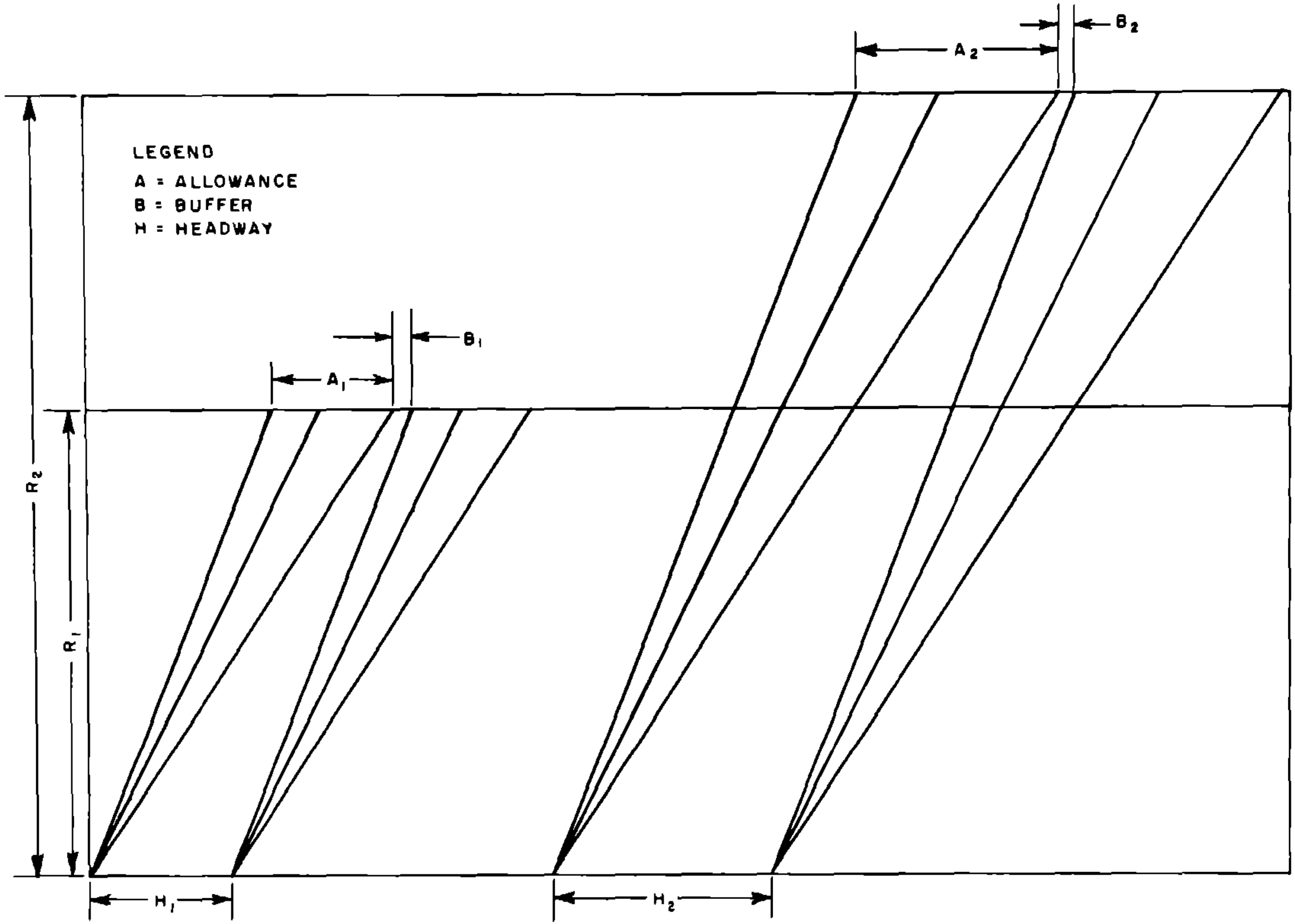


FIG 3 EFFECT OF ROUTE LENGTH (R) ON HEADWAY (H)

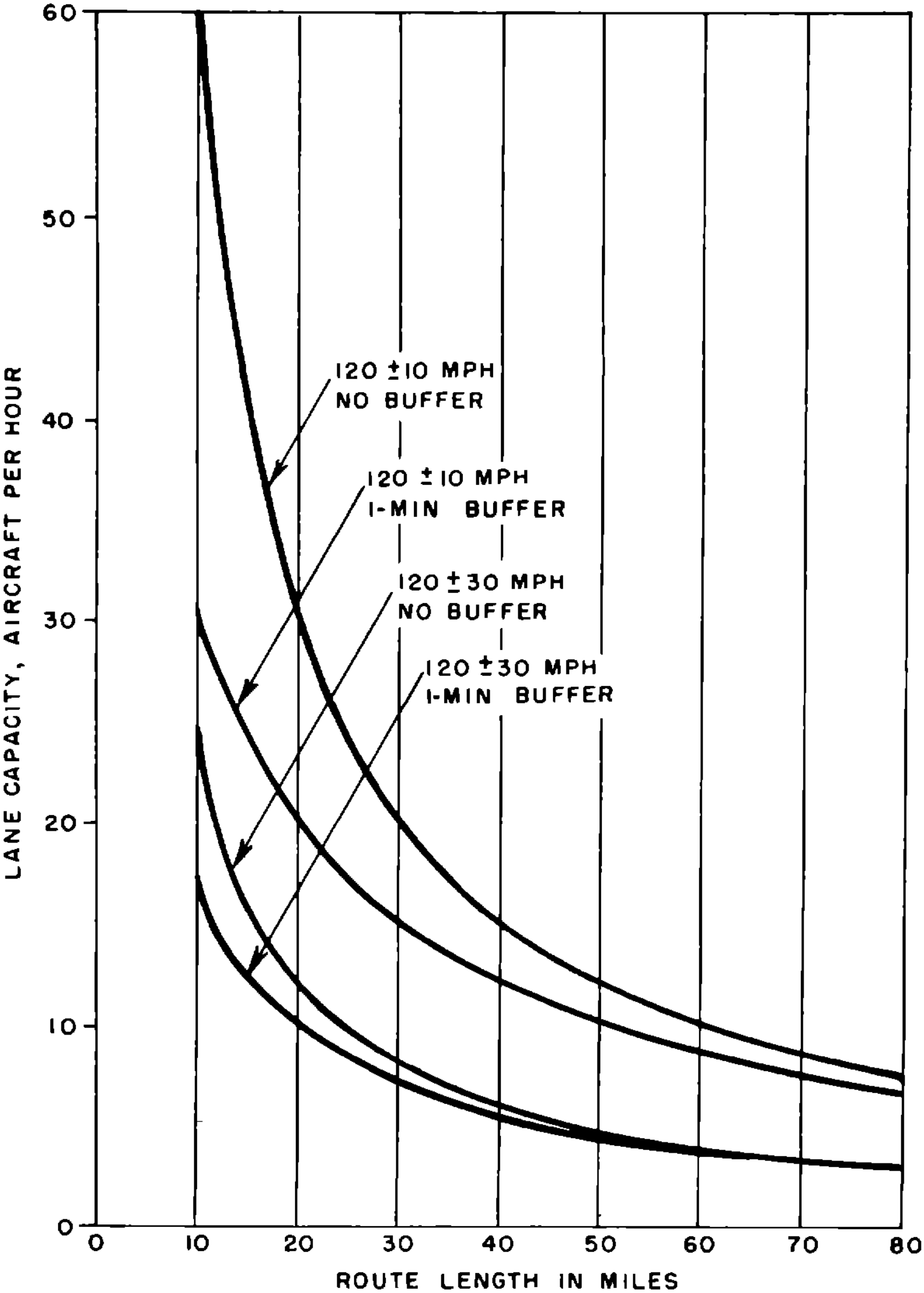


FIG. 4 EFFECT OF ROUTE LENGTH ON CAPACITY

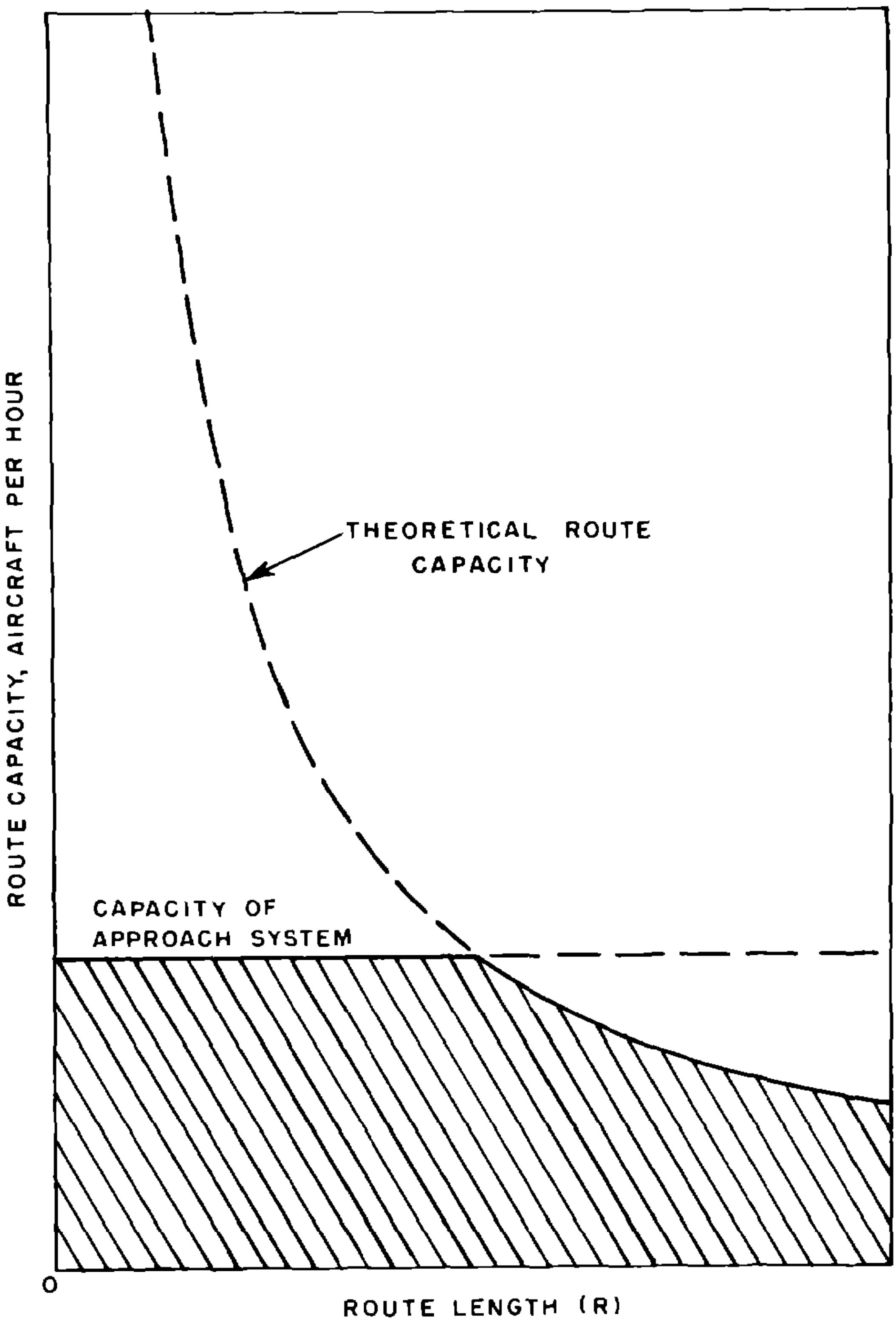


FIG. 5 EFFECT OF APPROACH CAPACITY ON ROUTE CAPACITY

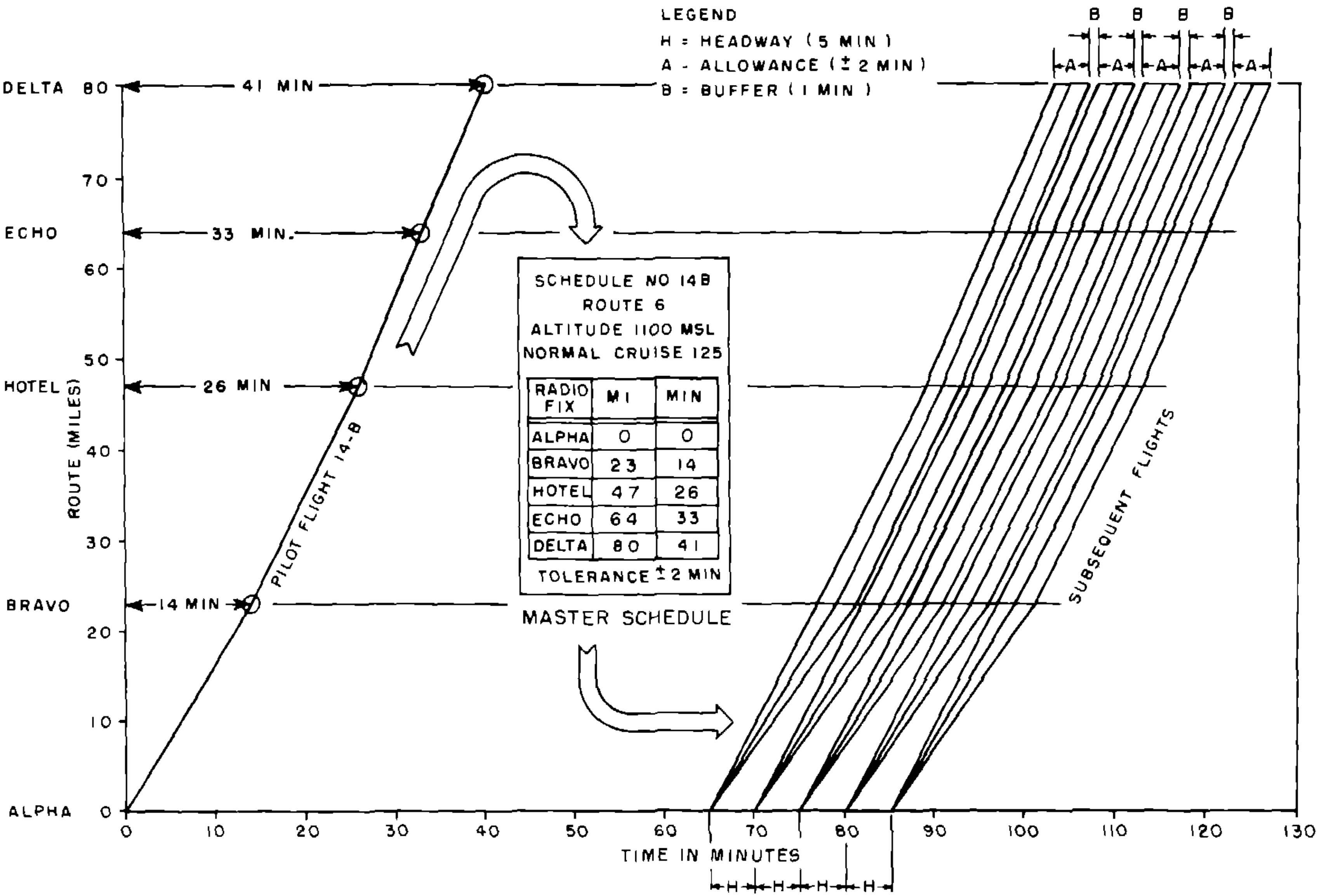


FIG 6 EXAMPLE OF SCHEDULING PROCEDURE

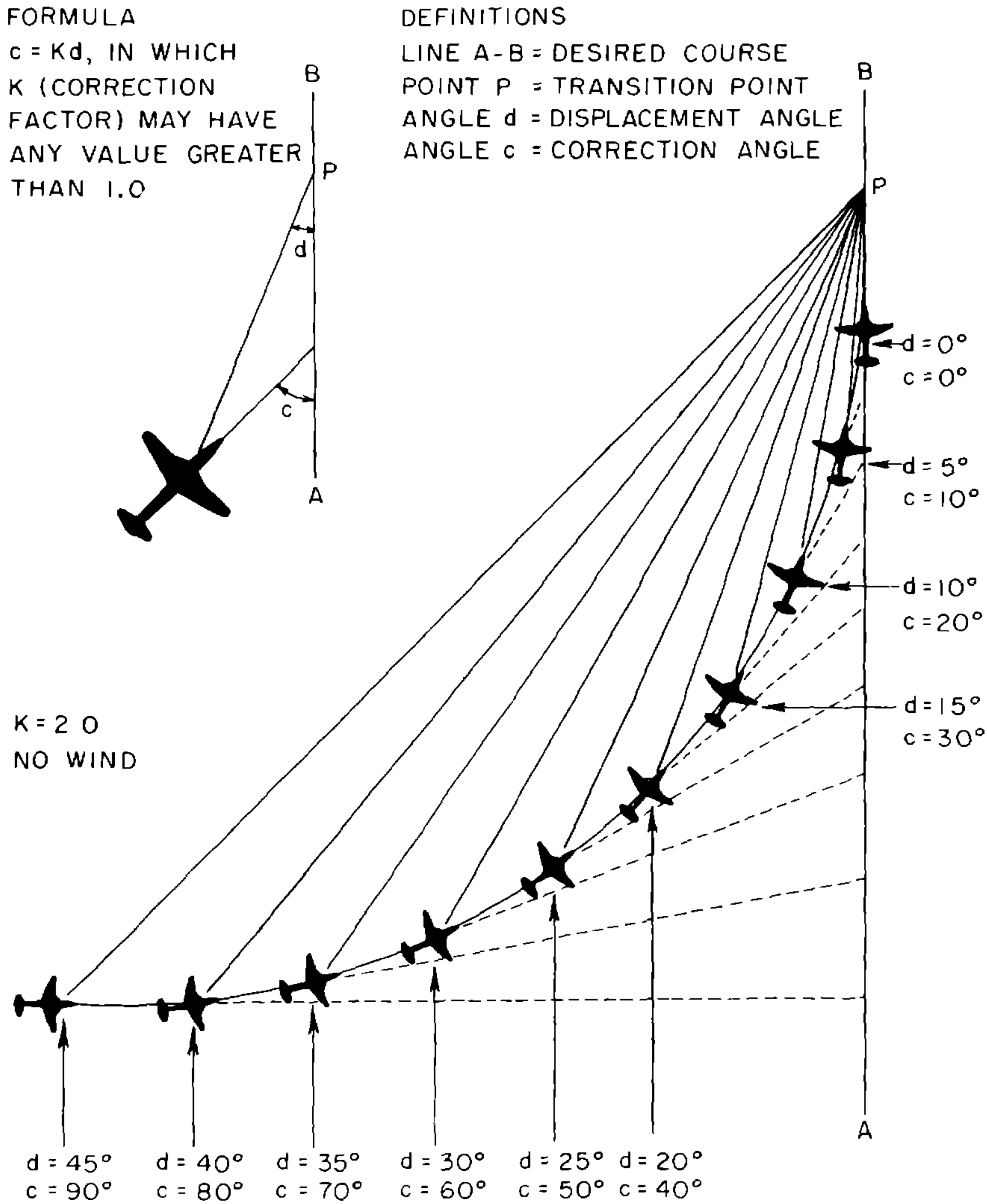


FIG. 7 TANGENTIAL APPROACH

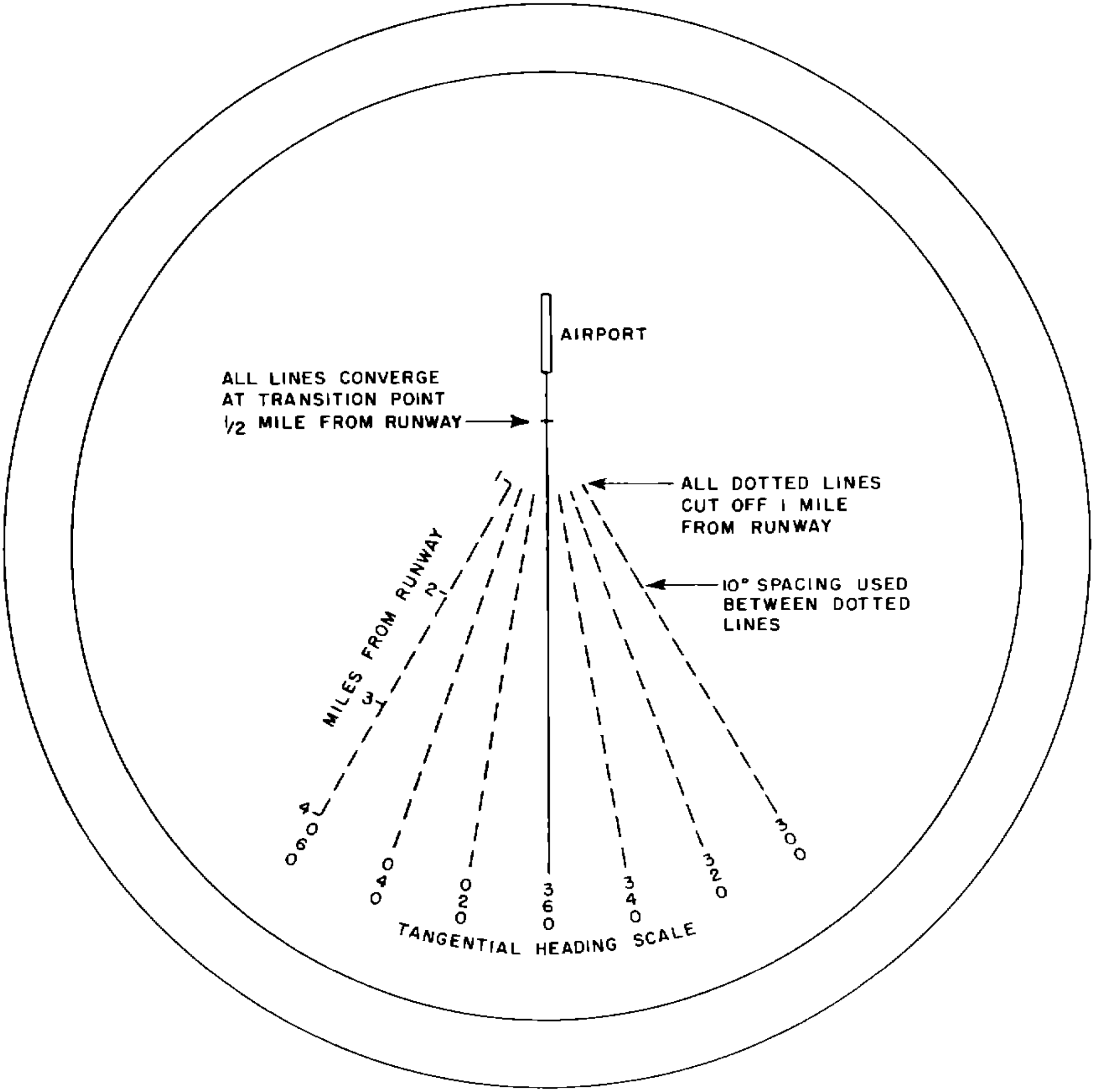


FIG 8 TANGENTIAL APPROACH GRID
FOR DECCA RADAR

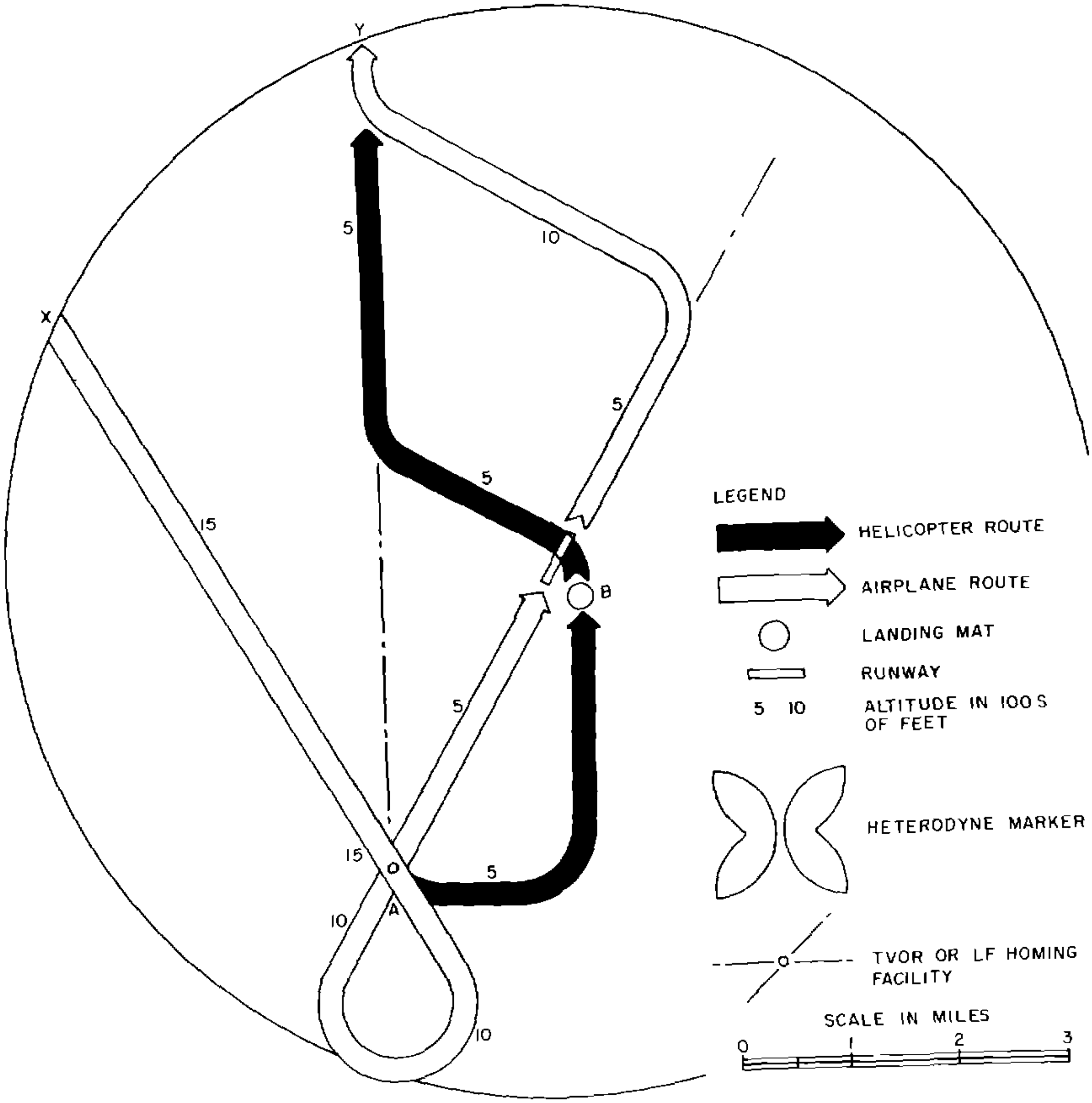


FIG 9 SYSTEM I - NORTHEAST LANDINGS

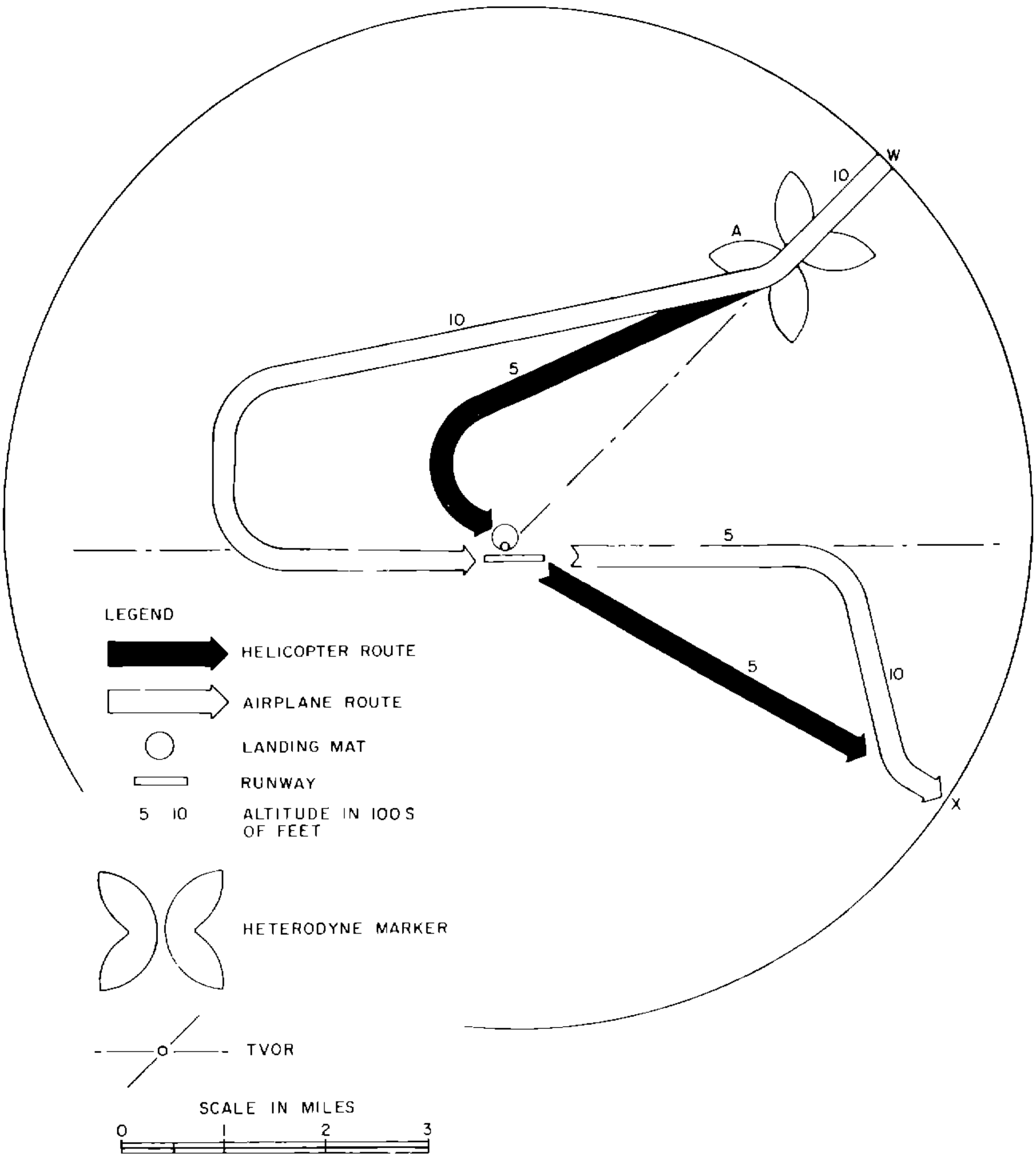


FIG 10 SYSTEM 2-EAST LANDINGS

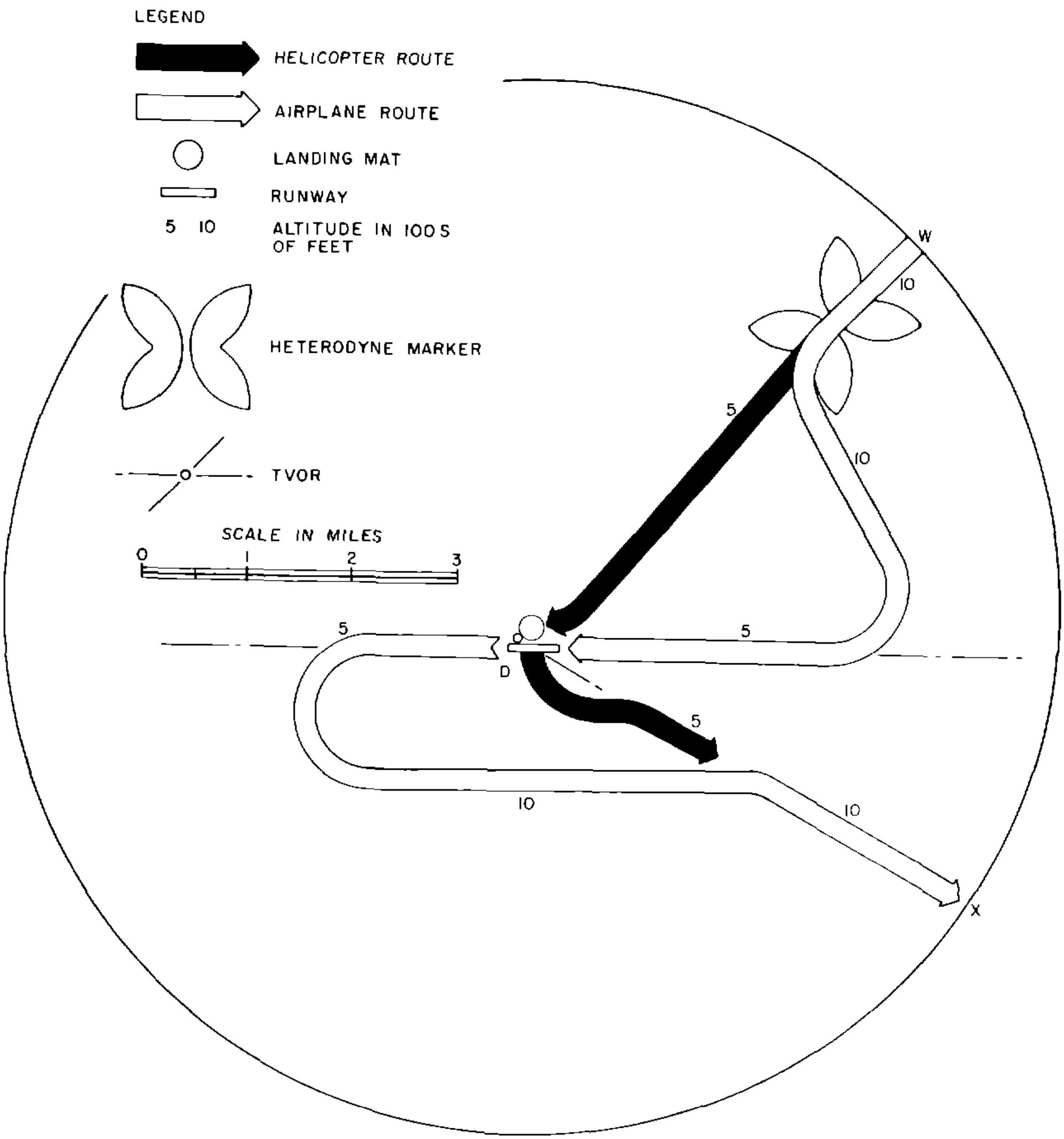


FIG 11 SYSTEM 2 - WEST LANDINGS

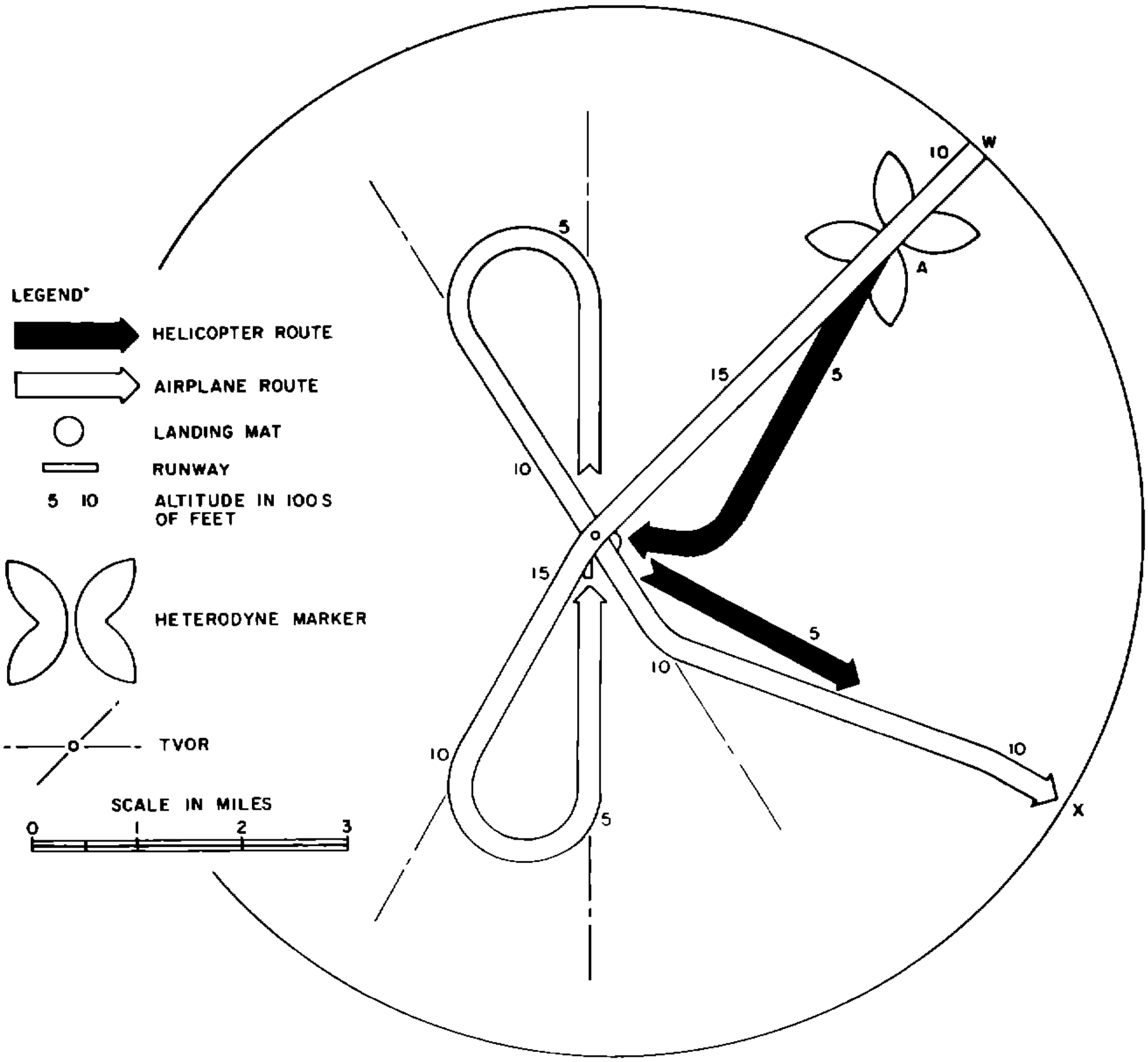


FIG 12 SYSTEM 3 — NORTH LANDINGS

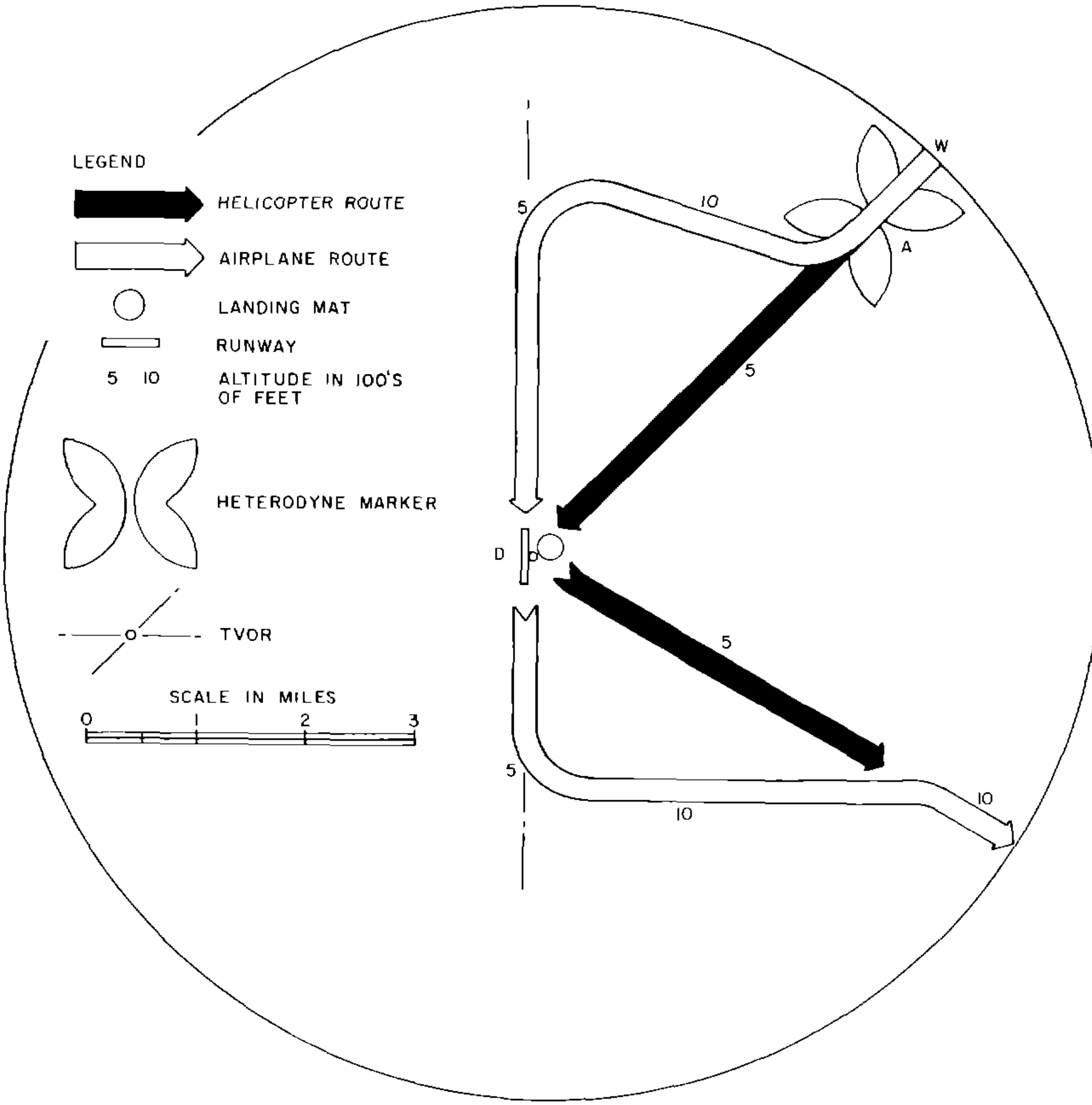


FIG 13 SYSTEM 3-SOUTH LANDINGS

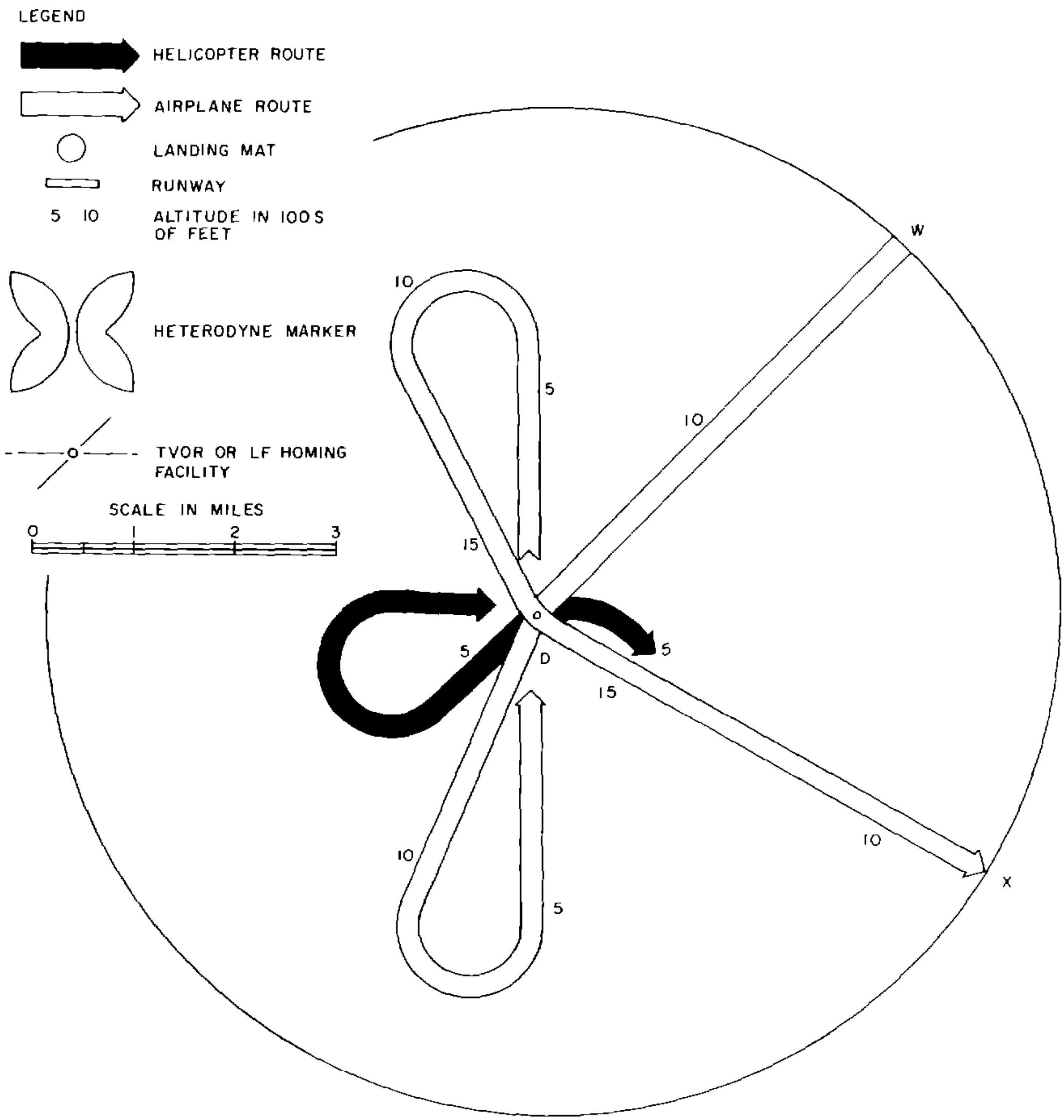


FIG 14 SYSTEM 3A — NORTH LANDINGS

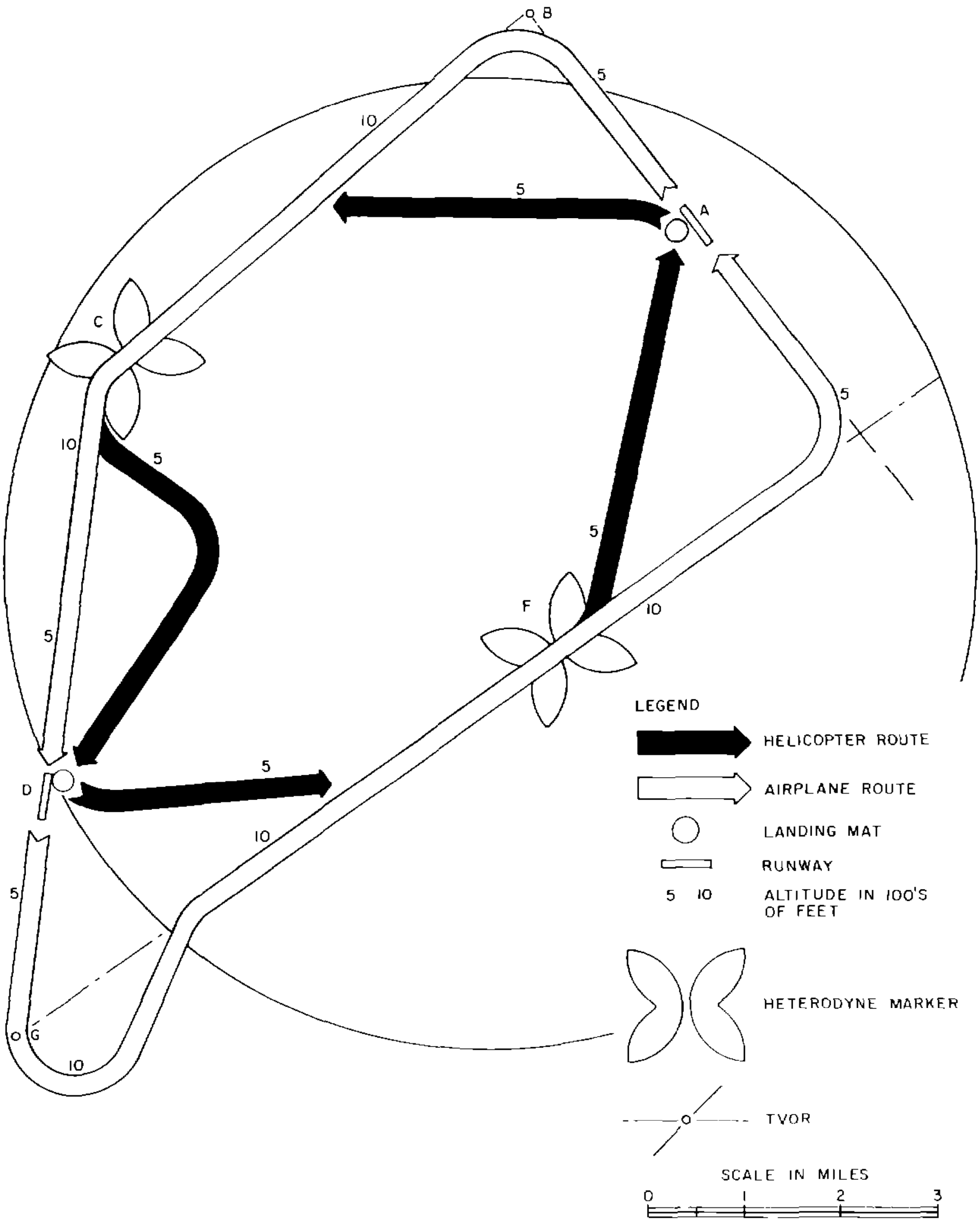


FIG 15 SYSTEM 4 - STRAIGHT-IN APPROACHES

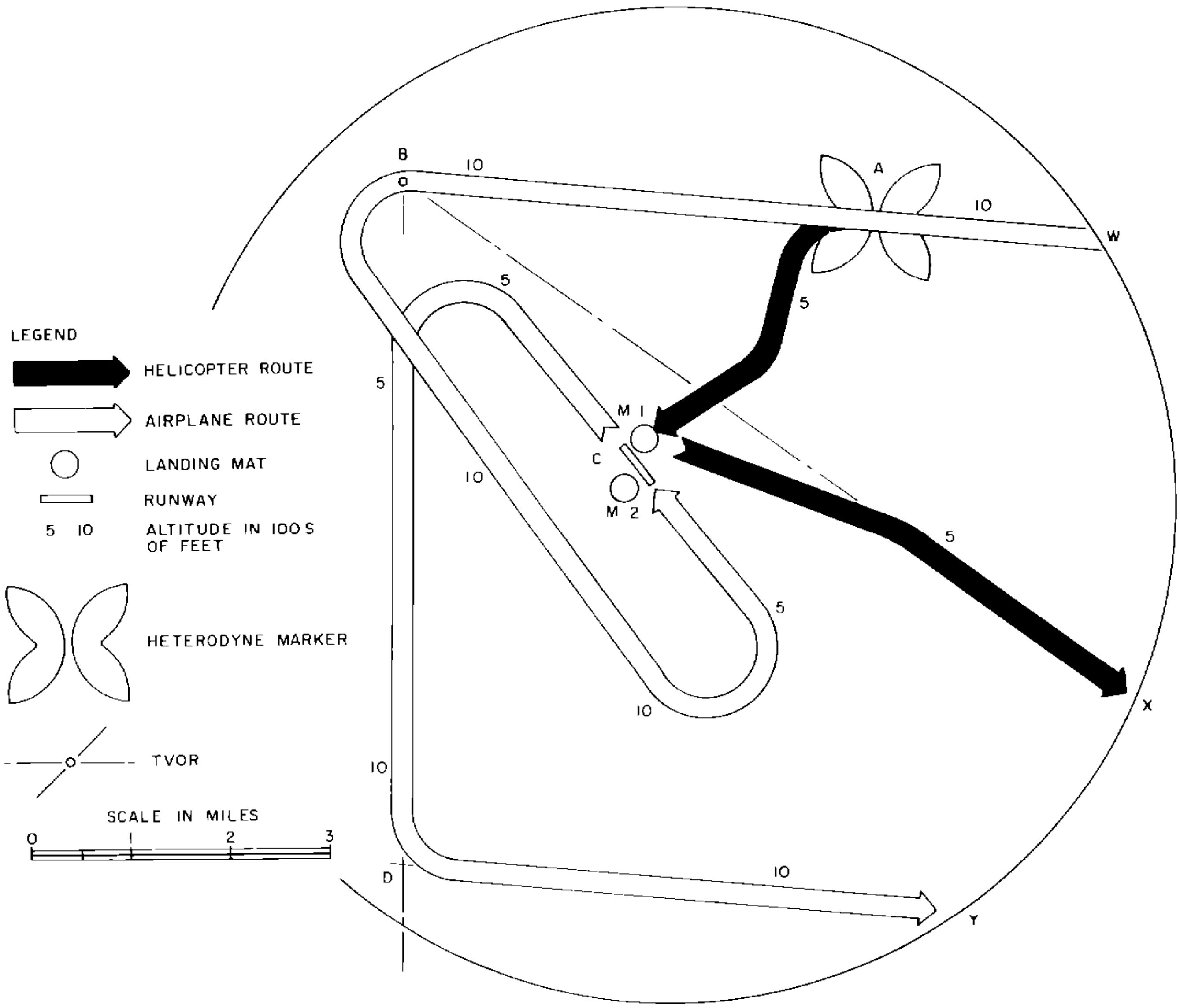


FIG 16 SYSTEM 5 — NORTHWEST LANDINGS

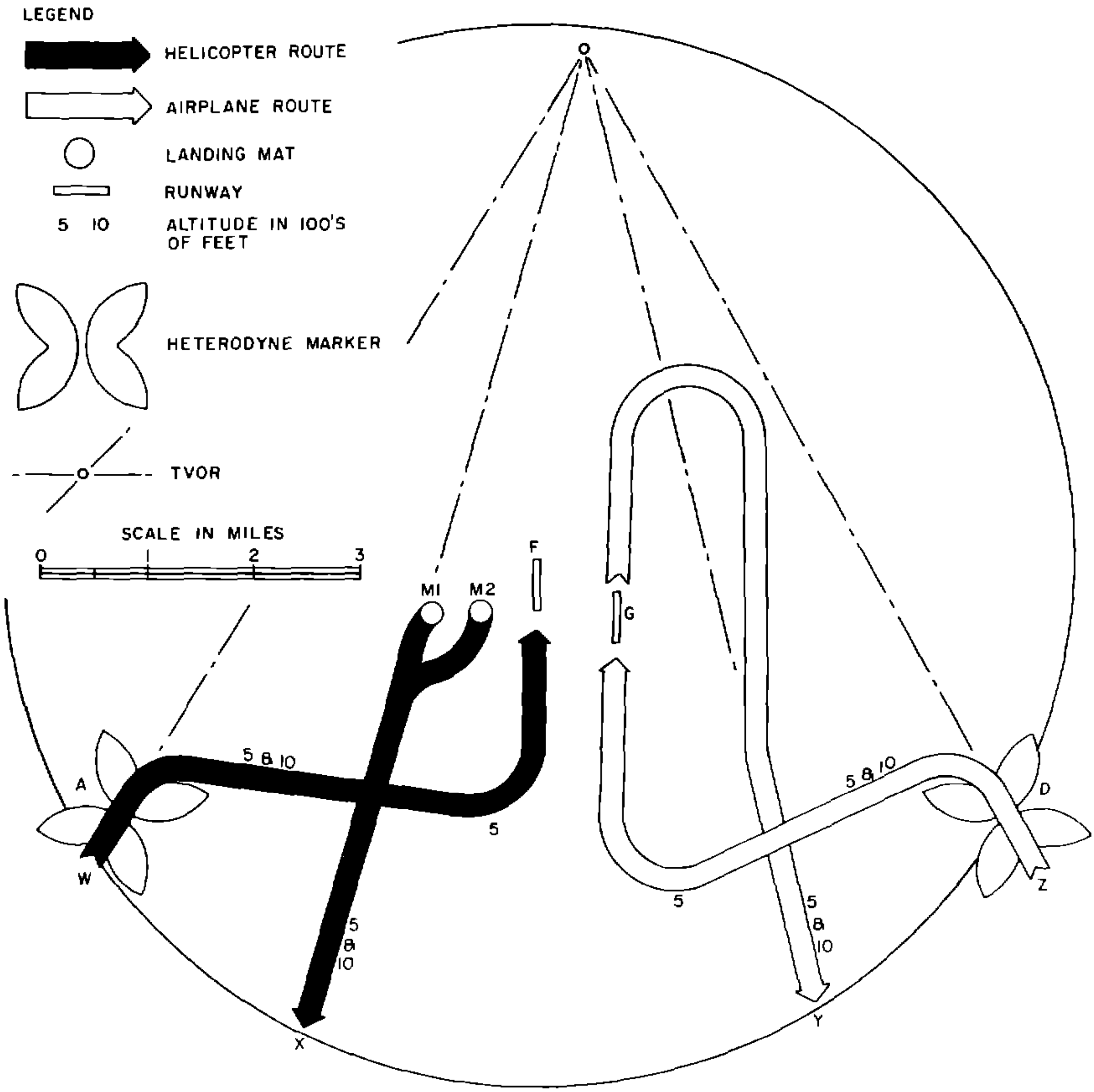


FIG 17 SYSTEM 6-NORTH LANDINGS

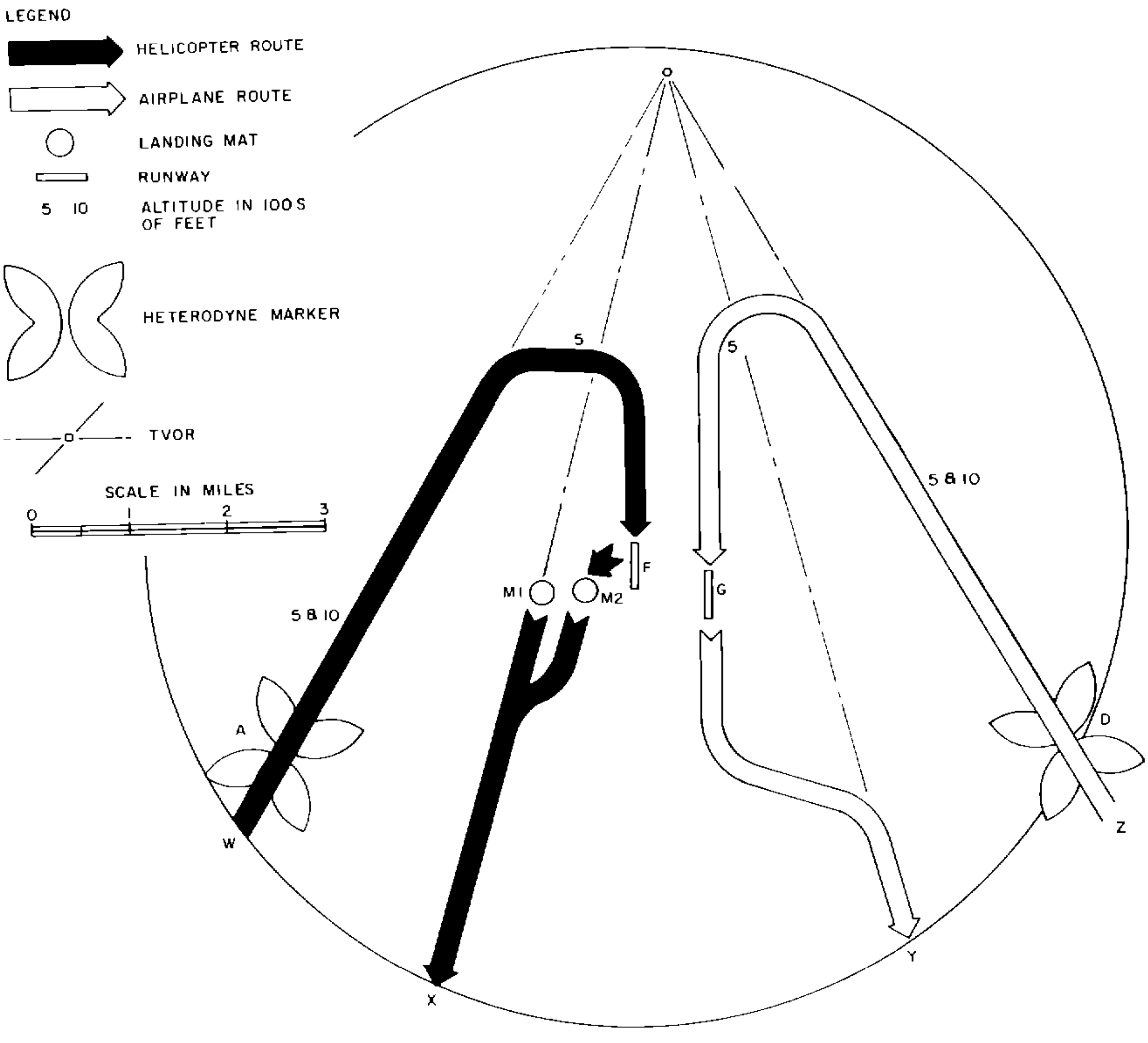


FIG 18 SYSTEM 6 — SOUTH LANDINGS