PART 2 : SECTION 4

CHAPTER 14

PILOT NAVIGATION

Introduction

1. Air navigation is the art of guiding an aircraft through the air, so that it arrives at a desired position at a calculated time. Pilot navigation is basically the same as conventional "navigator" navigation, the difference being one of technique only. The limitations of cockpit space preventing the use of plotting instruments, and the preoccupation of the pilot with flying the aircraft limiting the use of computors, together demand simplified procedures wherever possible.

2. The varying roles of single-seat aircraft, such as high-level interception, photographic reconnaissance, low-level close support, have all tended to prevent the adoption of any single recognized method ; but if the basic principles which are common to all forms of pilot navigation are understood, more advanced methods and refinements can be readily appreciated.

The Pilot Navigator's Problem

3. The basis of air navigation is the triangle of velocities, fully explained in A.P. 1234A, Section 1, Chapter 1, paras. 87 *et seq.* Crew navigation entails the observation of the aircraft's progress in flight so that true values are then used in subsequent triangles of velocities to relate heading and true airspeed to track and ground speed, making precise navigation possible. It is possible that at least two components of the triangle, *i.e.* heading and true airspeed, will be recorded automatically by dead reckoning (D.R.) instruments.

4. Solution of navigational problems by triangles of velocities in flight requires plotting and computors, which are in the main denied to the pilot navigator. Therefore his technique must permit simpler interpretation of visual and radio observations of flight progress.

5. Single-seat aircraft may be provided with an air position indicator (A.P.I.), but this does not eliminate the necessity for a computor and some simple form of plotting. As the speed of the single-seater increases, however, the pilot's ability to contend with this form of navigation decreases. In jet aircraft it is questionable whether he should use any type of computor, while any form of plotting is almost impossible.

6. For the pilot navigator, flying and navigation are allied activities, the predominance of one or the other being decided by the operational role. The navigational factors contributing to a successful sortie are discussed under the following headings :—

(*a*) The standard required.

(*b*) Flight planning.

(*c*) Aircraft performance.

(*d*) Mental dead reckoning.

(*e*) Map analysis and map reading.

STANDARD REQUIRED

Practical Limits Required

7. The standard of accuracy required varies with the role. Long flights above cloud, without aids, demand a high degree of flying accuracy to maintain accurate D.R. On the other hand, operational requirements reduce flying accuracy. In such cases it may be necessary to maintain a mean heading and airspeed and be within tolerable limits.

8. Accuracy, subject to the limitations imposed by particular operational roles, should normally be confined to :—

(*a*) Heading $\pm$ 2°.

(*b*) Speed $\pm$ 5 per cent. of I.A.S.

(*c*) Altitude $\pm$ 200 ft.

Effect of Inaccuracies

9. Some effects of flying inaccuracies on navigation are given in the following examples :—

(*a*) *Heading.*

T.A.S.	450 kts.
Heading error	5°
Time	20 mins.

Displacement from track = 12½ n.m.
This is equivalent to an unexpected 37½-kt. beam wind component.

(*b*) *Speed.*

Planned I.A.S. = 200 kts. at 40,000 ft.

Actual I.A.S. = 205 kts., due to careless flying.

Result = 32-kt. error in T.A.S., which is equivalent to a forecast wind error of 32 kts. This represents a ground error of about 10 n.m. in 20 mins.

(*c*) *Altitude.* Accurate altitude to within a few hundred feet is of minor importance navigationally, *e.g.* :—

At 40,000 ft. I.A.S. = 220 kts.
T.A.S. = 453 kts.
At 39,000 ft. I.A.S. = 220 kts.
T.A.S. = 445 kts. or 8 kts. error for 1,000 ft. error in altitude.

FLIGHT PLANNING

Introduction

10. The increasing complexity of flying operations makes it necessary to minimize the time spent on any one particular function in the air. Accurate pre-flight planning, amended as necessary in flight by rapid mental calculations, will contribute materially to the success of any sortie.

11. By careful study of the route before take-off, a mental picture of the track can be formed. This greatly simplifies the recognition of landmarks. By flight planning, map reading can be confined to definite times when check features are scheduled to appear. The sense of preparedness for what lies ahead has considerable influence on successful air navigation.

12. Flight planning is only possible for sorties conforming to a strict flight pattern. Operational factors often rule out the use of a flight plan, in which case knowledge of aircraft performance and adeptness in the use of mental calculations are important.

Ideal Flight Procedure

13. Pre-flight planning should normally be carried out on a basis which requires the pilot to map read at the following intervals :—

(*a*) Immediately after leaving base, to provide a definite point of departure and to establish a time of departure as the basis of ensuing E.T.As.

(*b*) At points along the track at appropriate flying intervals to check the progress of the flight, so that any deviations from the flight plan may be noted and the necessary corrections made.

(*c*) At a final point close to the destination, so that previous alterations may be confirmed and final adjustment made if necessary.

14. The frequency with which observations are made depends on :—

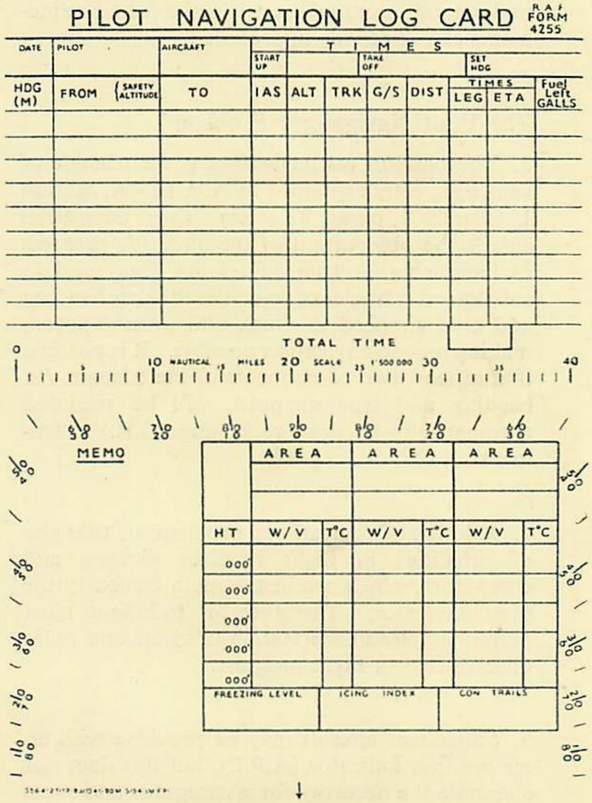
(*a*) The accuracy of navigation required.

(*b*) The alterations demanded by operational and other factors.

(*c*) The navigational aids available, including opportunities for map reading.

Pilot Navigation Log Card (Form 4255)

15. The Pilot Navigation Log Card is designed so that the information required in flight can be recorded in the simplest manner. It has a scale on the front lower edge of nautical miles on a standard 1 / 500,000 topographical map. The reverse is marked off in 5° and 10° divisions to assist the estimation of angles.


PILOT NAVIGATION LOG CARD
R.A.F. FORM 4255

DATE	PILOT	AIRCRAFT	START UP	TIMES TAKE OFF	SET HDG

HDG (M)	FROM (SAFETY ALTITUDE)	TO	IAS	ALT	TRK	G/S	DIST	TIMES LEG	TIMES ETA	Fuel Left GALLS

TOTAL TIME

0 10 NAUTICAL MILES 20 SCALE 1:500 000 30 40

MEMO

	AREA	AREA	AREA
HT	W/V T°C	W/V T°C	W/V T°C
000'			
000'			
000'			
000'			
000'			
FREEZING LEVEL	ICING INDEX	CON TRAILS	

Fig. 1. The Pilot Navigation Log Card (Form 4255) Showing Both Sides of the Form

Preparation of Maps

16. Hard-and-fast rules cannot be specified for the preparation of maps for air use. A track line is required to provide a datum for checking flight progress, and flight intervals may be indicated on it by any of the following methods :—

(*a*) *Time Scales*. These can be at intervals of 10 minutes (5 for high-speed aircraft) at the estimated ground speed.

(*b*) *Proportional Division*. The track may be marked at $\frac{1}{4}$, $\frac{1}{2}$, and $\frac{3}{4}$ intervals (or $\frac{1}{3}$ and $\frac{2}{3}$) and annotated with corresponding flight times. Interpolation for mid-points by either method is simple.

(*c*) *Distance Scales*. Ten-mile intervals provide a useful reference in estimating distances and in applying the one-in-sixty rule (see paras. 31to33), as also does the scale on the edge of the log card.

17. When radio aids are to be used, the portions of the compass rose applicable to each station to be used, may be plotted at 10° intervals and extended close to the track line, to simplify hand plotting of position lines.

18. Dotted lines drawn at 5° or 10° on either side of the track through departure and destination points are most useful for quick examination of heading alterations. The angle of track error can be estimated by noting the location of a pinpoint in relation to the intended track and drift line, and appropriate action taken as outlined in paras. 29 and 30.

19. Map sheets should be folded so that the complete track coverage is possible with the minimum number of page turns, but without refolding in flight. They should then be numbered and stacked in order of use for insertion in the cockpit. An emergency set of maps, enclosed in an envelope and placed securely in the cockpit, may relieve an embarrassing situation if a map drops beyond reach or is blown out of the cockpit.

Planning Sequence

20. A logical sequence for any flight involving single-seater technique is as follows :—

(*a*) Review all information relevant to the sortie (*i.e.* operational instructions, Form D, navigation details, etc.). Decide on the aim of the sortie and bear this in mind throughout the planning.

(*b*) Study the synoptic situation. Obtain the wind velocities and air temperatures required for flight-plan calculations.

(*c*) Select a pre-flight planning chart, and a set of maps for the route.

(*d*) Decide on the route to be followed (unless already specified), considering the aim of the sortie, the weather, the navigational aids available, and any other tactical factors involved.

(*e*) Draw in the tracks ; measure track angles and distances and record them on the pilot navigation log card.

(*f*) From the data given in Pilots' Notes or the Operating Data Handbook, decide on R.A.S. and fuel consumption for each stage of the flight. Using the forecast temperature, convert R.A.S. to T.A.S.

(*g*) Calculate headings to steer using the forecast winds, and log them. Winds are usually forecast for various stages of the flight and should be interpolated where these stages do not coincide with the legs to be flown.

(*h*) Re-check all calculations mentally.

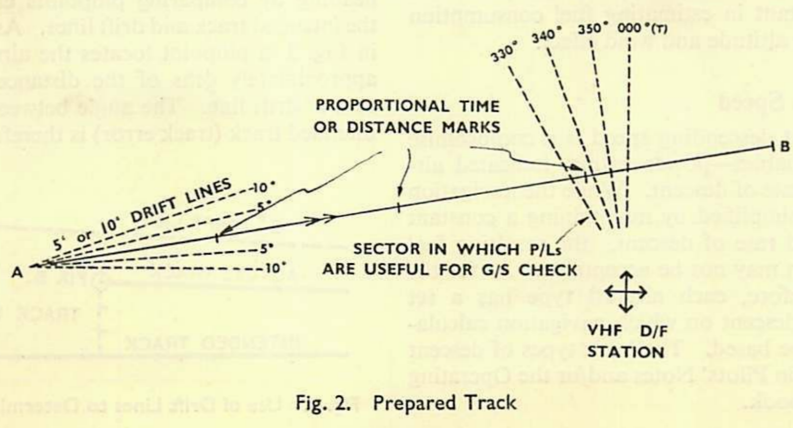


Fig. 2. Prepared Track

(*j*) Transfer tracks to topographical maps to be used in the air, and plot in the aids to mental D.R. mentioned in paras. 16 to 19, marking in also the E.T.As. at prominent check-points, preferably in a contrasting colour.

(*k*) Draw in tracks to diversionary airfields from the target area or other focal point. Calculate headings, ground speeds, and distances to run. Work out flight times and enter all data in the flight plan.

AIRCRAFT PERFORMANCE

Recommended Speeds and Engine Settings

21. One of the governing factors in every navigational problem is that of airspeed. It is also the main factor governing fuel economy in level flight. Recommended speeds, together with the power settings and fuel consumption, are given in Pilots' Notes or in the Operating Data Handbook.

Best Climbing Speeds

22. It is important to reach flight altitude as quickly as possible so that fuel economy can be achieved. The best rate of climb is attained if a particular airspeed and recommended power setting are used for each stage of the climb. These vary with altitude and constitute the normal climbing schedule for the aircraft type. They are given in Pilots' Notes and/or the Operating Data Handbook.

Time to Altitude

23. The performance data in Pilots' Notes and/or the Operating Data Handbook give the time for each stage if the climb to absolute ceiling is made under I.C.A.N. conditions. These times are most important in estimating fuel consumption to operating altitude and wind effect.

Descending Speed

24. The best descending speed is a compromise of three variables—power setting, indicated airspeed, and rate of descent. While the navigation problem is simplified by maintaining a constant airspeed and rate of descent, the resulting fuel consumption may not be acceptable. As for the climb, therefore, each aircraft type has a set pattern for descent on which navigation calculations must be based. The basic types of descent are detailed in Pilots' Notes and/or the Operating Data Handbook.

Calculations of True Airspeed

25. **The Climb.** The calculation of true airspeed from indicated airspeeds which vary during the climb is simplified by preparing a table based on the performance charts and tables, showing the variations of I.A.S. and times to altitude.

26. **The Descent.** A similar table may be prepared for normal descent, using the same method as for the climb.

Changes from I.C.A.N. Conditions

27. Differences in temperature from the I.C.A.N. standard, while affecting only the take-off distances and operational ceilings of piston-engined aircraft, must be taken into account for jet-engined aircraft. Variation in the density of the air caused by temperature change has a significant effect on the time taken to reach operating altitude. This in turn alters considerably the navigation problem and calculations of fuel consumption. Performance charts should therefore also be prepared for conditions both warmer and colder than the I.C.A.N. standard.

MENTAL DEAD RECKONING

Definition of Mental D.R.

28. Mental D.R. is the mental calculation of an aircraft's progress so that its position can be assessed and alterations to heading and airspeed estimated to arrive at a required destination at a calculated time.

Use of Drift Lines

29. As mentioned in para. 18, drift lines are useful for the estimation of quick alterations of heading by comparing pinpoints en route with the intended track and drift lines. As an example, in Fig. 3 a pinpoint locates the aircraft over B, approximately $\frac{3}{5}$ths of the distance from track to a 5° drift line. The angle between actual and intended track (track error) is therefore 3°.

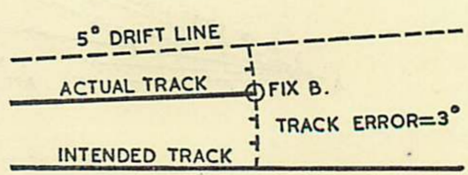
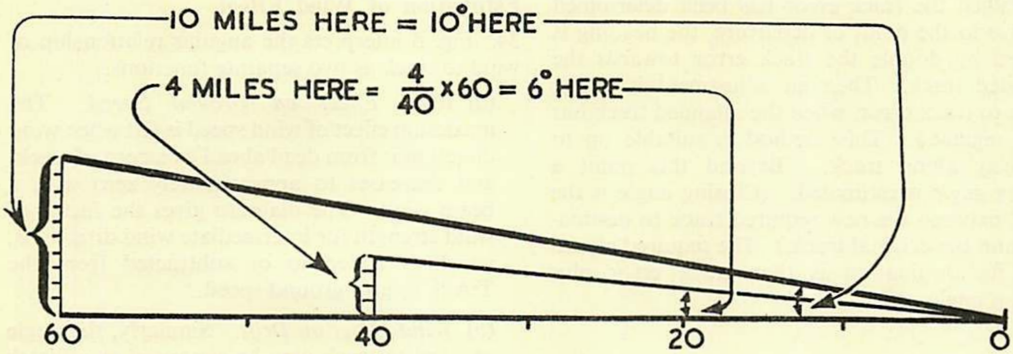
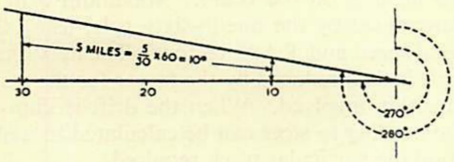


Fig. 3. Use of Drift Lines to Determine the Track

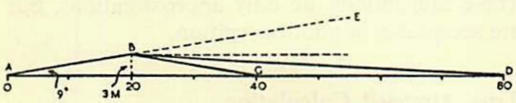


BASIC APPLICATION OF THE ONE-IN-SIXTY RULE.



TO DETERMINE TRACK ANGLE :—

Estimate angle between track and meridian or parallel by observing displacement at an arbitrary distance from point of intersection, and applying 1 : 60 rule. Add or subtract angle to or from parallel heading.



CALCULATING A FIRST ALTERATION TO HEADING :—

$$\text{Track error} = \frac{60}{20} \times 3 = 9^\circ$$

Heading Correction at B,

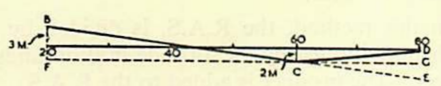
(*a*) to destination,

$$= \angle EBD$$
$$= \angle BAD + \angle BDA$$
$$= \frac{60 \times 3}{20} + \frac{60 \times 3}{60}$$
$$= 9^\circ + 3^\circ$$
$$= 12^\circ$$

(*b*) to return to track,

$$= 2 \times \angle BAD$$
$$= 2 \times 9^\circ$$
$$= 18^\circ$$

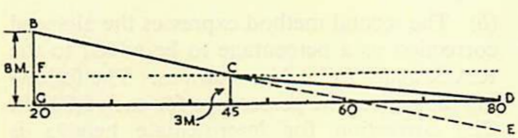
(Heading altered 9° back at G)



HEADING CORRECTION AFTER SECOND FIX ON OPPOSITE SIDE OF TRACK :—

Heading alteration at C,

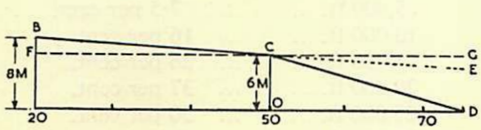
$$= \angle DCE$$
$$= \angle BCF + \angle DCG$$
$$= \frac{60 \times (3+2)}{40} + \frac{60 \times 2}{20}$$
$$= 7^\circ + 6^\circ$$
$$= 13^\circ$$



HEADING CORRECTION AFTER SECOND FIX ON SAME SIDE OF TRACK (RETURNING TO TRACK BEFORE DESTINATION) :—

Heading Correction at C,

$$= \angle DCE$$
$$= \angle BCF - \angle CDG$$
$$= \frac{60 \times (8-3)}{25} - \frac{60 \times 3}{35}$$
$$= 12^\circ - 5^\circ$$
$$= 7^\circ$$



HEADING CORRECTION AFTER SECOND FIX ON SAME SIDE OF TRACK (RETURNING TO TRACK BEYOND DESTINATION) :—

Heading Correction at C,

$$= \angle DCE$$
$$= \angle DCG - \angle GCE$$
$$= \angle CDO - \angle BCF$$
$$= \frac{60 \times 6}{25} - \frac{60 \times (8-6)}{30}$$
$$= 14^\circ - 4^\circ$$
$$= 10^\circ$$

Fig. 4. Uses of the One-in-Sixty Rule

30. When the track error has been determined relative to the point of departure, the heading is altered by double the track error towards the intended track. Then an adjustment is made, equal to track error, when the intended track has been regained. This method is suitable up to half-way along track. Beyond this point a *closing angle* is estimated. (Closing angle is the angle between the new required track to destination and the original track.) The required alteration for destination is then track error plus closing angle.

The One-in-Sixty Rule

31. The one-in-sixty rule is based on the fact that one nautical mile subtends an angle of 1° at a distance of about 60 nautical miles ; 5 miles subtend 5°, etc.

32. In applying the rule, the triangle relevant to the navigational problem is identified, and the ratio of the length of the long side to 60 is established. This ratio may then be applied to the angle to reveal the length of the side opposite to it ; or conversely, to the opposite side to reveal the angle it subtends. Fig. 4 illustrates some practical applications of the one-in-sixty rule.

33. The assumption that a specific alteration of heading results in a corresponding alteration in track is not strictly true, because the direction relative to the wind is altered ; consequently the drift may not remain as it was before. For alterations up to 20°, however, the change of drift can be neglected. For track alterations greater than 20°, a new heading should be calculated by the method given in para. 34.

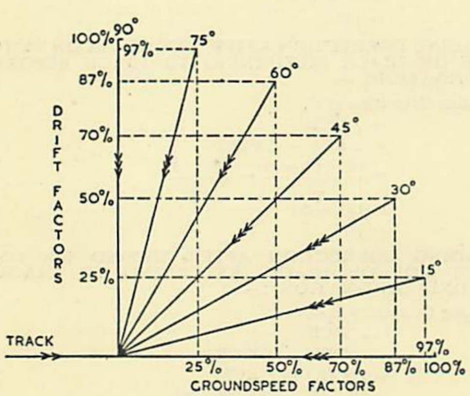


Fig. 5.
Diagram for Calculating Drift and Ground Speed

Estimation of Wind Effect

34. Fig. 5 interprets the angular relationship of wind to track as two separate functions.

(*a*) *Wind Effect on Ground Speed.* The maximum effect of wind speed is felt when wind direction is from dead ahead or astern of track, and decreases to approximately zero with a beam wind. The diagram gives the factor of wind strength for intermediate wind directions, which is added to or subtracted from the T.A.S. to give ground speed.

(*b*) *Wind Effect on Drift.* Similarly, the angle of wind to track may be expressed as a factor of the maximum possible drift resulting when the wind is on the beam. Maximum drift is determined by the one-in-sixty rule, using the wind speed and T.A.S. vectors. The maximum drift is then reduced by the factor for the wind direction involved. When the drift is known, the heading to steer can be calculated to make good the particular track required.

These calculations are only approximations, but are acceptable in pilot navigation.

True Airspeed Calculation

35. Two methods are given below for use in mental calculations for converting R.A.S. to T.A.S. Vol. 1, Part 1, Sect. 1, Chap. 2 should be read in conjunction with these methods.

(*a*) $R.A.S. + \frac{R.A.S.}{60} \times Alt.$ (*in thousands of feet*) $= T.A.S.$

In this method, the R.A.S. is divided by 60, then multiplied by the altitude in thousands of feet. The product is added to the R.A.S.

Example :— R.A.S. = 360 kts.
Altitude = 15,000 ft.

$\frac{360}{60} \times 15 = 90$; $360 + 90 = 450$ kts.

(*b*) The second method expresses the airspeed correction as a percentage to be added to the R.A.S. *under I.C.A.N. conditions.* The following table gives the percentage for each 5,000 ft. The correction for intermediate heights is obtained by interpolation.

5,000 ft. ...	... 7·5 per cent.
10,000 ft. ...	... 16 per cent.
15,000 ft. ...	... 26 per cent.
20,000 ft. ...	... 37 per cent.
25,000 ft. ...	... 50 per cent.
30,000 ft. ...	... 64 per cent.
35,000 ft. ...	... 80 per cent.
40,000 ft. ...	... 100 per cent.

36. The method in para. 35 (*a*) is sufficiently accurate for use up to 25,000 ft. The method in para. 35 (*b*) gives an approximation at all altitudes but does not allow for compressibility error in the A.S.I. Vol. 1, Part 1, Sect. 1, Chap. 2, para. 19, deals with compressibility error in detail. There is no need to memorize all the table, but sufficient can be memorized for the usual altitude at which the aircraft is flown.

Calculations for the Climb

37. For altitudes up to 20,000 ft., the following formulae may be used to determine a mean altitude for which the T.A.S. and wind velocity (W/V) may be calculated and used throughout the climb or descent :—

(*a*) *For Constant Rate of Climb* (*or Descent*). Altitude at lower level + $\frac{1}{2}$ change in altitude. *Example* :—For a constant rate of climb from 2,000 to 20,000 ft., or descent through the same levels, mean altitude (for planning)

$$= \text{Lower level} + \tfrac{1}{2}\text{ change in altitude}$$
$$= 2{,}000 + \tfrac{1}{2}\,(18{,}000)$$
$$= 2{,}000 + 9{,}000 = 11{,}000\text{ ft.}$$

(*b*) *For a Decreasing Rate of Climb.* For altitude at lower level + $\frac{2}{3}$ change in altitude. *Example* :—For a decreasing rate of climb from 2,000 ft. to 20,000 ft. mean altitude (for planning)

$$= \text{Lower level} + \tfrac{2}{3}\text{ change in altitude}$$
$$= 2{,}000 + \tfrac{2}{3}\,(18{,}000)$$
$$= 2{,}000 + 12{,}000 = 14{,}000\text{ ft.}$$

38. The foregoing formulae are based on certain assumptions of wind behaviour and aircraft rate of climb, which frequently differ from actual conditions. The variations are usually acceptable in pilot navigation up to 20,000 ft., but above that altitude they can no longer be ignored and more accurate methods must be used, as indicated in paras. 22 and 26.

Estimation of Distance

39. Constant practice on the ground in the mental estimation of distances on maps of various scales is necessary to improve accuracy. In addition, the following aids may be used :—

(*a*) *The Pilot Navigation Log Card.* A graduated scale of nautical miles on the normal topographical map (1/500,000) is marked along the lower edge of this card. If used with 1/1,000,000 maps, the distance measured will be twice that shown on the card ; if with 1/250,000, the distance measured will be half that shown on the card.

(*b*) *Hand Measurements.* The span of the hand from the thumb to little finger provides a reliable measure, if its dimension is known in terms of the scales of maps used. The distance from thumb-nail to knuckle crease is useful for short distances.

(*c*) *Parallels of Latitude or Reference Graticules.* On a map these provide useful visual aids to distance measurement.

Estimation of Direction

40. As with the estimation of distance, constant practice is necessary to improve accuracy, but this can be assisted by the use of one of the following methods :—

(*a*) *Pilot Navigation Log Card.* The reverse of the log card is graduated in 5° and 10° divisions and should be used to give the number of degrees to add to or subtract from the nearer cardinal direction.

(*b*) *Bisecting the Angle.* Having decided in which quadrant the required track lies, the angle can be estimated quite accurately by progressively halving the sector in which it lies, and finally interpolating the estimated "bracket lines".

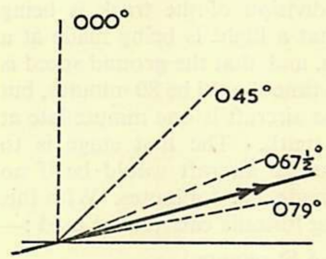


Fig. 6.
Angle Bisection to Determine the Track Angle

Estimation of Time of Flight

41. Fractional proportion is the basis of mental calculations of flight time. For example, suppose it is required to estimate the time of flight to cover 250 n.m. at a ground speed of 190 kts. Taking the nearest multiple of 60 to the given speed (180 kts., or 3 n.m. per minute), the time of flight would be 250 divided by 3 = 83 minutes. But 190 is 10/190 (or approximately 1/20) faster than 180, therefore the time of flight must be reduced by 1/20 of 83, or 4 minutes. The time of flight is therefore 83 − 4 = 79 minutes.

42. In flight, once two definite fixes of the aircraft's position have been located on the map, the distance between them represents a known time interval which then serves as a measure for other distances, by using the usual methods of interpolation—halving, doubling, etc. Knowledge of ground speed is therefore not always necessary.

Amendments to Time or Speed of Flight

43. When fixes reveal that the ground speed is at variance with the flight plan, mental calculations are required to amend the E.T.A. or alter the I.A.S. to maintain the planned E.T.A. It should be appreciated that if any alterations of speed are necessary they should be made as early as possible.

44. Amendment to E.T.A. can be estimated by fractional proportion. For example, an aircraft arrives at a check point after 18 minutes flying instead of the expected 20 minutes, thereby gaining 2 minutes in 20, or 1/10. If 50 minutes of flight time remain, the aircraft may be expected to gain a further $50 \times 1/10$, or 5 minutes of time. Thus the aircraft will arrive $2 + 5 = 7$ minutes ahead of the original E.T.A.

45. A method of calculating the required revision of speed to maintain E.T.A. also involves two stages, but is frequently much simpler, particularly where fractional division of the track is being used. Suppose that a flight is being made at a T.A.S. of 180 kts. and that the ground speed is such that the total time should be 80 minutes, but it is found that the aircraft is one minute late at the first quarter mark. The first stage is to calculate how late the aircraft would be if no adjustment were made, *i.e.* 4 minutes. With this figure the following formula can now be used :—

$$\text{Additional T.A.S. required} = \frac{\text{T.A.S.} \times \text{Time late on E.T.A.}}{\text{Actual time to go to E.T.A.}}$$

$$= \frac{180 \times 4}{59} \quad \text{or} \quad \frac{180 \times 4}{60} \text{ (approx.)}$$

$$= 12 \text{ kts.}$$

Note : The use of I.A.S. instead of T.A.S. will not normally cause appreciable errors.

46. **Precomputation of T.A.S. Adjustments.** Calculations in the air to arrive at a readjustment to T.A.S. can be reduced to a minimum by precomputation with the Appleyard scale when flight planning. As an example, assume a distance of 240 n.m. has been flown at a T.A.S. of 160 kts., giving a D.R. ground speed of 180 kts. The total time will be 80 minutes, and the aircraft should be at the quarter, half, and three-quarter marks at 20, 40, and 60 minutes respectively.

(*a*) First, precompute for being one minute late at the quarter-way mark. The aircraft will have covered 60 n.m. in 21 minutes, instead of 20, so that its ground speed is 172 kts. instead of 180 kts. Speed must therefore be increased by 8 kts. to regain the D.R. ground speed. If a further increase of speed is made to cover the next quarter in 19 minutes the aircraft will be back on schedule at the half-way mark. To do this it must cover 60 n.m. in 19 minutes, which requires a speed of 189 kts., so speed must be increased by a further 9 kts. until the half-way mark is reached.

(*b*) Similarly, computing for one minute early at three-quarter-way, it is found that speed would have to be reduced by 9 kts. to regain the D.R. ground speed, and by a further 8 kts. to lose one minute over the next quarter of the flight. A note of these figures can be made on the flight plan thus :—

Adjustments to T.A.S. for 1 min. in 20			
	Late	+8	+9 kts.
	Early	−9	−8 kts.

These figures will give, in the first column, the necessary adjustment to T.A.S. to restore the actual ground speed to the D.R. ground speed, and, in the second column, the adjustment necessary to gain or lose one minute over the next section.

(*c*) Multiples of these figures can be used with reasonable accuracy. For instance, if the aircraft were three minutes late at quarter-way, speed could be increased by $3 \times (8 + 9) = 51$ kts., and having regained schedule at half-way speed could be reduced by $3 \times 9 = 27$ kts., to make good the D.R. ground speed over the remaining distance. Similarly, if such an increase was not practicable with the aircraft in question, the speed could be increased by $3 \times 8 = 24$ kts., to restore the ground speed, and then increased by 9 kts. which will enable the aircraft to pick up one minute in each of the remaining quarters.

47. The application of these calculations to increase airspeed, when time is being lost, is similar.

48. It should be realized that in a slower type of aircraft it may be possible to use an Appleyard scale for these ground speed calculations. Even when this is possible, however, such calculations should still be checked mentally in the manner described above.

Dog-Leg Procedures

49. When time has been gained, the dog-leg procedure may be used to lose it. Heading is altered 60° in either direction for the length of time that is to be lost, then altered 120° in the opposite direction for the same length of time to regain track, when normal heading is resumed. The aircraft will thus have flown two sides of an equilateral triangle, and the time spent in flying the dog leg will be twice that required to fly the direct track (Fig. 7(*a*)).

50. A similar procedure, altering heading first 30° in one direction, then 60° in the other until track is regained, may be used for small adjustments to E.T.A. For every minute to be lost, heading should be altered for 4 minutes away from track, and 4 minutes towards track (Fig. 7(*b*)).

51. The use of dog-leg procedures to avoid obstacles, bad weather, etc., enables E.T.As. to be amended simply and quickly.

52. (*a*) If there is a choice of a turn either to port or to starboard for the dog leg, it is normally better to turn into wind, if there is a cross-wind. This ensures that the original track will be crossed on the second leg.

(*b*) When a large amount of time has to be lost by dog leg, a single dog leg will take the aircraft a long way from the original track, and it is better to carry out a series of short dog legs so that the aircraft remains close to the track.

(*c*) It should be noted that the aircraft will be carried down-wind from track by a distance equal to the wind effect for the extra time spent on the dog leg. In conditions of strong cross-wind, therefore, the aircraft may have to turn early on the second leg to maintain its required track.

MAP ANALYSIS

General

53. Every pilot should be familiar with the general properties of the various types of maps, and the symbols used. In map analysis the process is carried a step further and attention is given to whole areas along the route, assessing in detail the various features thereon so that a full mental picture is built up. Apart from its operational use in familiarizing the pilot with his flying areas, target, etc., this is an excellent way of improving map reading ability.

Feature Analysis

54. When extracting detailed information, a logical sequence of analysis is necessary. The following is an example :—

(*a*) General location.

(*b*) Relief.

(*c*) Coastlines and water features.

(*d*) Agricultural and built-up areas.

(*e*) Communications.

(*f*) Special features.

The actual selection of features will depend on the type of sortie.

General Location

55. Under this heading, the general aspects are considered, *e.g.* whether the area is coastal or inland, flat or mountainous. An area summary for the route and surrounding area should then be made. This will consist of dividing the route into sections having similar general characteristics. For example, heavily built-up areas, hill moors, and so on.

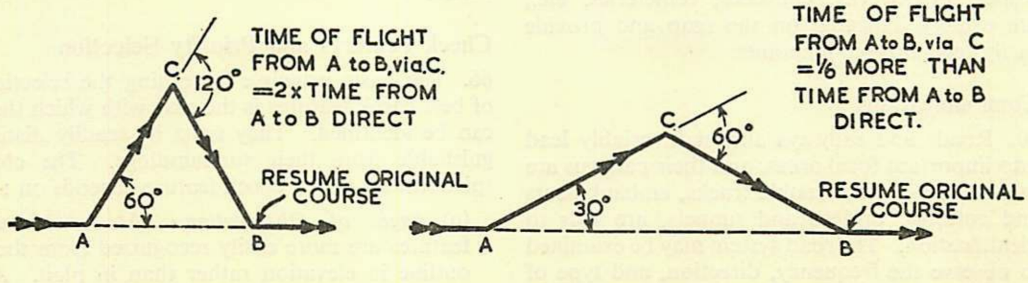


Fig. 7. Dog-Leg Procedures

Relief

56. Relief is normally well portrayed on nearly all maps by contours with or without layer tinting. Such information can normally be assimilated at a glance and the height of the highest ground in the area assessed for safety purposes. However, when low flying it is possible to obtain either cover or valuable pinpoints from hills, valleys, etc., so that a closer study becomes necessary. The approach should then be as follows :—

(*a*) Are the hills in ranges and, if so, what is their direction ?

(*b*) Are the slopes steep or shallow ?

(*c*) What are the minimum and maximum heights of ground ?

(*d*) Are the valleys deep and broad or just shallow indentations, etc. ?

Coastline and Water Features

57. The nature of a coastline is important ; cliffs, sand dunes, and width and nature of beaches being the outstanding features. Indentations such as estuaries, lochs, fiords, etc., are excellent fixing features. The direction of flow, size, and watershed pattern form the basis of analysis for rivers. Lakes are very distinctive landmarks, being recognizable by their shape, type of shore, position of islands, and surroundings (marshes, forest, etc.). Their relation to other features forms useful patterns which simplify map reading.

Agricultural and Built-up Areas

58. Again, the general features of the area are studied. The shapes of wooded areas and types of trees, ploughed or cropped land, and terracing will, if indicated, give the pilot navigator a valuable insight into what to expect on the sortie.

59. Built-up areas also form distinctive landmarks by virtue of their size and shape, and the patterns they form with other towns or line features. Mines, brickworks, churches, cemeteries, etc., are usually indicated on the map and provide easily recognizable pinpoints.

Communications

60. Roads and railways almost invariably lead into important focal areas, and their patterns are useful. Single and double tracks, embankments and cuttings, bridges and tunnels, are aids to identification. The road system may be examined to observe the frequency, direction, and type of surface. By-passes, bridges, traffic islands, etc., should be noted to complete the mental pictures.

Special Features

61. This heading covers the remaining miscellaneous features such as airfields, wireless stations, power lines, oilfields, lighthouses, etc.

MAP READING

General

62. The following points are particularly applicable to single-seater technique. There are four basic factors upon which the success of map reading depends :—

(*a*) Knowledge of direction.

(*b*) Knowledge of distance.

Note.—*(a) and (b) combine to make anticipation and recognition of landmarks possible.*

(*c*) Identification of features.

(*d*) Selection of landmarks.

Direction

63. The first action in map reading is to orientate the map. By so doing the pilot navigator relates the direction of land features to their representations on the map, and so aids recognition.

Distance

64. When the map has been properly orientated it becomes easier to compare distances between landmarks on the ground with their corresponding distances on the map, thus facilitating the fixing of position.

Anticipation of Landmarks

65. In pre-flight planning the relationship of easily recognizable features to the intended track is noted, and a time established at which the aircraft will be in their vicinity. Thus, in flight, the map reader is prepared to make his visual observations at a particular time, avoiding undue diversion of attention from other details of the sortie.

Check Features and Priority Selection

66. The basic principle governing the selection of best check features is the ease with which they can be identified. They must be readily distinguishable from their surroundings. The conspicuousness of any check feature depends on :—

(*a*) *Angle of Observation.* At low levels features are more easily recognized from their outline in elevation rather than in plan. As altitude is increased the plan outline becomes more important.

(*b*) *Dimensions of the Feature.* A feature which is long in one direction and sharply defined in the other is better ; the length makes the feature easier to see despite airframe restrictions to downward vision, and its shorter dimension permits an accurate estimation of the aircraft's relation to the feature, either in tracking along it or in timing the movement of flight directly above it.

(*c*) *Uniqueness of the Feature.* To avoid ambiguity the ideal feature should be the only one of its particular outline in the vicinity.

(*d*) *Contrast and Colour.* These properties play a large part in the identification of a particular feature. Map reading may be complicated by seasonal variations, *e.g.* deciduous woods in summer and winter, and landscapes before and after extensive snowfalls. Contrast and colour also play their part in identifying coastlines after a long sea crossing.

Fixing by Map Reading

67. Map reading techniques largely depend on the weather and are evolved for :—

(*a*) Conditions which permit continuous visual observations of the ground.

(*b*) Conditions which limit visual observations of the ground to unpredictable intervals.

Map Reading in Clear Weather

68. By means of a time scale on the track, graduated either to the ground speed of the flight plan or to the actual ground speed observed from two or more previous fixes, the pilot navigator can be prepared to look for a definite feature at a definite time. As a check on identification additional ground detail surrounding the feature should be positively recognized.

69. *Thus when in continuous contact with the ground, map read from map to ground.*

Map Reading in Cloudy Conditions

70. This technique is used when flying through broken cloud or when descending through cloud.

71. The pilot first estimates a circle of uncertainty for his position, based on a 10 per cent. error of the distance flown from his last known position. As a steady heading is maintained the circle of uncertainty will move along with the estimated D.R. position, increasing in diameter.

72. The pilot then studies the ground features over which he is passing, noting outstanding features and the sequence in which they occur. He then attempts to identify these features on his map within the circle of uncertainty and so establish his position and track made good (T.M.G.).

73. *Thus when seeking to establish position, map read from ground to map.*

USE OF RADIO AIDS

Introduction

74. The basic requirement in pilot navigation is to relate the actual progress of the aircraft over the ground to the required track, so that any corrections may be made to heading, airspeed, or E.T.A. to arrive over a desired position at a specific time. When map reading, the position of the aircraft is related to identifiable land features, and the information interpreted by means of a map. When using radio observations, the ground transmitting station takes the place of the landmark and the information obtained of the aircraft's relation to it is interpreted by means of maps or specially prepared radio charts. When visibility permits both visual and radio observations, one can be used to corroborate the other.

75. The type of information obtained varies with the type of radio aid ; some provide an immediate fix while others merely reveal the bearing of the aircraft from the aid.

V.H.F. D/F

76. The simplest method of checking track is to request a true bearing from the point of departure by V.H.F. D/F. This will reveal track error. If the error is doubled and applied as a correction for the length of time that the aircraft has been flying, track will be regained. A simple alteration of heading will then hold the aircraft on track.

Example :

1000 hours	Base. Set heading for B. Intended track 090°(T).
1010 hours	Q.T.E. Base 098°(T). Alter heading 16° port.
1020 hours	Check Q.T.E. 090°(T). Alter heading 8° starboard. If no check Q.T.E., still alter heading 8° starboard.

True bearings from destination may be used to determine the closing angle, or for simple homing.

77. **Ground Speed Checks.** Flight planning should have revealed D/F stations on either side of track. Position lines obtained from these provide accurate ground speed checks if the angle of intersection with the track is at least 60°. For convenience in plotting, the map should be prepared as described in para. 17.

78. The calls made on V.H.F. should be carefully planned so that every bearing received is useful.

Position Fixing, Using V.H.F. D/F

79. From the foregoing it will be seen that two or more intersecting position lines will give a fix. For pilot navigation the need for rapid fixing usually limits the number of position lines to two. These should cut each other at as near to right angles as possible.

80. As bearings will usually be obtained successively, it will be necessary to transfer the first in relation to the second. If the first bearing is taken from a D/F station ahead or astern of track, its transfer in relation to the next bearing will be achieved simply by extending it.

81. The procedure for obtaining a two-position line fix is therefore :—

(*a*) Obtain a true bearing from a station ahead or astern of track, and plot the appropriate portion of the position line near the D.R. position.

(*b*) Obtain a true bearing from a station on the beam, and plot a portion of the position line to intersect the first. The intersection of the two is the fix at the time of the second position line.

82. **V.H.F. D/F Fixer Service.** In some areas where fixer services exist, the above procedure is unnecessary since three D/F stations will take bearings simultaneously on an aircraft's transmission. The control station plots the bearings obtained and relays the fix to the aircraft.

Tunable Beam Approach (T.B.A.)

83. With T.B.A. the beam directions are fixed and therefore provide definite position lines only when the aircraft is actually in the beam.

84. The beams likely to be used should be plotted as true bearings (magnetic headings to the beacon are usually quoted) at the pre-flight planning. When approaching the beam the receiver is tuned to the appropriate frequency, and the beam signal should then be heard. It is important to identify the beam by its call letters which interrupt the beam signal at approximately half-minute intervals.

85. If the aircraft is flying a track which intersects the beam, a clear A or N will first be heard, depending upon which sector the aircraft happens to be in. As the beam is approached, the clear letter merges with a steady background signal, the combination being known as the *twilight zone*. As the aircraft enters the beam the steady signal only is heard ; and the passage through the beam is timed until the letter of the opposite sector is heard faintly through the steady signal. The aircraft has now reached the twilight on the opposite side of the beam. The times of entering and leaving the beam are averaged, and the mean time will be the time on the position line.

86. This type of position line can be used to intersect other radio bearings or line features to give a fix.

Voice Rotating Beacon

87. This is a ground transmitting station with a constantly rotating aerial system which transmits a beamed signal. A voice recording is synchronized with the rotation of the aerial system to announce the Q.D.M. for the beacon. The voice transmissions are heard faintly until the beam swings through the aircraft's position, when they increase considerably in volume. The Q.D.M. of the beacon is the direction announced by the loudest voice transmission.

88. A position line is obtained from this radio aid. When the transmitting station is located at the destination a homing can be made.

LOW-LEVEL PILOT NAVIGATION

General Review

89. Low-level navigation may be described as any navigation carried out during flight less than 500 ft. above ground level. The main problems of flight at low level arise from the more limited panorama and the restriction in the use of radio aids. At 100 ft. over the sea the horizon is nearly 12 miles distant ; but over land at the same height, the range of vision may be reduced to less than a mile by undulating terrain. Thus the number of landmarks visible at one time under normal conditions is much smaller.

90. Another difficulty is that of identifying landmarks from an entirely different perspective. At high airspeed the plan outline of the individual feature and the patterns it makes with others are of little value when viewed obliquely. In addition, high-speed flight close to the ground compels the pilot navigator to give more time to flying his aircraft. Therefore, if low-level sorties are to be carried out successfully, navigation must be very efficient and, as far as possible, automatic. This ability can only be attained by constant practice, a thorough knowledge of the problem involved, and application of the correct technique. Since the radius of turn at high speed can be several miles, allowance must be made for this effect when large changes of heading are necessary.

Selection of Maps

91. While map selection is mainly a question of personal preference, consideration should be given to the number of sheets involved for the entire track before a final choice of scale is made. While a $\frac{1}{4}$ inch to the mile map is suitable for slow aircraft, the $\frac{1}{8}$ inch to the mile (1 / 500,000) is usually better for high speeds.

92. Large-scale maps, such as the $\frac{1}{4}$ inch to the mile and the 1 inch to the mile series, are useful when planning a sortie for which great accuracy of detail is required in target areas and at turning and check points. Large-scale maps invariably show relief in great detail, and are valuable when determining the best method of approaching and leaving a defended area. Landmarks to identify the starting point of lead-in features, etc., may be selected from the large-scale map.

93. Having planned the flight on a large-scale map, any relevant information on it not included on the 1 / 500,000 map to be used in flight should be transferred onto this map. The in-flight map should be thoroughly prepared before take-off.

Planning the Low-Level Sortie

94. It is impossible to complete a detailed planning thoroughly and successfully without a comprehensive realization of what the sortie involves. The main point to consider at this stage, when studying the available information in conjunction with a map of the area, is the best route to be followed after considering the factors discussed in the following paragraphs.

95. **Mountain Ranges and High Ground.** With these are associated changeable weather, bad visibility, low cloud, turbulence, etc., involving pinpointing difficulties. Intense concentration is required to maintain a constant altitude above rugged country.

96. **Bad Weather Areas.** The areas down-wind of industrial centres should be avoided as the visibility in them is likely to be poor.

97. **Sea Crossings and Landfalls.** Sea crossings should be kept as short as possible to facilitate navigation, with due regard to tactical requirements. Coast crossing points should be selected to give unmistakable landfalls well before the actual crossing, *e.g.* promontories, high cliffs, or lighthouses.

98. **Length of Sortie.** An indirect route should never be followed at the expense of a reasonable safety margin of fuel. It may be better to complete a shortened route without overload tanks and fewer available landmarks, thus gaining tactical freedom and improved aircraft performance.

99. **Direction of the Sun.** It is very easy to overshoot landmarks when flying into the sun, and obstacles obscured by glare may be quite hazardous. Flying up sun in industrial haze makes map reading from low level difficult, and accurate attacks virtually impossible.

100. **Weather.** The most carefully laid plans and calculations are easily upset by unexpected changes in the forecast weather. However, such changes need not upset the pilot who possesses a sound knowledge of weather in general, and local weather in particular, and is prepared to back that knowledge with common sense. When flying in conditions of poor visibility care should be taken not to lose visual contact. As soon as contact is lost the aircraft should be climbed on track up to the safety altitude.

101. **Routing.** When planning the sortie the tactical factors must be correlated with the most effective use of navigational aids when selecting the route. Of particular importance are line features such as rivers, roads, or railways leading to the target. Fig. 8 illustrates what well-conceived routing can achieve. When large changes of heading are made at high I.A.S. the planning should allow for the radius of turn (the *diameter* of the turning circle is approximately equal to two-thirds of the speed in miles per minute).

Map Reading

102. When considering the suitability of a landmark as a check point on a low-level sortie, the following points should be borne in mind :—

(*a*) The landmark must be clearly visible. Its height above ground level is therefore important.

(*b*) It must be the only feature of its particular kind in the immediate area.

(*c*) It should extend on each side of the track to absorb any likely track error.

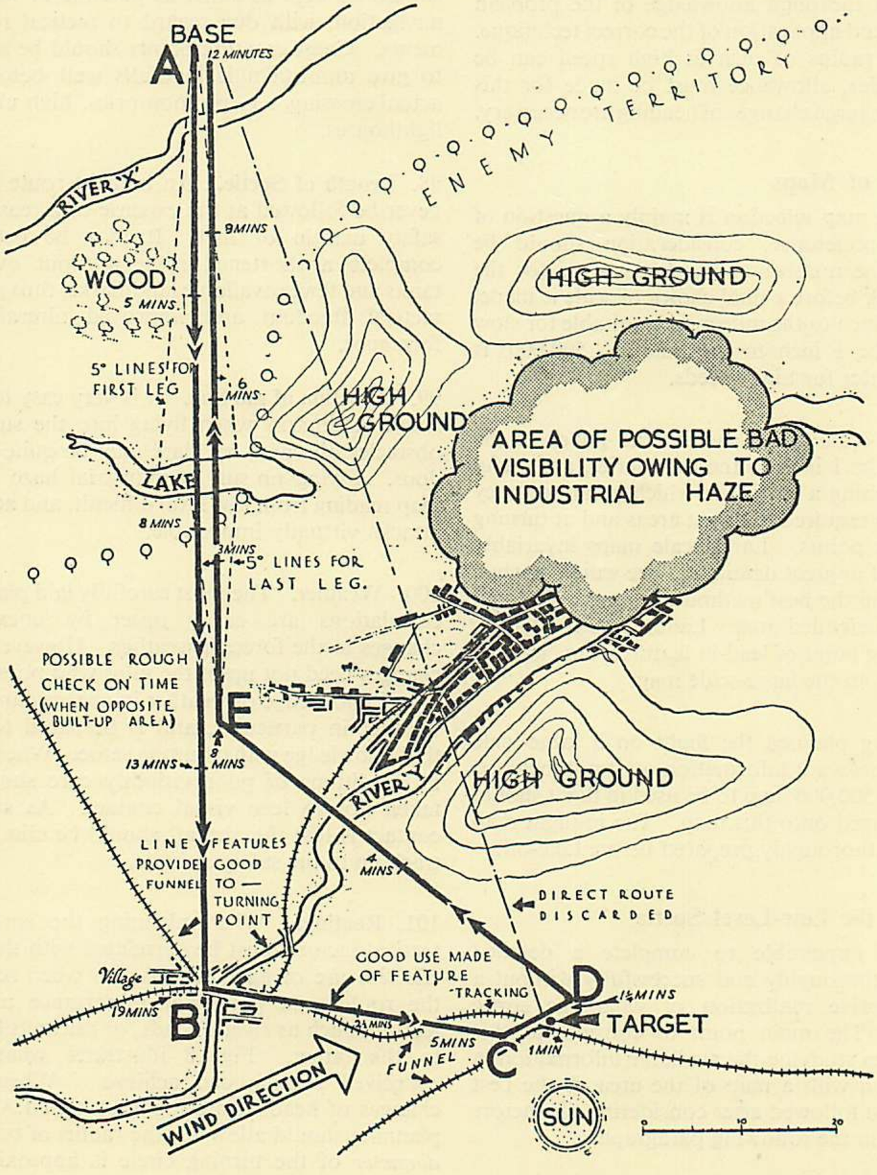


Fig. 8. Example of a Well-Planned Routing

103. Examples of good low-level landmarks are large wooded hills, towns on hillsides, and isolated coal-mines or factories, the slag heaps or chimneys of which rise above the surrounding countryside. Hills and valleys are easily visible from low level and will partly compensate for the reduced field of vision.

104. The number of major pinpoints required depends on the length of the sortie, the speed of the aircraft, and the prevailing weather. A first-class pinpoint every 10 minutes is ideal in good conditions ; but if there is any doubt about the accuracy of the forecast wind, or the visibility at any point, a smaller time interval is advisable.

105. The pilot navigator should never orbit to look for features, as this upsets the carefully prepared flight plan and time scales. If tactical factors allow, however, a climb to several hundred feet just before the E.T.A. at the next check feature increases the range and field of vision. This course is recommended when uncertain of position in the early stages of a sortie, but tactical considerations may preclude it over enemy territory.

106. Finally, although it is impossible to maintain a constant heading and airspeed at low level, the experienced pilot navigator averages the errors introduced by detours round obstacles, etc., by applying equal corrections in the opposite sense (see paras. 49 to 52) and will amend his E.T.A. or airspeed by comparison of planned and actual times of arrival over check features.

Feature Tracking

107. While D.R. is the usual basis of air navigation, its inaccuracies at low level can be largely overcome by resorting to the technique of feature tracking. The fundamental principle of this method is the use of topographical line features (railways, roads, rivers, coastlines, mountains, valleys, etc.) to provide a continuous and accurate indication of track, thus permitting an exact approach to points on or near the line feature. Line features should be close to the desired track and easily recognizable.

108. **Funnels.** When two such line features intersect they are said to constitute a funnel, which is of great importance to the pilot flying by D.R., as track errors can be corrected by flying into a funnel until one of the line features is reached. This can then be followed to the destination or check point. Fig. 8 also illustrates this technique.

HIGH-LEVEL PILOT NAVIGATION

Introduction

109. Some additional factors to consider when navigating at high level are :—

(*a*) The difficulty of predicting high-level winds accurately.

(*b*) Navigation in prolonged climbs and descents.

(*c*) Map reading may be restricted by cloud.

(*d*) The altered perspective for map reading.

(*e*) The increased range of radio aids.

Selection of Maps and Charts

110. For high-level map reading a scale of 1 / 1,000,000 is recommended as a practical scale as the need for detail on a map diminishes with increased height.

Selection of Ground Features

111. It is not proposed to list all landmarks but rather to give an order of usefulness for normal flying at high altitudes. This is usually as follows :—

(*a*) Coastlines.

(*b*) Lakes and estuaries.

(*c*) Large rivers and canals.

(*d*) Main roads.

(*e*) Large towns.

(*f*) Railways.

(*g*) Small towns.

High-Altitude Navigation Technique

112. The climb is started at a convenient point near the aerodrome. During the climb a pinpoint may be obtained as a rough check on the correct heading. As soon as possible after levelling out the pilot navigator should pinpoint his position to check the progress made during the climb. As for navigation at any other level, the aim is to obtain reliable checks on track and ground speed at suitable flight intervals.

Map Reading

113. Map reading in clear weather is much simpler from high altitude than from low level owing to the improved field of view and range of visibility. Ground features are seen in plan as on

a map; they are more easily recognized individually and the patterns they form with other ground features are helpful.

114. While map reading is simplified, pinpointing becomes more of a problem, because it is difficult to determine the true vertical from aircraft to ground and downward vision may be severely limited. The position at any moment can be established in either of the following ways:—

(*a*) By judging the bearing and distance from a ground feature to one side of the aircraft.

(*b*) By observing the proportionate distances of the aircraft from two recognized features, one on each side of the aircraft.

115. In the first procedure, the judgment of distance may be developed by estimating the distance between two ground features and then checking the estimate against the actual distance measured on a map. With practice, distances can be estimated visually with sufficient accuracy. With the map correctly orientated the bearing of the aircraft from the check feature can be easily estimated.

116. The second method is based on similar principles except that with two ground features appearing simultaneously, one on each side of the aircraft, distance in terms of miles is unnecessary. The distance from one is interpreted as a proportion of the other, and the fix is then located between those check features on the map in the same proportion.

117. The awkwardness of pinpointing can be avoided by selecting line features which run parallel to the track or at right angles to it. Long line features are easily seen from directly above; and by their relative direction along or at right angles to the track serve as a check on track or ground speed respectively. The fact that track and ground speed are not assessed simultaneously, as they are with the pinpoint, does not detract from the value of this technique.

CONSIDERATIONS OF HIGH-SPEED NAVIGATION

Principal Considerations

118. While the basic navigational calculations remain the same for any flight speed, it is interesting to analyse the possible influence of high speed on pilot navigation technique. Increased airspeed may be considered in two ways:—

(*a*) For a given time, the distance travelled will be greater.

(*b*) For a given distance, the time of flight will be less.

119. The need for accurate steering becomes apparent, for any deviation from heading will result in a larger displacement from track than would have been the case at a lower airspeed, and allowance must also be made for the distance covered in turns as the radii of turns are greater.

120. Fractions of minutes must now appear in E.T.As. and allowance must be made for turning radii, otherwise the aircraft may not come within visual range of the required ground position. Visibility and the speed of human reaction must be given full consideration in establishing the safety factors of a low-level sortie.

121. At high speed, variation in airspeed has less effect on the resulting ground position or E.T.A. A 5-kt. error in airspeed over a distance of 300 miles flown at 200 kts. causes an error of about 7 miles in ground position, or an error of 2½ minutes in flight time. At 600 kts., the same airspeed error results in errors of only 2½ miles in position or 15 seconds in E.T.A.

122. Wind effect also decreases with an increase in airspeed, as the time in which it can influence the flight is reduced. A 50-kt. wind, at an airspeed of 200 kts. can produce a maximum drift of 14½° and vary the still-air flight time for a 300-mile distance from 18 minutes less to 30 minutes more. At airspeeds of 600 kts. the same wind produces a 5° drift, and varies the still-air flight time by only 2½ minutes. Aircraft capable of 600-kt. airspeeds usually operate at altitudes where winds are generally stronger and less predictable than those encountered by the 200-kt. aircraft. Any tendency to minimize the effect of wind on high-speed aircraft is therefore unwise until more is learned of the upper air.

123. In general, flying and navigating an aircraft requires greater skill as speeds increase; wind errors decrease but steering errors increase; and although wind and airspeed errors result in smaller variations in E.T.A., seconds must now be considered. Finally, the pilot navigator's attention must be divided between flying and navigating in unequal proportions, because the

time required for accurate flying is likely to increase. Consequently, efficiency in navigation must be maintained by complete familiarity with the application of mental D.R. calculations augmented wherever possible by accurate and thorough pre-flight planning.

124. Track keeping can frequently be assisted by careful routing as in the case of low-level navigation.

PROCEDURE WHEN UNCERTAIN OF POSITION

Introduction

125. The procedure to be adopted by the pilot navigator when he is uncertain of his position cannot be laid down as a series of hard-and-fast rules. It varies in each individual case.

126. A pilot who has two-way communication with the ground should, if at all uncertain of his position, make full use of available D/F and fixing facilities **before it is too late for assistance to be given.**

No V.H.F. Contact Available

127. Occasion may arise when V.H.F. contact cannot be made and, in the absence of other radio facilities, the pilot is unable to fix himself by reference to the ground.

128. The subsequent action depends on numerous factors including weather, terrain, the type and endurance of the aircraft, always bearing in mind the primary aim, which is :

"The successful completion of the mission or, failing this, the landing of the aircraft".

129. In general the following guiding principles prevail :—

(*a*) *Safety*. Check :—
- (i) Safety altitude.
- (ii) Fuel remaining.

(*b*) *Why Lost?* Check :—
- (i) Compass reading.
- (ii) I.A.S.
- (iii) Wind velocity (if possible).
- (iv) Operation of watch.
- (v) Previous log entries.

(*c*) *Action*. Two examples of action which might be taken under differing circumstances are given in paras. 130 and 131.

Lost, No Visual Contact Established Without Going Below Safety Altitude

130. Depending on the prevailing weather, locality, and remaining fuel, fly for range towards the most suitable area for descent (generally over the sea), and when within this area descend to the minimum safe altitude. The E.T.A. at this area should be calculated depending on the D.R. error since the last fix (see paras. 68 to 73). If contact is established when over the sea fly back towards the coast. If minimum safe altitude is reached without making contact, climb to the safety altitude and, making allowance for D.R. error, fly to an area suitable for abandoning the aircraft.

Lost, In Visual Contact with Ground, and Likely to Remain in Contact

131. Fly for endurance. Turn towards the nearest unique line feature. Review the D.R. position by taking into account all factors which may have affected it. On the way to the line feature attempt to fix position by map reading, using the techniques described in paras. 68 and 69. When position is established decide whether destination or diversion airfield is within range.

132. **It is essential to allow sufficient time for the procedure to have a reasonable chance of completion, and action must never in any circumstance be delayed.**