Royal Institute of Navigation
Land Air Sea Space

THE GUILD OF AIR PILOTS AND AIR NAVIGATORS

VISUAL NAVIGATION TECHNIQUES FOR PILOTS

G-ANG

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FOREWORD

In the modern world, almost every human being can expect to travel considerable distances during the course of his or her life. While many are content to rely on others taking them where they want to go (navigating), an increasing number do it themselves, often with the help of modern technology.

The Royal Institute of Navigation since its inception has aimed to improve the standards of navigation on land, sea and in the air. While airborne navigation relied on traditional maritime methods of observation and calculation, specialist navigators were required in aircraft, especially those carrying passengers commercially. However, as actually flying the aircraft became simpler, mapping improved and technology developed, pilots were able to take on the navigation responsibility themselves and become professional navigators. Those who use an aircraft for pleasure or business are also navigators.

Traditional methods provide safe navigation over areas of the world which lack modern ground facilities (satellite navigation systems are not infallible). However, the increasing complexity of airspace over the United Kingdom has meant that many of these traditional methods have become unsuitable for practical navigation in this country. Although many experienced pilots have developed their own ways of navigating light aircraft satisfactorily, the Institute felt that there was a need for some guidance on simple techniques which pilot navigators can employ to minimise risk and maximise enjoyment in the air. Its General Aviation Navigation Group has therefore produced this guide, which draws on experience from many sources and is aimed at those pilots who are setting out to be navigators. It is therefore also aimed at flying instructors, in the hope that they will pass on these techniques to their students.

This booklet is only concerned with the techniques required for following a planned track over the ground. Although it touches on the application of various matters usually referred to as 'airmanship', readers are advised to refer to other documents, such as Pooley's PPL guide on 'Navigation', for further guidance on integrating that essential subject into their aerial navigation.

We are grateful to the Guild of Air Pilots and Air Navigators, whose instructor committee have contributed to the content, and who have assisted generously with the production costs. We also thank Flyer magazine for their help in distribution.

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CHAPTER 1

BASIC NAVIGATION TECHNIQUE

1.1 A circuit analogy

When flying in the circuit, we are navigating our way round the circuit pattern. When navigating round the circuit, some pilots aim to fly over certain points on the ground. For example; "On runway 27 I turn onto the downwind leg when I reach the main road. I roll out pointing at the left end of the lake. When I pass the farmhouse with the red roof, I turn onto base leg, aiming to turn final over the line of trees".

If the runway (or the aerodrome) changes, a whole new set of ground features must be learnt. This is exceedingly time-consuming, and pilots must be able to fly a standard circuit pattern for any runway they need to use, at any aerodrome. That means they cannot memorise all the possible places where they may wish to change their direction; - they learn to start from a known point (the runway) and fly calculated headings, using a known feature (the runway) to decide if and when to change the heading.

For example, on runway 27:
"The wind is 300/15. I shall climb straight ahead, pointing right to stop drift (*1* - maybe 275 degrees), turn left onto a crosswind heading right of South (*2* - 190°?) to stop me drifting. When the runway threshold is in my eight o'clock I shall turn downwind on a heading left of east (*3* - 085°?). As I fly downwind, the runway should be just inside the wingtip. I can adjust my heading to get to that distance out. When the threshold reaches my eight o'clock in this wind I shall turn onto a base leg heading left of North (*4* - 350°?). Just before lining up with the runway direction I shall turn onto final allowing for drift from the right (*5* - 275° again?)."

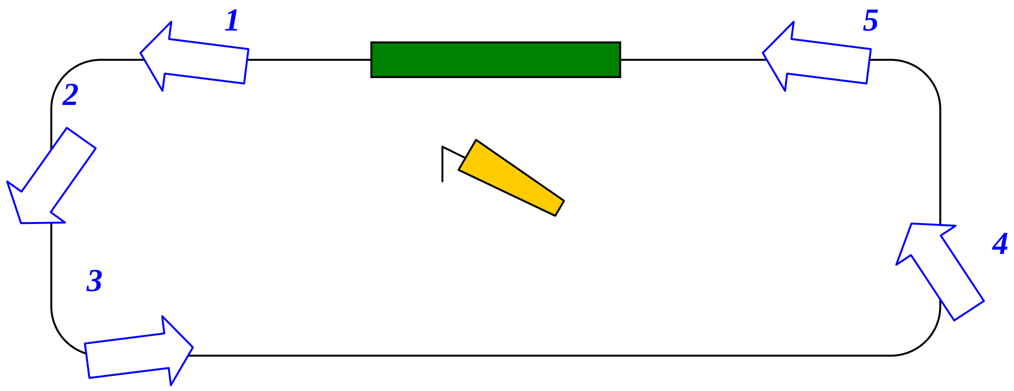


Figure 1.1 - the circuit pattern

Either technique could be used in any form of navigation, not just in the circuit. The first method involves a great deal of pre-flight map study. Although it can work when flying on a planned route, weather or other factors can force a pilot to go somewhere he had not previously planned, and something akin to the second circuit method must be used during an unplanned diversion, because the pilot has very little time available to study. More importantly, he should be looking outside, not at his map!

1.2 General navigation

Let us expand on the circuit pattern explained above where the pilot started from a known point (the runway threshold from which he took off). Starting from a known point is the first principle of navigation.

After setting off, we must fly a steady heading, adjusted to prevent the wind drifting us away from where we want to go (our intended track). We use features which we can recognise (the runway threshold), to indicate when we must turn. We use features which we can recognise (the runway beside us) to decide if our heading is correct. When we have no reference, or no time to use it (pre-landing checks) we fly a steady heading. If we know our reference (runway) will become invisible (a right hand circuit perhaps) we can look ahead for other ground features to refer to while we can still see that original reference, or we can turn a given time after losing sight of it. We end up where we want to be, on final with the runway in front of us.

The same applies in general navigation. We start from a known point, and fly a calculated heading until the next known feature appears. We compare our position with what it should be, and adjust. We then fly that calculated heading until the next known reference appears, and we fly to put ourselves in the correct place relative to that. It is a continuous process, but it consists of a series of steady headings interspersed with actions relative to a known feature (or fix point).

As detailed later, the map must be studied, but mainly to recognise the fix (reference) points which the pilot will use. These must be recognised from the air (and from a considerable distance, as we shall see). Other features need not be memorised, although we should have a general idea of the area to be flown over.

The pilot should set up a "work cycle" of; 'FIX POINT ACTION - FLY STRAIGHT AND LEVEL - CHECKS - FLY STRAIGHT AND LEVEL - RADIO CALL (OR OTHER ACTION) - FLY STRAIGHT AND LEVEL - FIX POINT ACTION'. Such a work cycle should allow the pilot to keep a good lookout, only glancing inside the cockpit for short periods to check items of information rather than study them.

1.3 Map reading

Map reading (or to be precise, map interpretation) requires practical teaching and quite a bit of practice. These notes are not intended to replace that practical work, but as hints to make that work easier.

The air above the UK usually contains cloud to a greater or lesser extent. Private pilots do not normally want to fly above the cloud, so the height we fly above ground is not usually very great. The actual cloud base must be high enough to allow us to fly safely and legally above the ground along our route, but pilots seldom elect to fly higher than about 2 to 3 thousand feet above ground level.

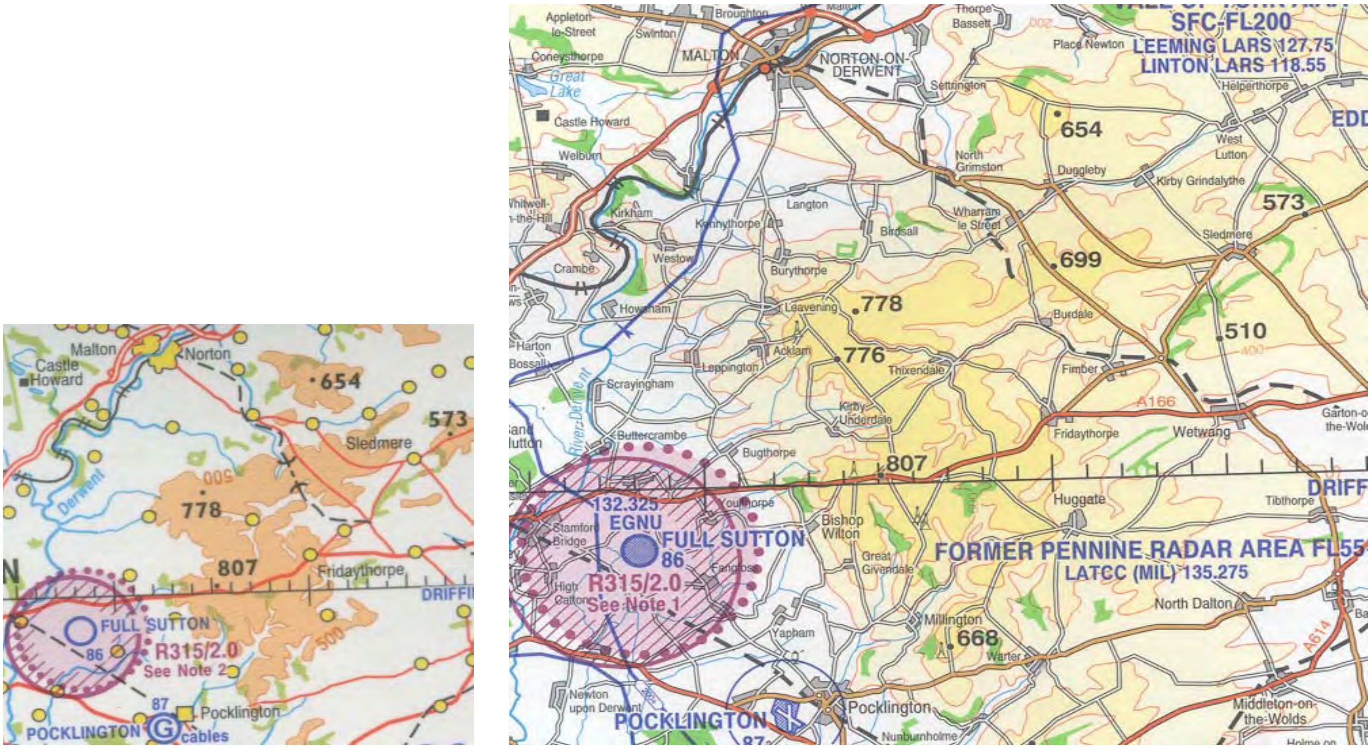
A map is a representation of the ground, presented on a flat surface. The ground is not flat, and neither are the features on it, so a pilot must learn to imagine the features marked on the map in 3 dimensions. That is the way they will appear to him, because the aircraft itself nearly always blocks his view straight down, and in any case he really wants to see his fix point far enough ahead to use it as a reference. From 2000 feet, he will be looking downwards only at an angle of about 4 degrees to see a fix point 5 miles away. Most of the objects he will be able to see will be those which have vertical extent (those which stick up).

Figure 1.2 Vertical feature

On the 1:250,000 chart, the airspace information provided is limited to that affecting flight below an altitude of 5000 feet, although the detail is much greater than on a 1:500,000 chart (for example, power cables are marked). We concentrate here on the half-million chart, but if you are sure you will remain at lowaltitude, a quarter-million may be more suitable, especially at low airspeeds and, for chart folding considerations, over relatively short distances. Figure 1.3 shows the same area on both charts.

1.4 Map interpretation

The first part of the map to interpret is the shape of the ground. This can be deduced by studying the pattern of the contour lines in conjunction with layer tinting and spot heights. For example, on a 1:500,000 chart, a small patch of brown in an area of white, with a spot height of 700 feet in the middle of it, can be interpreted as a small hill rising at least 200 feet above the surrounding ground. However, care must be taken in interpretation; if the spot height is marked as 505 feet, it is possible that the ground rises very shallowly in the area, and may not be visible as a hill at all.



1:500,000 chart   1:250,000 chart

Figure 1.3 Ground elevation

The increased number of different tints and contour lines on the 1:250,000 chart can be seen in figure 1.3 and are usually considered to make it easier to interpret ground shape. Because of that, and the increased general detail, many consider such a chart easier for route study, even if they do not always use it in the air.

Rivers are very useful to help interpret ground shapes. They always flow through the lowest ground in the area, so a river in ground with contour lines marked usually indicates a valley in the same direction. Rivers flow towards even lower ground, so the general lie of the land can often be deduced from the direction of the rivers. In figure 1.2, there is a railway tunnel shown on the 1:500,000 through some high ground. That is another indication of steeply rising ground; engineers are reluctant to drill tunnels unless they have to.

Any flat feature on ground sloping upwards as the pilot looks at it will be much easier to see than the same feature on ground sloping away from him. For example, the wood marked in figure 1.4 would be easy to see if approaching from the North, but difficult to identify if approaching from the South (the contour line which lies at the Southwest corner of the wood must be 1500 ft amsl because the tint does not change).

Line features such as roads, railways and rivers are easier to see when looking almost along them than when they cross one's track. This is especially true if they are in a valley. For example, if flying in a NorthEasterly direction, the river, railway and road passing through Sanquar in fig 1.4 would be much more difficult to see than if the aircraft were approaching them heading West or NorthWest.

A useful exercise is to look at an area on the map and practise interpreting the shape of the ground. Having studied the map on the ground, fly to the area on a good day and check the accuracy of one's interpretation.

Figure 1.4 Sloping ground

1.5 Fix planning

The UK contains many features which can be used as “fix points”. In fact, pilots trained overseas are often rather overwhelmed by the number of features available.
However, a “fix:

1. must be visible from flying height. A transmission mast might be obvious against the sky from low altitudes, but not when high above it. Line features may be hidden by high ground.
2. must be unique. That does not mean it must be the only road or railway or town in the area, but the pilot must have studied it and its surroundings beforehand to make sure he is not misled by other roads, railways etc which might be confused with the chosen fix.

Always work from large to small during fix selection and study. For example:

- “A large town - 3 miles to the right of it a lake with a dam on the right of it - just left of the lake a railway line going towards my 11 o’clock - 2 miles beyond the lake a dual carriageway crossing 9 o’clock to 3 o’clock - the bridge where the dual carriageway crosses the railway is the fix”

Good route study involves imagining yourself flying towards the fix. For example:

- “I fly right of the large town, left of the lake, follow the railway with my eyes to the dual carriageway bridge - position the aircraft over that pointing on heading”

Mark your chosen fixes in a convenient way, ideally at intervals of about 6 minutes flying time. More than 8 minutes allows time for errors to build up, less than 4 minutes gives little time for looking out. As in figure 1.5, some pilots draw ellipses (ovals) around them, others draw lines across track leaving gaps.

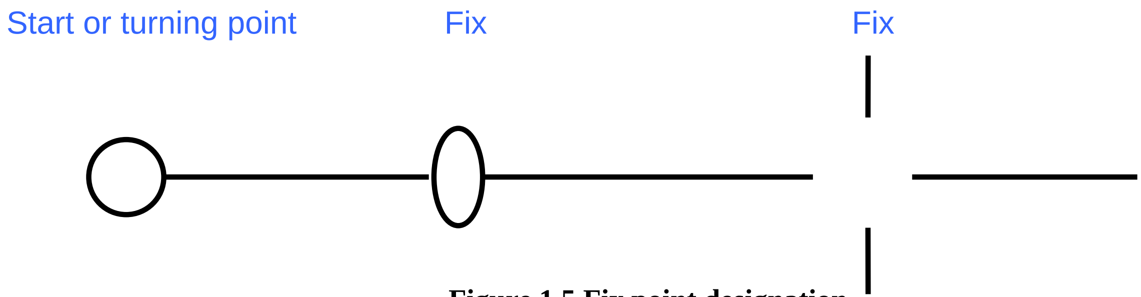


Figure 1.5 Fix point designation

1.6 Route planning

The shortest distance between two points is a straight line. The shortest distance on the surface of the earth is actually a great circle, but within the UK we can draw a straight line on a chart and that equates pretty well to the great circle. When planning to fly, we know our start point and our intended destination, so it should be a simple matter to draw a straight line on the map which joins these points and then fly along it.

However, several factors can make such a simple straight line less than ideal. It may not pass over many obvious features which could be used for fix points. It may pass over areas over which we do not wish to fly (large built up areas or inhospitable terrain for example). It may pass through, or very close to, controlled or restricted airspace, and weather phenomena such as low cloud over hills may cause problems on the direct route. Finally, we may want interesting views while flying.

The planned route should be a compromise between two considerations. We want to minimise the distance flown (therefore time, and fuel used), but we also need to minimise the effort required for navigation.

The altitude we plan to fly is important. In general, in a single-engined aircraft, we should always be able to select and glide to a safe landing area if we have engine problems. That usually means that the legal minima of 500 feet away from possible human activity or 1000 feet above the smallest built up ‘congested’ areas (for those of us who may fly over them) are unlikely to be sufficient. How much height above ground do *you* need for a forced landing pattern? We might consider an altitude which gives at least 2000 feet clearance above most of the ground and 1500 feet above any particularly high points to be adequate.

A clear plastic ruler placed on the map between our start point and destination, as if we were about to draw a straight line, allows us to make some initial assessments. We can see the ground elevations in the general area and choose a suitable cruising altitude. We can then look along the ruler’s edge at the direct route.

Does this cross or pass close to (we cannot guarantee that we shall follow our track exactly) controlled or restricted area boundaries, aerodrome traffic zones, parachuting or gliding sites or other airfields? If so, can we fly over, under or through these areas at our planned altitude? Is there a safe margin for error? If not, we should split the route into sections or “legs” with one or more turning points between them. We should choose an obvious fix point as the turning point and study each leg individually.

Does the direct route take us over areas where it would be difficult to land in an emergency (for example a large unbroken stretch of woodland)? Again we may need to choose one or more turning points before selecting the actual route we plan to fly.
Route planning can be done well in advance of the actual flight, when wind direction and runways in use are unknown. Although it is perhaps easy to plan to fly from one aerodrome “overhead” to another, accurate navigation would require us to climb to cruising altitude (following the circuit pattern as we climb) then set heading from that overhead. To reduce time and fuel, we may wish to choose a suitable fix point in the general direction of our first track which we can see (and keep in sight) while climbing from whichever runway is in use at the time, and start navigation proper from there.

Place the ruler between this start point to either the first turning point or the destination overhead (a standard join is always advisable at a new aerodrome, but follow whatever procedure is published). The line of the ruler is the intended track. Look along the track and note whether suitable fix points are available at around 6 minute intervals (ideally dividing the track into halves, thirds or quarters). If not, consider changing the previously selected turning points or insert an additional one to make things easier.

Mark suitable fix points, perhaps as in fig 1.5. Draw a line on the map to join the start and end point of the leg. Use a pencil on a paper chart, or a washable pen on one covered with plastic. You can make the lines permanent later. Leave gaps in the line over the fix points and any other obvious major features. If the track passes along a line feature, leave a gap which allows you to see it, as in figure 1.6. Finally look at the map to identify a major feature which will confirm you are going approximately the right way after every turn. In figure 1.6 the coast line to the left, as marked, would make an excellent such "confidence feature".

Figure 1.6 Leg planning

Detailed planning can be done using a navigation computer, either traditional "whiz-wheel" or electronic. However, with practice, the dead reckoning techniques described in chapter 3 can also provide quite accurate figures. Whether you use computer or dead reckoning for planning, use the other as a check.

Once detailed planning is complete on the day, place small marks along the legs at intervals of one or two minutes flying time from the start of each leg. Calculate the heading and time you expect to take from take-off to your start point, because many pilots have mis-identified that point. Calculate the headings and times from the previous turn you expect to arrive over each fix point, and write these down (but do not be too exact – the nearest half minute is usually accurate enough). Also calculate timings to the boundaries of any controlled airspace you intend to fly through.

1.7 The navigation log

The essentials for safe navigation are a map, a compass, and a clock. However, some form of written plan is also needed to assist in calculations and to record them for use in the future (most trips are initially planned several days in advance). It is used to record information which you might need during the flight, such as radio frequencies, and to record any important information received during the flight, such as an air traffic clearance. It is also useful to keep a record of what actually happened in flight, especially if you change your original plan, or become unsure of your position.

The navigation log shown at figure 1.7 contains all the essential information as well as many other useful items, but many other versions are available.

Items such as leg tracks, distances, safe and planned altitudes, TAS, magnetic variation and fuel consumption can be measured or calculated and listed on the log. Pilots can use one line for each leg, but one line for each fix point allows easier reference in flight. Other information such as radio frequencies and navigation aid details can also be included well in advance of the flight, as can the altimeter setting regions whose pressure settings may be used.

Flight Log

Taxi	Takeoff	Set Hdg	Land	Chocks

From	To	alt	safe alt	TAS	W/V	Trk T	drift	Hdg T	Var	Hdg M	G/S	Dist	Time	fuel use	fuel rem	ETA	ATA
											Tot						

Alternate

Station	Freq	SSR Code	Pressure setting

Clearances

navaid ident	Freq	P R	QDR/ range	Time

Figure 1.7 Navigation log

On the day of the flight, the winds and other weather information can be written down and used to calculate the IAS and headings required, and also the groundspeeds, which can in turn be used to find times and fuel used. Before take-off, we can copy down any airfield information and departure clearance onto the log, and also the regional pressure settings.

In flight, we can refer to the log before and after each of our turning points, and when amending headings and ETAs. We can also log the actual times at turning points and fixes, as well as any allocated transponder codes and radio frequencies. Any radio aid position lines or fixes can also be recorded.

1.8 Log on chart

Although some form of navigation log is important, many pilots choose to write much of the information contained in it on the map itself to reduce cockpit clutter, especially important in an open cockpit. A soft pencil is ideal for writing on paper charts, but if the chart is laminated with clear plastic, grease pencils (sharp ones) or special pens are required.

At the start of each leg, you may wish to write all the information needed for the routine checks you will carry out. A box containing the information, and a reminder to start the clock, may be placed alongside the track itself at sufficient distance to allow all necessary map features to be read.

In-flight information can be written on the chart as it happens or is passed to the pilot, but the map becomes cluttered and the information difficult to decipher. You might prefer to use a log form in flight for recording information, even if you duplicate the planning information on the map.

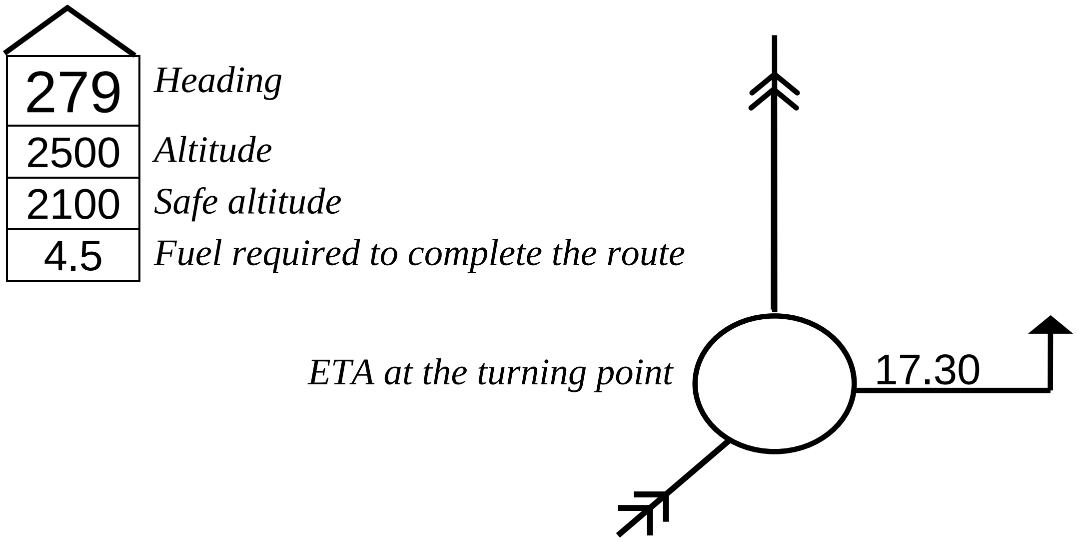


Figure 1.8 Turning point

1.9 GPS information

If you are fortunate enough to have a satellite navigation system available, part of the pre-flight planning should involve loading the route, including fix points, in the GPS receiver's memory. You should check you have done this properly by 'running' the route if you can in the receiver's simulator mode, and/or checking it on the map display against your chart. Some sets may have a selectable alert function which can advise you when your next waypoint (fix point) is a certain distance or time ahead.

If your route takes you into controlled airspace which might require ATC clearance, or over high ground which might be a problem in poor weather, plan a route around these possible problems. Most GPS receivers allow you to bypass unwanted waypoints in flight by selecting GO-TO a waypoint further ahead in the flight planned route.

Most GPS receivers include a navigation computer function, useful for the detailed planning. Do not forget to check the resulting figures using dead reckoning as described in chapter 3.

Airspace databases rapidly become out-of date, although many pilots continue to use them as the basis of their GPS display. Things will have changed, and even those supposedly current may have errors, so always check your route against a current ICAO chart. Although it is tempting to cut corners and allow your GPS to do all the work for you, remember the satellite navigation system itself may suffer interference, so always do your normal planning first.

CHAPTER 2

EN-ROUTE TECHNIQUES

2.1 Introduction

Accurate planning makes navigation easy; there should be little need to make major changes in the air. However, planning errors, weather changes and flying inaccuracies will often force you to alter your headings and timings to a certain extent from those originally planned.

Your navigation log contains your plan, and you can follow that plan by referring to the log in the air. If you are able to fly the plan without any alteration you need write nothing more. However, it is advisable to write down any changes you make with the time you made them. Use the log (or the chart) for that.

2.2 Looking ahead

The reason for selecting fix points is to maximise the time available for looking outside the cockpit. You should have calculated and noted the times at which you expect to reach each fix point. You want to be looking for each fix (or a “lead-in feature”) as soon as it becomes visible, so you should remind yourself of what you expect it to look like (by lifting the map into your field of view) soon after you set heading from the previous fix. Then, while looking ahead for weather (note the cloud just above the horizon in figure 2.1) and other aircraft, you will recognise it when it appears. Remembering it will hopefully appear in front of you, but at an angle downwards, you need to start looking in earnest about 2 minutes before you reach it (6-8 kilometres at most light aircraft speeds), so that is probably a suitable time to remind yourself again, although in good visibility you may want to be looking earlier. If the fix was loaded into a GPS set, you may have been able to set it up to warn you 3-4 miles in advance. In any case, the GPS can direct your eyes in the correct direction.

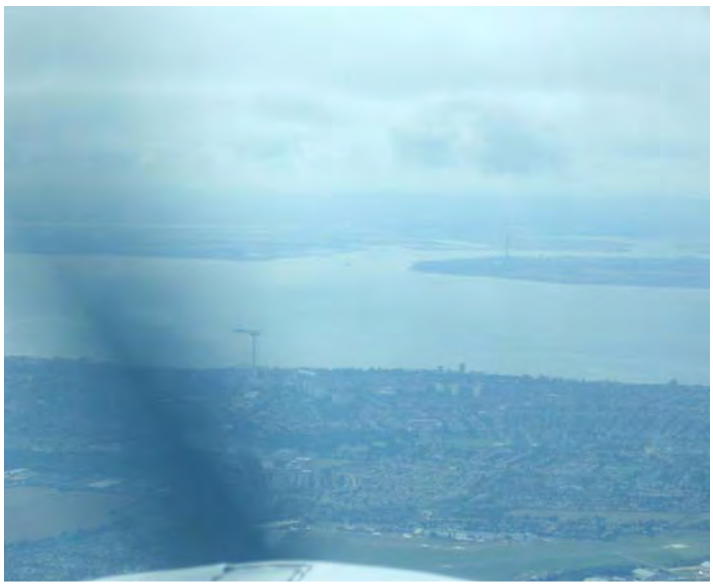


Figure 2.1 Fix point ahead

2.3 Timing Corrections

On a long leg, you will have planned several fix points which you expect to pass over at particular times. Ideally these will be easily seen from a distance before you get to them, and you will be able to adjust your heading to fly over them. You do however, want to know how the timing is going. You may need to inform ATC of any changes to your ETA, but more importantly you need to know when the next fix point will turn up so that you can see it in time!

In an ideal plan, your fixes should be at more or less equal distances along the leg, for example dividing it into quarters. That means if you started the leg at a known time, and are a certain time late at the first fix, you will be twice that time late at the second fix, three times that late at the third fix, and four times that late at the end of the leg, as in figure 2.2. You will have a “cumulative error”. Different proportions produce similar calculations. **Pre-flight planning** should include considering these calculations.

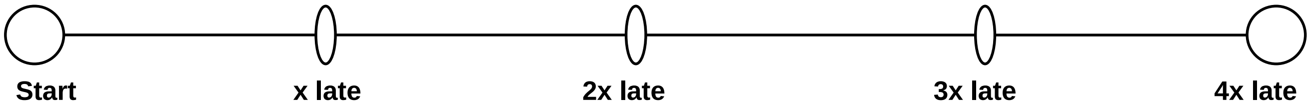


Figure 2.2 Proportional fixes

There may be times when the leg is not suitable for such proportional division, in which case you may need to use more complex mental arithmetic; for example if you arrived at a fix point at 7 minutes instead of the planned 6½ minutes (30 seconds late), then you will be 45 seconds late at a planned 10½ minute fix point, or 55 seconds late at a planned 12 minute fix point. Again you should have **planned** such calculations beforehand. However, it is not a good idea to try to calculate more accurately than the nearest half minute. In the above example, half a minute late at the first fix means you should expect to be a minute late at the next fix and a minute late at the third one.

Hopefully, you will arrive at a fix close to the time you planned. However, if you need to amend the times you expect to arrive at future fixes, it is most important to **look at the clock carefully** and **write down** your time at the fix **immediately** you get there and **before** you start any calculations**.** Pilots may upset ATC if they do not pass accurate ETAs, but they **get lost** if they make the calculations backwards - for example thinking they are late when they are actually early! ETA amendment is not a high priority; flying comes first and navigation second.

As you continue to fly along the leg, you may find you need to make further corrections. In the case of proportional fixes, quarters become thirds and thirds become halves. In the less than ideal case, corrections become more complicated, but should be smaller. Again it is important to read the clock carefully and write before calculating.

A final word on timing. Many pilots have forgotten to start the timing clock at the start of the leg. The natural reaction is to switch it on as soon as you notice. Restrain yourself. You should have put timing marks at one or two minutes spacing along your leg. Sacrifice some flying accuracy to decide exactly when you are passing one of these minute marks, and start the clock then, as in figure 2.3. Then write down in an obvious place at what timing mark you started the clock. If you cannot find a ground feature, add the timing mark to the last ETA for your last turn point and start then.

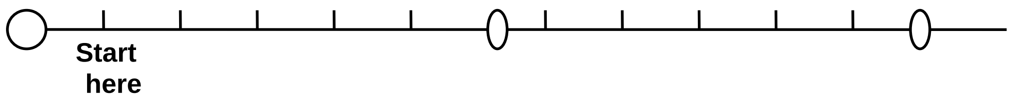


Figure 2.3 Timing marks and missed clock starting

If you cannot do this easily, then any timing error at the first fix must be assumed to be a "once only" error and if for example you are 1 minute early at the first fix, you must assume that you will be one minute early at the next fix and at all subsequent fixes. Only if you can be sure of an exact start time can you use the "cumulative error" techniques.

2.4 Heading corrections

Some corrections will be due to incorrect planning, incorrect wind estimation, or an inaccurate compass. These are "cumulative errors" because they will continue to take you away from your planned track and should be compensated for. Many corrections, however, will be forced on you by inaccurate flying. These are "once only errors", and should be ignored once you have returned to planned track. Knowing which are "cumulative" and which "once only" is important. Always admit to your flying inaccuracies, and try to improve.

Here is a hint. When you know where you are, say out loud "I am **left** of track so I must turn **right**" (for example). Leave the heading bug (if you have one) on your original heading until you have made the calculations, then look at your position again, say the words again, and turn the heading bug the way you decided to turn the aircraft.

2.5 The one-in-60 rule

This 'rule', when combined with the other techniques, provides a way of making accurate heading corrections. The name derives from the fact that at fairly small angles (less than 40 degrees or so), if the aircraft travels for a distance of 60 units then the number of units it has travelled sideways is approximately the same as the number of degrees between the "planned track" and the "track made good". It works because in mathematical terms the sine of a small angle is approximately 1/60 of the number of degrees in that angle. In figure 2.4, the angle of 1 degree has produced a "distance off" of 1 mile after a "distance gone" of 60 miles. If the angle were 5°, the "distance off" would be 5 miles.

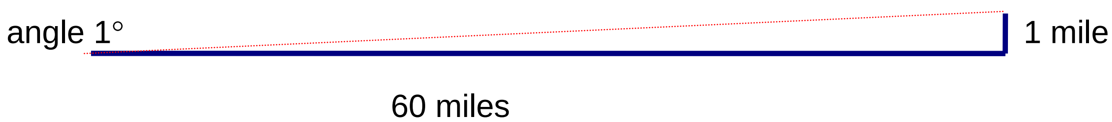


Figure 2.4 The basis of the 1 in 60 rule

The rule can be used in reverse. If we have travelled 60 miles, and are 4 miles off track, we have drifted 4 degrees in that direction. If we have travelled 30 nm, and are 3 nm off track, we would be 6 nm off after 60 nm, so have drifted 6 degrees off track.

Practise some 1 in 60 calculations.

Distance off = 3 nm left *(9° left)*	Distance gone = 20 nm	What is the track error?
Distance gone = 90 nm, *(6° left)*	Distance off = 9 nm left	What is the track error?
Distance gone = 30 nm *(2½ nm right)*	Track error is 5° right	How far off track are we?

The formula is: ***"Track error =*** $\frac{\textbf{Distance off}}{\textbf{Distance gone}}$ ***x 60"***

However, understanding the principle leads to fewer mistakes than trying to remember the formula parrot fashion.

2.6 Once-only errors

If your fix point is well chosen, you should see it in plenty of time to fly over it. No further action need be taken. However, you may see it so late that you would need to make a heading change of more than about 30º to overfly it. In that case, continue as planned but note where you were when you passed the fix. You can then adjust your heading to fly to the next fix point, perhaps by using the '1-in-60 rule' or a derivative. For example, if you are 2 miles left of track on a "once only" error, and you have 20 miles to go to the next fix, you should alter heading by 2 x 60 ÷ 20 = 6 degrees to the right. Again, good planning should allow you to **prepare** for such a calculation. Once you see the next fix, hopefully you can fly over it.

Figure 2.5 Missed fix

However, in UK airspace, we seldom have the freedom to remain off track for long. We should return to track as soon as practicable. If we are a mile off track, an alteration of heading by 30 degrees towards that track will return us to it after flying 2 miles. If we are flying at 120 knots groundspeed (2 miles per minute) we shall have reached our original track again in one minute, so pilots who fly with a groundspeed close to 120 knots have a fairly simple way of returning to track: 30 degrees for as many minutes as they are off track. However, for pilots flying at 90 knots, the time required would be 1½ minutes, and if 60 knots, two minutes, neither of which are particularly easy to remember and use.

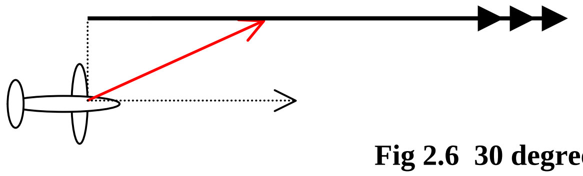


Fig 2.6 30 degree closing

A change in heading of more than 30 degrees is likely to cause major timing problems, so should be avoided. However, a similar derivative of the one-in-sixty rule can be used to return us to track in a particular time, and pilots can find other ways of simplifying the one-in-sixty rule to suit their own taste and cruising speeds.

Here is one possible example. At a groundspeed of 90 knots, 10 degrees heading change would move us one mile closer to track in 4½ minutes. At a groundspeed of 60 knots, it should take 6 minutes. We should remember that we are only really trying to stay within a mile or so of track, with the specific aim of seeing our next fix early enough to fly over it. Pilots of aircraft which fly with groundspeeds between 50 and 100 knots could remember this simplified technique of turning 10 degrees towards track for every mile they find themselves off track, and turning back onto their planned heading after 5 minutes. Since hopefully our fixes have been planned every 6-8 minutes, even if we forget to turn back until we are looking for that next fix we should be able to see it.

2.7 Cumulative errors

Cumulative errors need to be corrected in three stages. First you must remove the error by compensating for it; then you must return to your planned track. Finally, you must alter your heading again to follow that planned track. In fact, the heading for stage 3 will be the same as for stage 1, but most people do not actually fly the stage 1 heading, but combine it with stage 2.

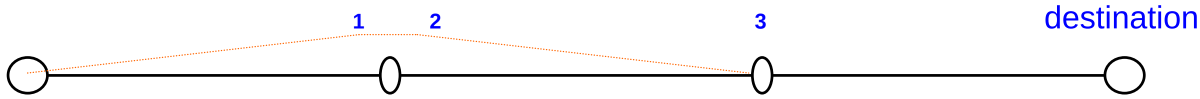


Figure 2.7 Cumulative errors

If your fix points are well chosen and you see the fix in time to fly over it, stage 1 is reduced to a mere calculation to determine the heading for stage 3 - you do not need to fly the corrected headings for stages 1 and 2 because you can return to planned track over the fix itself. However, things are not always that easy.

Stage 1 involves finding out the angular error between your planned track and the track you have actually flown ("track made good"). Again the 1-in-60 rule or a derivative will make life easy. **If you started from the planned start point**, divide the distance you are off track by the distance you have travelled, and multiply by 60 to find the angular error. Turn that amount **towards** track, and you will parallel it. Note this heading; you need it for stage 3.

Many instructors recommend pre-planning for this stage. They will suggest you draw lines at a fixed angle to your planned track, so that you can see at a glance what your track error is (how many degrees you are off track) without making any calculations.

All you need is one error line at a 5º angle on one side of track, and you can "interpolate" any other error angle.

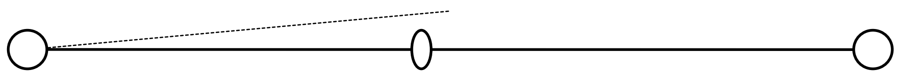


Figure 2.8 Pre-planned angle off

Once you have altered heading to parallel track, you could act as in the once-only paragraph above, and divide the distance off track by the distance you must travel to the next fix, multiply by 60 and alter your stage 1 heading by that amount to find your stage 2 heading. When you see the next fix, or if not, at the time you should be passing it, return to the stage 1 heading for stage 3.

However, if you planned your fix points close to the ideal equal distances along track, you can reduce the calculations at stage 2. Once you have calculated stage 1, just double the change and you will return to planned track at the next fix. Turn back by your original angle off to maintain it.

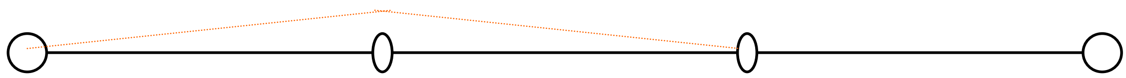


Figure 2.9 Returning to track

Again, some instructors recommend drawing lines at an angle from the end point, or destination, of your leg. A five degree line is again sufficient for interpolation. However, this only works to take you to the end of the leg, so if you have a long leg with many fix points, it may be unnecessary because you should be back on track with a corrected heading long before then.

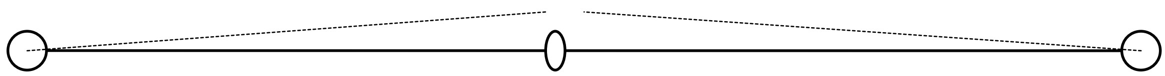


Figure 2.10 Pre-planned angle off and end angle

Arithmetical mistakes are likely to lead to minor inconveniences, but it is very easy to get the numbers right and make your corrections the wrong way. That gets you lost! Unlike timing errors, cumulative heading errors should be compensated for as quickly as practicable, but take the time to be careful. Ideally, you should see your fix early enough to decide your corrected heading before you arrive over it.

If you were unfortunate enough to miss the start point of the leg, or you know you have been inaccurate in your heading keeping in the air, you must treat any errors at the first fix as "once-only" errors.

2.8 Major errors

These are usually the result of some distraction putting you off track, perhaps because you forgot to cross-check information at the last turning point – see paragraph 2.12. Once you realise where you are, use the once only error technique, and all should be well. However, at some time you might have to make a diversion away from your planned track, and more calculations will be needed, as shown in the next chapter.

2.9 Help for the arithmetically challenged

Using the one-in-sixty rule as described earlier should allow you to return to track either at a given time or by the next fix point. However, few private pilots can expect to make arithmetical calculations while flying an aircraft without producing errors in one or the other. Many may just decide "I am left of track, I shall turn right by 20 degrees, wait for a bit then turn back again". At least that brings you closer to your track, and hopefully close enough to see the next fix. While this cannot be considered accurate navigation, better this rough and ready system than to turn an exactly calculated number of degrees for an exactly calculated time but away from track instead of towards it!

The human brain cannot cope with too much work at one time. Do not be afraid to admit to yourself that calculations are becoming difficult, and be prepared to adopt even this simple technique. However, do write down what you did, and when, if at all possible. And remember, if you are looking well ahead and know what you are hoping to see, you may be able to avoid making arithmetical calculations completely.

2.10 Reading map, log and instruments

The 'fix point' technique allows you to spend virtually all your time looking out of the cockpit. When looking to the front you can see that the aircraft is flying level (by the pitch attitude) and straight (towards some object on the horizon – but remember drift). You can also look for the next fix, which you should recognise from your pre-flight planning, and for any possible weather hazards, as well as other aircraft.

When reading the map or your log to remind yourself about information contained on it, lift it up to just below the cockpit coaming so your eyes can drop quickly down to the information required then back up again. Every second spent looking inside allows a jet aeroplane to come 600 yards closer!

When you need to check information from an instrument, especially a clock or a compass, first look around outside the cockpit. While scanning the sky, clear your mind of what you expect to see, then look at the instrument and read the information **out loud**. **Then** look at your plan to see if the information you see is the information you want. Then **cross check** with the other instruments, for example check the DI against the compass. Use other information in the cross-check also; for example the relative position of the sun, and the track indicated on your GPS if you have one.

2.11 Setting heading

Your DI may have a "bug" to indicate planned heading. Before setting a new heading on the DI, the bug will be (hopefully) on the present heading. First, **scan** outside carefully, then **read** the new heading from your map or log. Look at the face of the DI, and turn the bug in the direction of your turn until it lies against the new heading. Then **look** in the direction of your turn to identify a feature which you can roll out on (perhaps your "confidence feature"), and at the same time check for aircraft, weather, and obstructions.

If you are making calculations during the flight, for example during a diversion, which involve applying drift, first set the new track, then turn the bug into wind by the amount of drift, then apply variation.

If your DI does not have a bug, you may be able to use another instrument, such as an RBI or OBS, on which to set your intended heading, using the same technique.

Once you are steady on heading, look for a ground or cloud feature as far directly ahead of you as possible so you can refer to that rather than the DI as you fly along. Remember if the wind is drifting you, you need to be pointing slightly into wind from your chosen point.

2.12 Turns

Get in the habit of making navigation checks every time you turn the aircraft. The simple mnemonic WHAT can be used if coupled with care and common sense. W stands for **weather**, H stands for **heading**, A for **altitude**, and T for **time**. Although the examples below suggest turning at pre-planned turning points, use the checks for **every** turn.

2.12.1 Before the turn

A WHAT check should be carried out as soon as you identify your turning point, or a minute or so before the turn if the point is not in sight. (A GPS set may be set up to warn you that you are approaching the turn waypoint.) ***W*** is the weather around (and behind) you – where is the safest direction to divert if you might need to? ***H*** is the heading you want to turn on to. Use the above technique for setting the new heading. ***A*** is a check of the new altitude - if you can, be level before you turn. Also remind yourself of your minimum safe altitude to complete the leg, or "safety altitude" if you have an instrument qualification and can climb above cloud. ***T*** means note the time you should be over the turning point. Say to yourself something like "I should turn at 22 minutes". If you see the turning point and are sure that it is coming up at the expected time, stop the clock ready for the next leg unless you are employing continuous timing.

If you have seen the turning point, position the aircraft so that you overfly it on the new heading, at the correct altitude. Otherwise, check your ETA and make the turn at that time - do not continue in hope.

2.12.2 At the turn

If you are using continuous timing, you must **note** the time over the turning point and leave the clock alone. However, many pilots will restart timing from the turning point. In that case, the most important action is to actually **start** the clock overhead. The point will of course be hidden at this stage beneath the aircraft structure. That means that when setting your heading you should have looked not only along your new track, but also at features beside your turning point which will be abeam you and visible to you on your new track. Of course, pre-flight planning can ease this job; if the turning point is a junction of line features you can visualise them at the planning stage.

2.12.3 After the turn

Time for another WHAT check.

W means check you have a clear flight path with suitable visibility between any cloud and the ground – otherwise change your plan NOW.

H means read the actual heading. However, you must first make sure you are flying the heading on the bug. Then read it carefully as in paragraph 2.10 above, first checking it against the compass and synchronising if required, then check against the plan, the **sun,** and if available the GPS track.

A means check your actual altitude against the plan - read it, remind yourself of the **minimum flying altitude**, and the **QNH**. If you are forced to fly at a different altitude from the plan, check for controlled airspace ahead. In addition, your TAS will be different. You can adjust IAS to maintain your planned TAS (reduce IAS ideally by 1½ knots per thousand feet, but make it 1 knot every 1000 feet if you have a headwind, 2 knots per thousand feet if you have a tailwind.)

The ***T*** is vital. Check the **clock is running**, log the time you turned if different from planned, and then look at your map or log to see what time the **next** fix point should appear. If the clock is not running, find a suitable place to restart it as in paragraph 8.2, and calculate and note down the time you should arrive at the next fixes. You should then check you are flying towards your "confidence feature", before reminding yourself what the next fix should look like.

Figure 2.11 Confidence feature

A fortunate pilot will have turned onto his new heading early enough to carry out his post-turn WHAT check **before** he actually overflies the turning point. In that case the ***T*** check includes actually starting the clock. Nevertheless, you should do a further complete WHAT check after the turning point is behind you.

Finally, after a careful lookout scan, carry out a routine safety check (FREDAW, FIRA or whatever mnemonic you use).

2.13 The activity cycle

The cycle of activity listed above, over perhaps 6 minutes, can be illustrated in a simplified form as in figure 2.12.

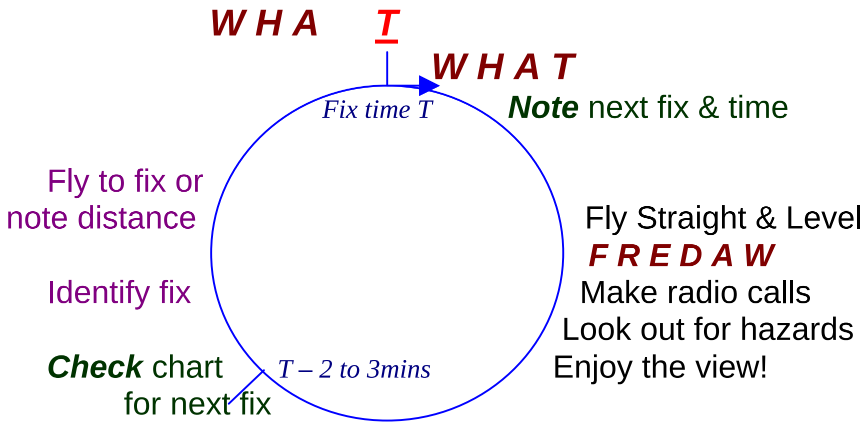


Figure 2.12 Simplified activity cycle

2.13 Operation at minimum level

Pilots of single-engined aircraft are rightly reluctant to fly close to the ground. In the event of engine failure, a certain amount of time is needed to select a field for a forced landing and to set up a safe approach to it. The risk of meeting a fast-moving military low-flying aircraft also increases considerably when closer than 600 feet to the ground, and the chance of receiving a radar (or even a radio) service from ATC is severely reduced.

However, pilots are occasionally forced unexpectedly to avoid cloud, icing, or controlled airspace by flying lower than planned. Apart from factors already mentioned, there are other important considerations.

The priorities in flying are always "1- AVIATE, 2 - **NAVIGATE**, 3 - communicate". The pilot must concentrate on avoiding the ground while flying at a safe airspeed. The horizon may be obscured by high ground, so attitude flying is difficult, and frequent power changes may be needed to maintain the correct airspeed while climbing or descending over undulating ground. Assuming that it is safe to continue between the cloud above and the ground below is dangerous; low level flying can only be safe if the pilot can actually see his clear route at all times. If you cannot see a safe route ahead, consider turning round and returning along the route you have just flown, where the weather should still be suitable. If you can find no clear route, it is safer to carry out a precautionary landing in a field which you can see rather than continue into the unknown.

One possible collision risk has already been mentioned. The danger of meeting other flyers, not only military ones, increases, especially in hilly country. Hang-gliders are found on the windward slopes of hills even when cloud is low. Helicopters work at low heights carrying out pipeline or powerline inspections. Birds also tend to fly closer to the ground than most aeroplane pilots are used to; they are difficult to see and avoid, and may cause considerable damage to an aircraft.

Another risk is that of colliding with the ground or obstructions on it. Fly at a height which is safe (and legal). Radio masts are thin, and many quite tall ones may not be visible until very close. They also have guy wires extending to a considerable distance around them. Do not rely on map information; remember that only those obstructions more than 300 feet above ground will be marked on the chart. Other obstructions such as electricity pylons and wind turbines are increasing in number.

Navigation, once the pilot has time to spare for it, is made more difficult for several reasons. The view ahead and around is restricted by the next fold of high ground. The first effect of that is the difficulty of maintaining a steady heading. Pointing the aircraft at a feature well ahead may be impossible; the compass must be checked more often. The second effect is that objects only appear when you are close to them, and when they are not obscured by high ground. It is possible to pass close to a major navigation feature and never see it, especially as a certain amount of the view close to the aircraft is blocked by the airframe.

Figure 2.13 Flight close to the ground

Turbulence becomes more of a problem the closer to the ground one flies. This again makes it difficult to maintain the correct airspeed and heading, and in extreme cases may even cause difficulty in reading the instruments.

Earlier we considered the angle at which we would expect to see features which we wished to use for navigation. As we fly closer to the ground, so the angle at which we are looking becomes ever flatter. If a feature does not have some vertical extent, we are unlikely to see it at low level. The shape of the ground takes on a much greater importance. We mentioned the dangers of obstructions; if a mast is marked on the map it may be useful as a navigation feature, but do not aim to fly close to it.

With so little time for navigation, looking at the map for any length of time becomes impossible. The importance of pre-flight route and fix study is never more obvious than when one is forced to fly close to the ground.

CHAPTER 3

DIVERSION TECHNIQUES

3.1 Introduction

A diversion from planned track is not just an exercise in a navigation test. British weather is unpredictable, and can prevent pilots from carrying out their original plan safely. Aircraft unserviceability or personal illness can also force a change to the planned route. Pilots must be able to change their route safely at any time, and accurately enough to find their new destination. The procedures used are often referred to as "dead reckoning" procedures, although the correct title is "deduced reckoning".

3.2 Initial actions

First, you need to realise you need to divert. By looking well ahead you can detect cloud below your intended flying height, or poor visibility making the horizon appear hazy. If you can descend to a lower but still safe altitude then do so but be ready for further problems.

Once you decide to divert, you need to find a **start** point for your diversion leg. That must be somewhere you can recognise, ideally your next fix point, but in any case should be **in front of you** along the track you are actually flying but **before** you reach the problem. Try to allow 2 - 3 minutes for a quick plan if possible, do not turn immediately. You must have a plan before you change heading! Just as for normal pre-flight planning, check the route for controlled and restricted airspace before committing yourself.

3.3 Heading estimation

Draw as straight a line as you can on your map from the start point to your destination (some pilots make a temporary fold in their map to provide the line). Timing can wait, but you need a heading. **Look** at your planned route, and ask yourself the following.

1. Is there a pre-planned leg which is parallel with the diversion route? If so, use that planned heading and timing mark spacing.
2. Is there a leg which is close to parallel? If so, measure or estimate the track but use the drift and timing mark spacing from the original planned leg.
3. Is there a leg which is the reverse of the diversion route? In that case you can use the reverse of the track, the reverse of the drift, and calculate the groundspeed by reversing the difference between the TAS and groundspeed from the original calculations.
4. Does the diversion track intersect 2 planned tracks? In that case you can estimate the track from the planned ones.
5. Does the diversion track parallel a line of latitude or longitude? In that case your track is either North, South, East or West.
6. If your diversion track is close to but not exactly the same as another line on the chart, you might be able to use the 1 in 60 rule to improve your estimates.

And do not be afraid to **use map features**. If the diversion track follows a line feature, fly along the line feature as shown in figure 3.1, and note what heading you require to follow that line feature. Continue on the same heading after the line feature leaves your track. Use the same technique if you can track towards a very obvious visible feature which lies along the diversion track.

Many pilots carry a protractor to measure angles. Otherwise, you may have to estimate track from interpolating whatever angles are available.

The GO-to function of a GPS set can simplify matters enormously, of course, but always make a rough estimation before following its instructions blindly.

Figure 3.1 Line feature

3.4 Dead reckoning

Most of these methods will give you an estimate of the track required, but unless you are very fortunate you need a heading. To prepare for this, you may wish to draw a **wind arrow** on his map or log, with the wind strength in knots and the "maximum drift" angle in degrees. That maximum drift which an aircraft will experience at any particular time depends on the wind speed and the aircraft's groundspeed. It can be easily calculated by dividing the forecast wind speed by the groundspeed in miles per minute. For example, with a groundspeed of 120 knots (2 nm per minute - see below), and a wind speed of 20 knots, the maximum drift which will be experienced due to that wind is 20 ÷ 2 = 10°. Because groundspeed varies with heading, the figure written beside the arrow has to be the maximum drift for the aircraft's TAS, which is an acceptable approximation in most cases, and can be refined with experience.

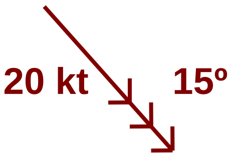


Figure 3.2 Wind arrow

Use the 'clock method' to decide how much of that maximum drift will affect you. If the wind is from the beam, or anything **more than 60º** from your track, you will have **all** that maximum drift. If the wind is along your track, there will be no drift, but if **30º** away you have **half** the drift; if **45º** you have **¾** of the drift, if **15º** you have **¼**, etc. (It is called the 'clock' method because the number of degrees the wind differs from track can be equated to the number of minutes on a clock, while the proportions are the same as the parts of the hour.) Turn **towards** the wind. Then you must allow for **variation** before you know your heading. Comparing your heading with the track shown on a GPS display will tell you the drift, but in the diversion case, the track is probably the information you are most interested in.

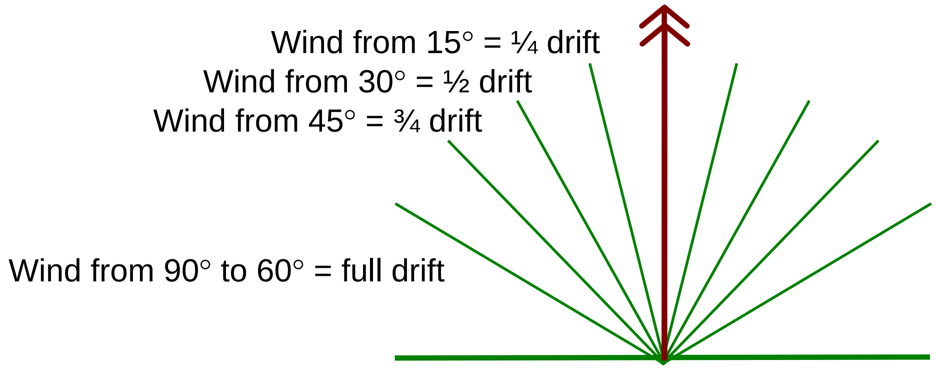


Figure 3.3 Drift proportioning - the clock method

Before you change heading, decide where the **sun** should be on the new leg, for example if your calculated heading is 170º and it is 5.30 in the evening, the sun should be above your right wingtip. When you have turned, check that the sun is indeed there. Even if the sun itself is not visible, shadows may give an indication. WHAT checks are at least as necessary now as on a pre-planned route.

3.5 Timing

If you do not have time to make timing calculations before you reach the point at which you start your diversion, do not worry. Concentrate on being over that start point, making WHAT checks as appropriate, and either **start your clock** over it, or write down the time on your nav log or map.

You looked at your original planned legs. Hopefully you can use timing marks at the same intervals as one of them, but if not you must make calculations. You can use the wind arrow and a similar technique to the clock system used in drift calculation. This time, if the wind is along your track or **within 30º** of it, the wind will have the full effect. Take your TAS and add or subtract the whole of the wind. If the wind is **on the beam**, there is **no** speed effect. If **30º from the beam**, it will affect you by **half** its strength. If **45º** from the beam, it will have **¾** of the full effect, if **15º** from the beam, it will have **¼** of the full effect. Again, a GPS set can indicate your groundspeed, even if you are not diverting to a loaded waypoint.

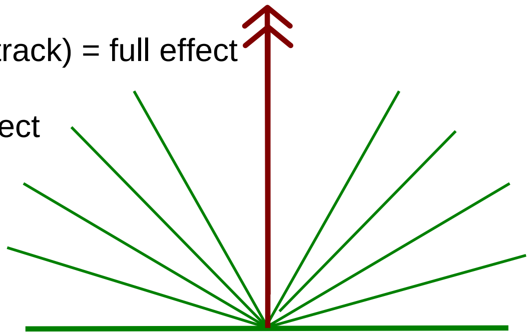


Figure 3.4 Speed effect - clock method

Of course, you can use your navigation computer if you carry it in the air, but lookout has priority over calculations!

Having worked out your groundspeed, you need to translate it into timing measurements. A computer will translate knots into miles per minute, but you can work it out yourself. 60 knots is one mile per minute, 90 knots is 1½ miles per minute, 75 knots is 1¼, 120 knots 2, and 105 knots 1¾. A ruler (or even a pencil) marked in miles is handy here, but it is possible, and simple, to use part of your body. The author's thumb is 5 miles wide on a 1:500,000 scale map. Measure your own hands to find parts which equal exact numbers of miles. When you drop your ruler, you may need to use them.

Having made a rough timing calculation, you can refine it fairly easily later. Make sure you have a **fix point** along your diversion leg, and make it as exactly halfway or one third of the way as you can. Do that even if it means you are using a smaller fix than you would wish to. Now your total time to the destination will be twice or three times the time to the fix point, and no more calculations will be needed! You can also make final adjustments to the heading using the techniques in the paragraph on "cumulative errors" in the previous chapter, even if your original heading was out by several degrees.

3.6 Fuel

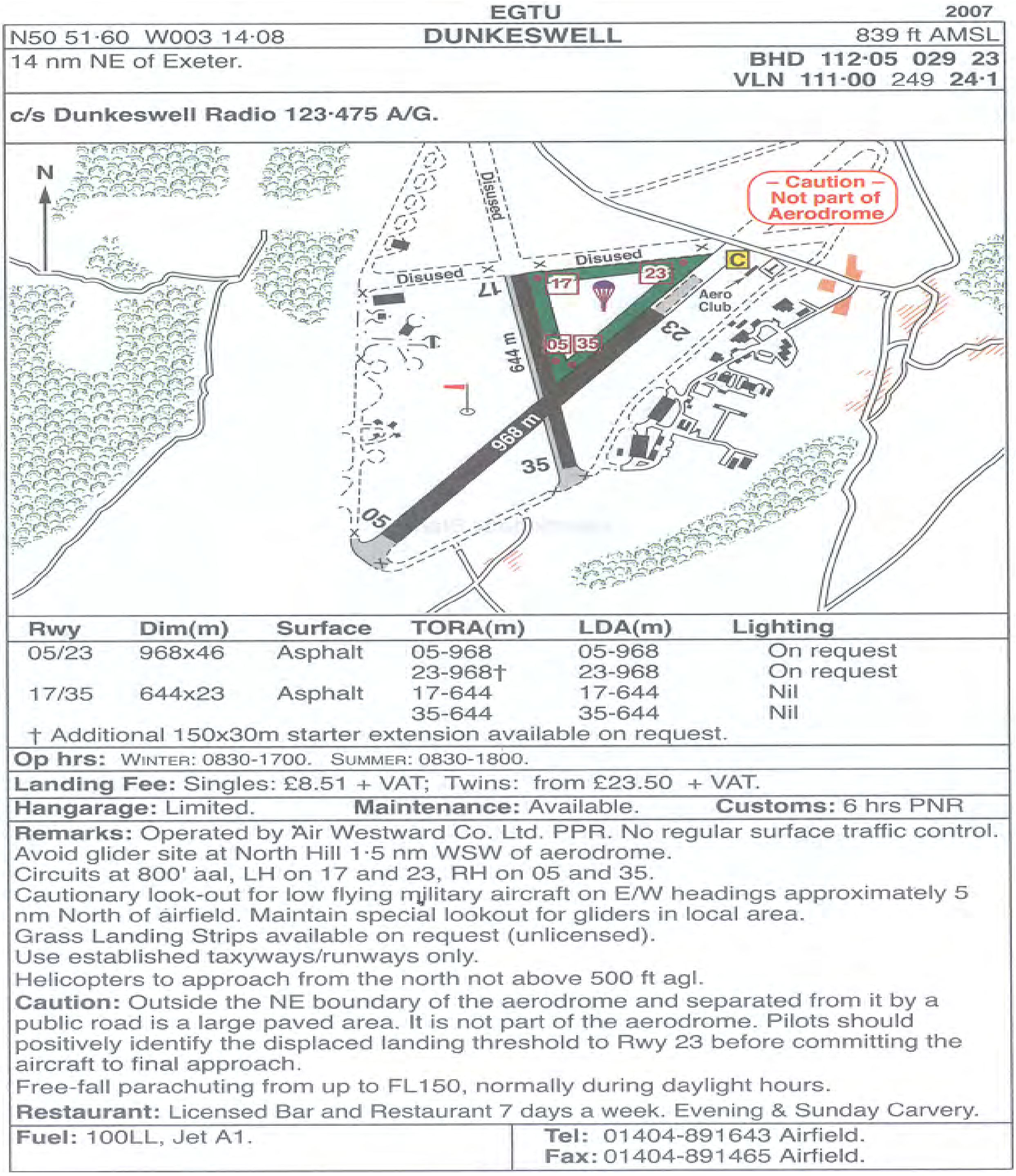
Of course, diversions are not easy. You will have started your diversion procedure for reasons of safety, so the diversion itself must be at least safer than your original plan. This will not be the case if you run out of fuel before you get there!

Fuel calculations are the important reason for making an estimate of ETA at your diversion destination. Once you have calculated your ETA, calculate your fuel remaining at the end.

3.7 Arrival procedure

Your diversion aerodrome will not be expecting you. You will not have planned an arrival there either, so before you reach their circuit pattern you need to prepare yourself. Find the radio frequencies as applicable (they are on the chart and associated card but be sure you keep that list up-to-date), and call up to tell them you are diverting there, asking for aerodrome details, weather if available, and special procedures. Be ready to copy the details down when the reply comes! Carrying a

VFR guide, such as Pooley's, can help you prepare for arrival at your diversion. Fig 3.5 shows a specimen chart published in that guide, giving not only the type and frequencies of the radio facilities, but the runway lengths and declared distances, many of the local procedures and an idea of what the field will look like.



EGTU 2007

N50 51·60 W003 14·08 — DUNKESWELL — 839 ft AMSL

14 nm NE of Exeter. BHD 112·05 029 23
VLN 111·00 249 24·1

c/s Dunkeswell Radio 123·475 A/G.

Rwy	Dim(m)	Surface	TORA(m)	LDA(m)	Lighting
05/23	968x46	Asphalt	05-968 23-968†	05-968 23-968	On request On request
17/35	644x23	Asphalt	17-644 35-644	17-644 35-644	Nil Nil

† Additional 150x30m starter extension available on request.

Op hrs: WINTER: 0830-1700. SUMMER: 0830-1800.

Landing Fee: Singles: £8.51 + VAT; Twins: from £23.50 + VAT.

Hangarage: Limited. **Maintenance:** Available. **Customs:** 6 hrs PNR

Remarks: Operated by Air Westward Co. Ltd. PPR. No regular surface traffic control.
Avoid glider site at North Hill 1·5 nm WSW of aerodrome.
Circuits at 800' aal, LH on 17 and 23, RH on 05 and 35.
Cautionary look-out for low flying military aircraft on E/W headings approximately 5 nm North of airfield. Maintain special lookout for gliders in local area.
Grass Landing Strips available on request (unlicensed).
Use established taxyways/runways only.
Helicopters to approach from the north not above 500 ft agl.
Caution: Outside the NE boundary of the aerodrome and separated from it by a public road is a large paved area. It is not part of the aerodrome. Pilots should positively identify the displaced landing threshold to Rwy 23 before committing the aircraft to final approach.
Free-fall parachuting from up to FL150, normally during daylight hours.
Restaurant: Licensed Bar and Restaurant 7 days a week. Evening & Sunday Carvery.

Fuel: 100LL, Jet A1. **Tel:** 01404-891643 Airfield. **Fax:** 01404-891465 Airfield.

Figure 3.5 Dunkeswell aerodrome

Unless there are special procedures published, aim to make a standard join from the aerodrome overhead, after studying any signals square even if you have air/ground radio contact. Fit in with the traffic already in the circuit pattern. All of this also applies when arriving at your original destination, for which of course you planned beforehand!

3.8 Assistance

Using the procedures above takes concentration and reduces the time available for looking out. Therefore do not hesitate to ask others for help if things go wrong and force you into a diversion situation. At the planning stage, you should have noted the radio frequencies for air traffic control radar units which may be able to help you. Whether or not you have already obtained a service from them, tell them your problem and ask for help. If you need urgent assistance, use the words “PAN PAN” to ensure they know that. Of course, a major emergency such as an imminent forced landing would involve the word “MAYDAY”.

Even without radar, certain air traffic control units can provide useful assistance using the radio. Some aerodromes, especially major ones, have VHF direction finding (VDF) facilities. These should be able to tell you your “true bearing” (sometimes referred to as a “QTE”), from them. If one of these is your diversion destination, the controller may even be able to give you a “steer” (sometimes referred to as a “QDM”) which is the magnetic track which you should follow to reach their aerodrome.

In the UK we are fortunate to have the services of “distress and diversion cells” at our main air traffic control centres. These are staffed by controllers who listen out on the emergency frequencies, including 121.5 MHz, to provide assistance to pilots with problems. If you are not in contact with an ATC radar unit, and you find that the safest diversion would take you through controlled or restricted airspace, or if aircraft unserviceability or the weather is making life difficult, do not hesitate to call the “D&D cell” for help. Again, use the words “PAN PAN” to indicate that you need urgent assistance. Note however that this service is only available in the UK.

3.9 Deliberate deviation from track

Sometimes the full diversion procedure is not necessary. Cumulonimbus clouds are not places for light aircraft, and the safe option is to turn back to base or divert if large cumulus develop and cunims threaten. However, sometimes an isolated cloud blocks your way home and you need to get round it. This technique uses the equal lengths of the sides of equilateral triangles, and can also be used to avoid congested areas at low level.

When you see the ‘threat’, consider which way you want to turn to avoid it. At an exact minute mark on the clock, turn that way by **60º**, as in figure 4.5. Keep flying on that heading until you will be clear of the cloud when you turn back through **120º**. Note the **time** you have flown on the 60º heading, and turn back 120º for exactly the same time. Turn back onto your original heading, and you will be late by the time you spent on the 60º leg! It is advisable to make your deviation for a whole number of minutes, of course.

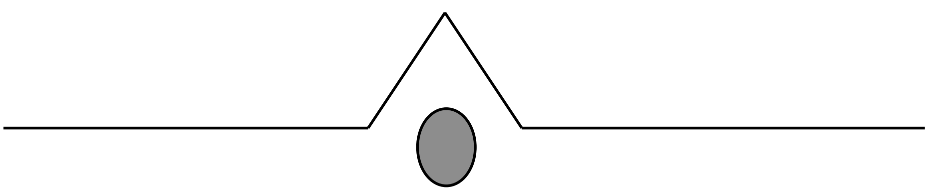


Figure 3.6 Track deviation to avoid an obstacle

A variation of this can be used if the weather problem is narrow but fairly long. After a certain number of minutes on the 60º leg, turn to parallel the original heading until the weather is past, as in figure 4.6, then turn back 60º towards track for the same time that you turned at first. Again, overall you will be the same amount late as you spent on the first 60º leg.

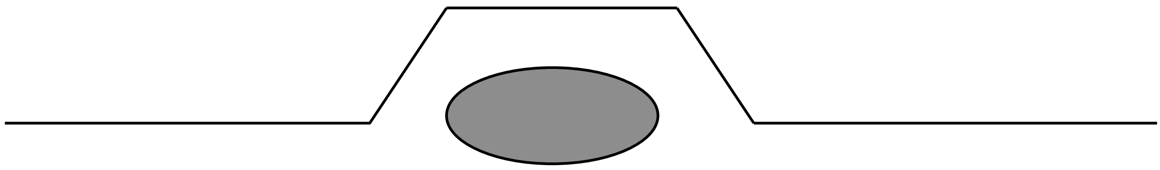


Figure 3.7 Paralleling track

3.10 Uncertain of position

Using the recommended techniques, it is unlikely that a pilot will become "uncertain of his position" (= lost!). However, mistakes occur, and every pilot should have a plan of action in case the worst happens.

3.10.1 Initial action

First, when should one start to worry? Until a pilot is experienced, ground features, including fix points, may not appear as he expected. Low cloud, or even cloud shadow, can prevent him from seeing what he expects to be an obvious fix. Unless one is close to controlled airspace, or running short of fuel (in either of these cases go straight to the paragraph headed "urgent action"), missing one fix should give no cause for concern. If the missed fix is a turning point, turn on time, restart the clock, and continue. If however a second fix is missed, it is time to find out where you are.

Finding out where you are first involves considering the situation, while continuing to fly as planned. Can you get a position line from a radio aid? Can you get a radio bearing from an aerodrome VDF? Are you flying high enough to receive either of these, or can you climb? Climbing is usually a good option if you can do it because you may be able to see a large feature which is outside your present view.

Look back along your route and note where you last **knew** (not 'thought you knew' where you were, and what time that was. Have you been flying the correct headings since? Have you read the watch correctly? Did you actually turn where you thought you did, or did you mis-identify the last turning point by mis-reading the watch? Make some dead reckoning calculations for every leg since you last knew your position, as if you were making a diversion. If you find a mistake, you should know where to look for the next features, or perhaps how to fly back to track.

Is there a large feature somewhere along your track which you cannot possibly miss (coastline, motorway, mountain range)? If you can afford to wait until you see that, you will have a line feature which you can follow until you can positively fix your position.

3.10.2 Urgent action

If in the UK you cannot afford to continue until something turns up, call the Distress and Diversion Cell on the emergency frequency of 121.5 MHz and ask for help. You need urgent assistance, so prefix your call with “PAN PAN” three times. The same applies if you have considered the situation and cannot identify your position from radio or visual line features, although if you feel that the situation is not urgent, you may wish to ask for a “Training fix” instead. If you are unable to make radio contact in a situation of urgency, select 7700 on your transponder to indicate to ATC and other aircraft that you have a major problem, while checking your radio volume, microphone connections, frequencies set etc.

3.10.3 Lost procedure

There is always the possibility that your calls for help are not answered. The formal “lost procedure” is designed for pilots travelling long distances over inhospitable terrain, or those without radios, but if no other options are available it can be used anywhere as a last resort. It should be noted that it gives no protection from controlled or restricted airspace

While continuing as planned, work out how long you have been flying since you last **knew** your position. Use your calculated groundspeed to decide how far you have travelled since then, and where you should now be. Quickly look to see if you can identify a feature on the map (a fix point) which should be ahead of you and that you should be able to recognise. While looking for that fix point, divide the distance flown since the known position by 10. Draw an imaginary (or real) circle with that radius around the fix (or your estimated position if there is nothing obvious to look for). Look OUTSIDE that circle on the map for an obvious line feature, such as a coastline, unique motorway or major river, (away from controlled airspace, of course). Once you realise you have reached where your fix should be, and you cannot see it, calculate a heading which will take you to that line feature from any point inside the imaginary circle, then fly to the line feature. Once you can see the line feature, fly along it keeping it is sight until you can positively identify your position along it. Cross-check with another feature before using diversion techniques to get you to a safe aerodrome.

3.10.4 Final option

If you are running out of fuel or daylight, choose a field and fly a precautionary circuit, initially to inspect it and then to land. Do not take off again until you have had the aircraft inspected.

SUMMARY

1. Plan the route and arrival to avoid problems

2. Plan to look ahead for features at about 6 minute intervals

3. Look out and well ahead

4. When steady on heading, aim for features on the horizon

5. Before turning onto a new heading check:

   W weather around you and along the intended direction
   H heading from the plog or map – select a feature to roll out on
   A altitude to be flown
   T time, note it and prepare to re-start the stopwatch if used

6. After turning onto any new heading check:

   W weather, is it safe to continue as planned?
   H heading, read the DI, check it against compass, GPS track, plog / chart, the sun or a confidence feature
   A altitude, any problems ahead such as controlled airspace
   T time, check watch running or time noted, when is next feature expected?