Civil Aviation Authority

USE OF GPS

Information and Guidance to Pilots

for

the use of GPS in Light Aircraft

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Most illustrations courtesy of Garmin UK and Honeywell

1 INTRODUCTION

a. The most familiar Satellite Navigation (or GNSS) system to most of us in the UK is the US Department of Defence "Navstar" Global Positioning System or GPS. Other systems are available, or in development, but this leaflet is based on the use of the Navstar GPS system.

b. Here you will find background information and guidance for General Aviation pilots in the use of stand-alone GPS equipment (ie. systems not forming part of an integrated Flight Management System).

c. Unless specifically approved for particular purposes, such equipment is only to be used as an aid to other forms of navigation.

2 SYSTEM AND SIGNAL ANOMALIES

a. The GPS system has generally shown exceptional reliability, but it has been known to suffer technical and human failure. Consequently, **GPS must not be relied upon as a sole navigation reference in flight critical applications**. Common sense dictates that pilots should not only familiarise themselves with the techniques required to use the system properly, but understand how it could go wrong and prepare for the unexpected.

b. AVAILABILITY
The receiver relies on maintaining line of sight between itself and the satellite. It needs to be able to 'see' several satellites (the number depends on the accuracy and integrity required) to provide a fix and, even with 24 satellites in orbit, there are times when insufficient satellites are 'visible' to provide that service.

c. GEOMETRY
Whilst enough satellites may be 'visible' to give a fix, at certain times their angular separation may be small, giving rise to poor accuracy. This reduction in accuracy is called "Dilution of Precision" or "DOP" and may be displayed as a number. A high DOP (more than 6) indicates that GPS position accuracy is significantly degraded and the information should not be used.

d. RAIM
More sophisticated receivers contain a processing algorithm known as Receiver Autonomous Integrity Monitor (RAIM). RAIM compares the information received from a number of satellites and alerts the user to an error. If enough satellites are visible, the function may be able to identify the faulty signal and discard it.

The presence of a working RAIM function only monitors one type of failure and does not guarantee the absence of a position error. RAIM availability at any time and place in the world can be predicted from satellite orbital information by receivers with appropriate software. However, RAIM prediction cannot foresee the failure of a satellite, nor the removal of satellites from service. Neither does it take account of terrain.

e. NOTAMs/NANUs
Notice Advisories to Navstar Users (NANUs) are the means of informing GPS users of planned satellite "outages". NANUs are available in the UK through the NOTAM system, and must be consulted to determine the availability of GPS and RAIM information. Some receivers can be adjusted to manually deselect a particular satellite if it is expected to be out of service.

f. FAILURE / ERROR
The satellite clock (the heart of the system) may drift off time, the satellite may stray from its orbit or its transmitter may simply fail. **It can take up to two hours for such failures and errors to be resolved**. At such times, unknown position errors have been reported (up to 2 km), despite the presence of RAIM.

g. TERRAIN SHIELDING

At low level, in regions of high terrain or obstacles, satellites can become hidden to the aircraft receiver. This may give rise to unexpected loss of position and/or RAIM .

h. DYNAMIC MASKING

Parts of the aircraft itself may get in the way, for example the outside wing in a turn. If this blanks the signal momentarily, the navigation capability may be degraded or lost, requiring several seconds of straight and level flight to re-establish navigation information.

i. MULTI-PATH REFLECTIONS

The signal may bounce off hills and structures before arriving at the receiver, giving rise to range errors from the satellite. Such errors are generally very small but may appear as a sudden change in position which the receiver interprets as a change in drift and groundspeed. This may lead to distracting messages declaring phenomenal wind shifts, and may be sufficient to destroy the integrity of the navigation information altogether.

j. INTERFERENCE AND JAMMING

The GPS signal received from the satellite is at very low power and is **vulnerable to interference**, either intentionally or otherwise. Sources of unintentional interference include UHF and microwave television signals, some DME channels, and harmonics from some VHF RT transmissions, as well as other reported sources. It is known that jamming devices are available which can easily disrupt signal coverage across a wide area. Military exercises and trials which include deliberate GPS jamming take place frequently, and are notified. Check NOTAMs for any areas likely to be affected.

k. SUNSPOTS

Because the satellites orbit at very high altitudes, radiation from the sun can affect their transmissions, or even their own navigation system. Particular flares or sunspots cannot be forecast, nor can their effect. However, NOTAMs include warnings of possible GPS signal interference when major disturbances are detected.

l. SELECTIVE AVAILABILITY

Finally, the satellites are the property of the US Department of Defence (DoD), which may move satellites around to improve cover over a particular area, thereby reducing the availability over others. Although the signal is promised to remain available for civilian use, the facility exists to insert random errors into the signals to reduce accuracy, or even to switch the whole system off completely.

3 EQUIPMENT

a. CARRIAGE OF EQUIPMENT

The installation or carriage of GPS equipment does not affect the requirement for a primary means of navigation appropriate for the intended route, as detailed in Schedule 5 of the Air Navigation Order.

b. VFR use only

When operating under Visual Flight Rules (VFR) outside controlled airspace, there is no requirement to carry any radio navigation equipment and there is no installation standard for GPS used only as an aid to visual navigation. However, equipment permanently installed (in any way) in an aircraft must be fitted in a manner approved by the CAA. If a hand held unit is carried, care should be taken to ensure that it, the antenna and any leads and fittings for them are secured in such a way that they **cannot interfere** with the normal operation of the aircraft's controls and equipment and do not inhibit the pilots movements or vision in any way. Consideration should also be given to their possible effect on the aircraft occupants if the aircraft comes to a sudden stop.

Equipment permanently installed…

c. IFR certification

If a GPS system has been certified as meeting the "Basic Area Navigation" (BRNAV) requirements this will be stated in a 'Supplement' to the aircraft Flight Manual. Such approval means only that the equipment is regarded as accurate for en-route purposes (within ±5 nautical miles for 95% of the time). There may be additional approval requirements to operate it in Terminal Areas (Including SIDs and STARs) or on an instrument approach. Even systems which are certified for Precision Area Navigation (PRNAV) may not meet the required navigation performance for use on an instrument approach. The use of such equipment for precision navigation will probably also require specific pilot qualification.

4 SYSTEM FAMILIARISATION

a. The individual manufacturers of GPS equipment each provide different functions in the receiver. There may also be major differences between individual receivers from the same manufacturer.

b. Before attempting to use the equipment in the air, pilots should learn about the system in detail, including:

- Principles of GPS
- System Installation & Limitations
- Pre-Flight Preparation & Planning
- Cross-Checking Data Entry
- Use of the System In Flight
- Confirmation of Accuracy
- Database integrity
- Human Error
- System Errors & Malfunctions

More detailed guidance on training is available in other CAA documents.

c. Essential learning, even for VFR use only and preferably with guidance from the manufacturer's representative or an instructor experienced on the individual equipment, should include at least the following:

a. Switching on and setting up
b. Checking the status of receiver, satellites, battery, and any database used
c. Loading waypoints
d. Loading a route
e. Loading alternate routes
f. "Direct" or "GO-TO" functions
g. Selecting alternate routes
h. What your database contains (and what it doesn't)
i. Use of RAIM function if fitted
j. Amending RAIM input if fitted
k. Regaining the last screen when you have pressed the wrong button!

d. Whether or not you find a suitable instructor, practise using the equipment on the ground before trying it in the air. Then take someone else to fly and navigate for you, while you are becoming totally familiar with the GPS. If you fly a single-seater, ask someone else to fly you in their aircraft while you practise.

e. If the check list supplied with your GPS equipment is complicated, inadequate or non-existent, use part of the learning process to write your own check-list for setting up and use in the air.

f. Although there is no requirement to demonstrate use of the GPS on any UK flight test, it is sensible to use it at least for some of the time when an examiner or instructor is flying with you. You may pick up some useful tips.

5 FLIGHT PLANNING

a. The attention a GPS receiver requires in flight can be minimised with careful planning and preparation before departure, releasing the pilot to other tasks whilst in the air.

b. Most modern units allow the user to enter a series of waypoints as a route or flight plan. Be familiar with how to do this, how to store it, and retrieve it for later use. Doing this significantly reduces the chances of making an error in flight, and allows more time for other things such as lookout or instrument flying.

c. **Plan the flight and prepare a map and log in the normal way.** Then enter the route information from the log, directly into the receiver as a "Flight Plan". This achieves three things;

1 The route information is created visually on a chart, helping to eliminate any gross error.

2 You have a back up should the GPS information become unreliable or unavailable in flight.

3 You are aware of the terrain over which you intend to fly, and can calculate safe altitudes (many databases do not consider terrain).

d. USER WAYPOINTS

i) If the aircraft and GPS receiver are your own, you may want to set it up to your own preferences. For example, you might have a favourite visual navigation route which you follow every time you depart or arrive. Most GPS receivers allow you to set up User Waypoints to guide you along such a route, even if there is an airspace database installed. Keep a record of all loaded User Waypoints for future reference.

ii.) It has been known for one pilot in a group or club to edit the data comprising a stored User Waypoint and leave it with the same name, but in a different position. Deleting or moving existing User Waypoints, or changing their names, should be **expressly prohibited** where the GPS is operated by more than one pilot. Any changes must be agreed by the group.

iii.) This underlines the need to check the position of waypoints in the flight planned route, and any possible alternative or diversion route, before departure. If this is not done, pilots cannot rely on any 'Go Direct' or 'Nearest' function in the air when working with User Waypoints.

iv.) When inserting a User Waypoint, ensure that the latitude and longitude co-ordinates you use are from the correct geodetic datum. The positions of an individual point may be up to a kilometre apart if referred to different datums. Although some receivers have the facility to convert position information between the WGS 84 datum used in GPS equipment and others, these conversions are not always absolutely accurate and can contain errors.

Positions may also be in different formats. Many receivers refer to positions as degrees, minutes and decimals of a minute, rather than the degrees minutes and seconds used in documents.

6 PROGRAMMING CROSS-CHECKS

a. Once the route has been entered, 'run' it to make sure you have not missed (or mis-entered) any waypoints. This may be called the 'Simulator' or 'Demo' mode.

b. If you have a map display, it is usually possible to display the route on the screen once it has been entered. Any gross error in the position of a waypoint or turning point should be obvious on the map. If there is no map, or it is too small to be of practical use, **compare the tracks and distances displayed on the GPS with the previously prepared flight log**.

any gross error should be obvious

compare tracks and distances

7 THE DATABASE

If you have an aviation database installed, ensure that it is current, and is valid for the area over which you intend to fly. Aerodromes seldom move far, but their serviceability, airspace, frequencies, reporting points and other information change often. An out-of-date database can lead (at best) to embarrassing and expensive error. At worst, it could be catastrophic. **Do not use an out of date database.**

Even a current database cannot be automatically assumed to be error free. Instances of database errors have been recorded, and only careful checking against current charts and the AIP may identify these. In addition, NOTAMs must still be consulted before flight.

8 INITIAL STATUS

On start up, check the status of the receiver and its battery. Compare the indicated GPS position with the aircraft's known position. If your aircraft is normally parked in the same place, it helps to enter the coordinates of that position as a User Waypoint. Each time you start up in that position, select 'go direct' to that waypoint. You will then see the current error of the GPS position. You can also compare the relative indicated position of a known database point (such as the Aerodrome Reference Point) with its actual position.

9 IN-FLIGHT USE

a. **The GPS system should NEVER be used in isolation.** The risk of loss or degradation of the signal, with the attendant possibility of a position error, is genuine. More importantly, the risk of human error in data input and display reading is extremely high and these errors can go unnoticed until it is too late.

b. It is easy to transpose numbers in one's head, and these errors are surprisingly persistent. Do not allow any such errors to lead you into trouble.

c. It may help to go through a three-stage exercise in setting up **any** navigation aid, including GPS;

1 Set it up and satisfy yourself that you have done it correctly.

2 Do something else – even if only for a few seconds.

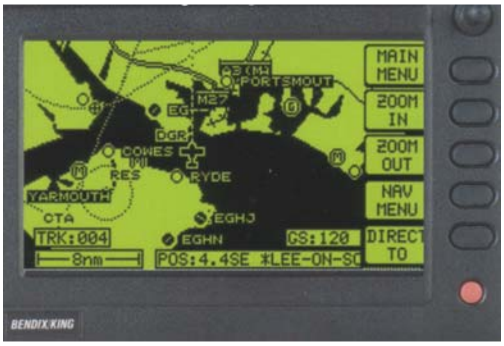
3 Go back and check again that the set up is still correct.

d. When flying in IMC or above cloud, only use GPS in combination with other radio aids to correlate with dead reckoning of the flight planned route and general situational awareness.

e. If the GPS display agrees with everything else you know, including dead reckoning, the navigation log, map reading and general situational awareness as well as radio navigation, then the GPS display is likely to be providing the most accurate information.

f. The accuracy of GPS will often expose the operational error of other navigation aids. Errors of up to 5º are normal in a VOR display (more on an ADF), and DME is only accurate to about half a mile. DME indicates slant range but GPS displays horizontal range, giving rise to a further small disparity, which increases as you approach the DME station overhead. Some apparent errors may of course be due to magnetic variation.

g. If flying visually, it is easiest (but not usually particularly accurate) to cross-check your GPS position with a recognisable feature on the ground. You could also compare indications from a radio aid station with the GPS range and bearing to that station. Any difference greater than the normal error associated with the radio aid indicates a problem with one or other aid. If you cannot cross-check with a third system, especially if short of fuel or near controlled airspace, consider asking an ATS radar unit or Distress and Diversion Cell for a position fix.



cross-check your position

h. To avoid becoming totally dependent on the GPS, ask yourself 2 questions regularly throughout the flight;

1 Does the GPS agree with at least one other independent source of navigation information?

2 If the GPS quits completely, ***right now***, can I continue safely without it?

If the answer is yes to both questions, you may continue to use the equipment for guidance. However, if the honest answer to either one of the questions is "No", then ***you must establish navigation by some other means***.

10 DIVERTING FROM THE INTENDED ROUTE

a. Re-programming the system in the air is time-consuming, and interferes with other procedures such as lookout. Like any cockpit operation, re-programming should not be undertaken whilst the aircraft is manoeuvring. Unless someone else can fly the aircraft for you, switch operation must be interrupted so that individual selections are interspersed with a thorough lookout (or instrument scan) every few seconds.

b. Anything you can do to reduce this re-programming will help. **Pre-plan likely route changes**, for example around controlled airspace in case you cannot obtain clearance, or around high ground in the event of bad weather. Have a note of the ICAO designators of all suitable diversion aerodromes.

c. Re-programming in the air is also much more likely to produce human errors. If you need to change your planned route, make at least a rough set of mental calculations (and note them down) BEFORE you turn onto the GPS track. Then if your new heading does not agree with your mental calculations, you will know you have made an error somewhere. **Check the new route on a map for terrain and any NOTAMed activity.** If your database is not current, you must check for controlled and restricted airspace also.

11 INSTRUMENT APPROACHES

a. Existing instrument approach procedures at some aerodromes are already provided in many receiver databases. These "Overlay" or "Monitored" approaches can present the pilot with a direct comparison with the terrestrial approach aid being used. **If your GPS receiver can do this, you must exercise extreme caution**. VOR and NDB approaches to beacons actually *on* the destination aerodrome usually provide a final approach path or track which is not aligned with the main runway centre-line. Even on a direct approach to a particular runway, pilots should not necessarily expect to be on the extended centreline of the runway.

b. The terrestrial approach procedure may include DME ranges from the threshold, missed approach point (MAP) or some other reference, such as the beacon. The GPS may give distance guidance to a different point, such as the Aerodrome Reference Point. Pilots should be aware of any differences in the distance information given to step-down fixes and/or the MAP, as this has the potential for catastrophic error.

c. **Overlays and Monitored approaches must only be used as supplemental information and the normal equipment for that approach procedure must be used as the primary reference**. Otherwise, disparity between the two displays and the potential for mistakes are just as likely to diminish the safety margins on an instrument approach as enhance them.

d. The safety values in the design criteria of any published approach are applied to known, surveyed obstacles and restrictions to the required flight path. **Disregarding the established approach procedures and published minima, in favour of reliance on the GPS, is not authorised and is highly dangerous.**

USER DEFINED APPROACHES

a. Pilots have been known to produce and follow their own approach procedures using GPS information. **This is potentially dangerous**. There is no ground based confirmation of position and the risk of mis-entering waypoints is high.

b. Furthermore, when flying towards a waypoint in normal, en-route mode, the course deviation indicator (CDI) normally indicates a track error of 5nm at full-scale deflection (or 1 mile per 'dot'). This is not accurate enough for any final approach, and only changes when either the sensitivity is changed manually or the aircraft is following a published *and correctly activated* GPS approach contained in the database. Changing sensitivity whilst on approach is a hazardous distraction.

c. Unless a *published* approach is activated, the receiver's RAIM function remains in en-route mode (even if the CDI scaling is changed manually) and there may be a position error of up to *2 nautical miles* before any RAIM alarm is given.

d. **User-defined approaches can be dangerous and are not authorised.**

12 THE FUTURE

Satellite navigation will one day almost undoubtedly form the basis of our radio navigation but in the mean time, the GPS system is fallible and should be used **with knowledge and caution**, not blind faith.

13 SUMMARY

1. Accuracy is not guaranteed
2. Apparent accuracy does not mean reliability
3. Understand your own equipment.
4. Train before using it.
5. Use standard settings and check lists.
6. Flight plan normally before loading a route.
7. Check the route before flight.
8. Load possible alternative routes.
9. Ensure database is the latest version.
10. Check the status on start-up.
11. Fly and navigate manually, only use the GPS once you have verified its accuracy against something else.
12. Do not rely on GPS for instrument approaches.

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