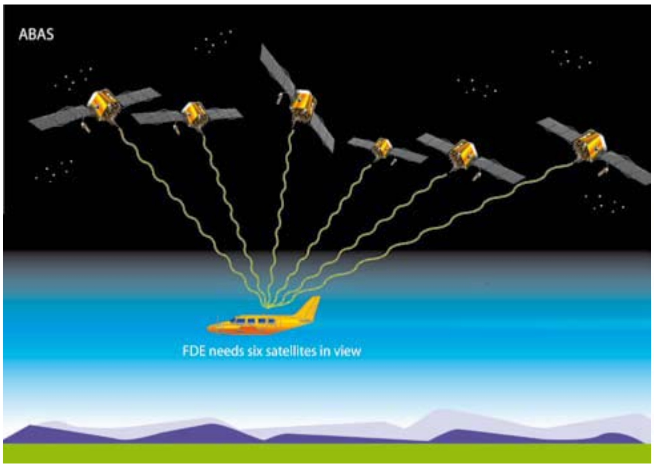
Aviation Safety

Use of GNSS/GPS in General Aviation

Safety Leaflet



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The introduction of Global Positioning Systems (GPS) took place some 50 years ago when the United States launched its initial satellites in support of military operations at the time of the Cold War. This was shortly followed by the Global Orbiting Navigation Satellite System (GLONASS) which was launched by the then Soviet Union in response to the US initiative. At that time access to the signals generated by these systems was restricted solely to military use.

Since those early days, access to the array of satellites has gradually been given for civil applications including aviation, however, the size, weight, complexity and cost of equipment precluded their use in General Aviation. Technological developments over the past 20 years or so have resulted in GPS systems becoming much smaller, lighter and less costly and today their use in the civilian world is common place such as simple hand held systems used by hill walkers to relatively sophisticated systems used on marine leisure craft, cars and aircraft.

Current developments include the European Union's 'Galileo' project which is intended to provide the world's first dedicated civilian Global Navigation Satellite System constellation (GNSS) for land, sea and air applications which will consist of an array of 30 satellites.

This information leaflet is aimed at raising the awareness of General Aviation stakeholders to both the positive benefits and possible dangers and disadvantages of using GNSS for navigational purposes.

The carriage or installation of GNSS equipment does not affect the statutory requirement for a pilot to carry out his primary navigation by means of traditional navigation practices using current and appropriate maps and charts. GNSS, therefore, must only be used as a secondary or reference aid to provide situational awareness.

GNSS systems have generally proved to be reliable, however, they have been known to suffer from both technical and human failure. It is important that pilots familiarise themselves with the procedures and techniques required to use the system properly but also to have an understanding of how the system can fail and be prepared for the unexpected.

HOW THE SYSTEM OPERATES

Timing is everything! In simple terms, the GNSS onboard receiver picks up signals generated by the array of satellites and the processor uses the time difference between the received signals to compute the distance of the receiver from each satellite. This is then further refined to fix the position of the receiver above the surface of the Earth. This position can be displayed as a latitude and longitude, grid reference or bearing and distance relative to a known point.

HOW ACCURATE IS A GNSS?

It is impossible to put a single figure on the accuracy of a GNSS system as it depends on a variety of ever-changing factors, many of which are related to the Earth's Ionosphere which is the largest single source of error. Some of the error factors are as follows:

- Position
- Time of day
- Season and solar activity
- Number of satellites in a constellation and their angular displacement from the receiver
- Update of satellite clocks
- Reflection from buildings and terrain
- Performance of the onboard receiver

CAN I TRUST IT?

Some method of alerting users that GNSS is not performing normally is critical to the safety of the system. Most GNSS units have inbuilt software to protect the integrity or measure of trust that a pilot can place on the information supplied by the system. This includes the facility to provide timely warnings to the user when the system should not be used for the intended purpose.

One of the most common systems is Receiver Autonomous Integrity Monitoring (RAIM) which continually checks the navigation solutions obtained from data received from various combinations of satellites, normally four. If all the satellites are working and are in an appropriate geometry, the answers should agree within defined limits applicable to the mode of flight. If there is a discrepancy, this triggers a loss of the integrity alarm.

More modern or sophisticated systems can exclude data from a faulty satellite from the calculation process. This is called Fault Detection and Exclusion (FDE) and it relies on six satellites and greatly reduces RAIM alerts allowing a flight to continue with integrity.

To be absolutely sure of the integrity of the information being supplied, a pilot must have a knowledge of the system and the alerts and warnings that it may generate and how to deal with the outcome. Overall the pilot must maintain an accurate navigation process, independent of the GNSS, to ensure that he is aware of his position at all times.

HUMAN FACTORS

As with any modern technology based system the use of a GNSS can introduce Human Factors errors into flight operations. While the positive benefit may be that it can reduce pilot workload in some areas, conversely it can raise the pilot workload in other areas and can also generate a false sense of security which, in the worst case scenario, can result in an element of 'press-on-regardless' causing pilots to continue a flight in marginal or poor conditions.

Some of the more common Human Factors issues to be aware of are as follows:

- Display conventions and modes of operation differ between units
- Many systems have small displays resulting in distraction and reduced lookout
- Many systems have small controls resulting in data entry errors
- Hand held or portable units can constitute a loose article hazard
- Over reliance on the GNSS

In a recently reported accident involving a GA aircraft during the take-off run, the hand held GNSS unit detached from its makeshift mounting and became jammed in the flight controls resulting in the aircraft crashing into trees just beyond the end of the runway.

HOW TO USE GNSS EQUIPMENT

Individual manufacturers provide instructions for use and pilots must make themselves fully aware of both the normal and failure modes of operation for the equipment intended for use.

Before attempting to use the system in the air the pilot should understand the following:

- Principles of GNSS operation
- System installation and limitations
- Integrity and validity of the database
- Pre-flight preparation and planning (creation of waypoints and routes)
- Cross-checking of data entry
- Use of the system in flight
- Confirmation of integrity
- System errors and malfunctions
- Human Factors and limitations

IN THE AIR

Many pilots use GNSS as an aid to VFR navigation, the key word being 'aid'. GNSS should never be used in isolation or when conducting a flight under IFR unless the system is properly certificated for use in such conditions and the pilot is appropriately trained and qualified.

Over reliance on GNSS accuracy and reliability has led some pilots to embark on a flight under VFR when the weather is below the VFR minima. This can result in loss of control due to disorientation or collision with unseen obstacles.

In a recent accident in Ireland, the pilot opted to continue flight in deteriorating weather conditions and lowering could base resulting in the aircraft being flown through an active wind farm, unbeknown to the pilot, as it was not indicated on the system database which was several years out of date. The pilot subsequently became disorientated, lost control and crashed.

Beware of using the 'GO TO/Direct To/DCT' function. GO To means exactly that, take me from here to the selected waypoint in a straight line. This function has resulted in many infringements of Controlled Airspace/Restricted Airspace/Prohibited Areas. Additionally, you must refer to your chart to ensure the new route will keep you clear of controlled/restricted airspace, terrain and any NOTAM activity.

Be aware that other aircraft may be navigating your intended routing but in reverse. On that basis it may well be worth considering setting up your route as a parallel offset based on the 'Right Hand Rule' to reduce the possibility of meeting the other aircraft head on as it comes towards you.

DO'S AND DON'TS

The following are a few tips on what a pilot should and should not do with regard to using GNSS equipment in the air.

DO	DO NOT
• Make sure you know your own equipment • Carry out thorough pre-flight planning as normal • Make sure portable systems are secure and antenna and leads do not interfere with controls • Make sure your database is up to date • Double check your route before flight • Load possible alternatives prior to flight • Check the system status and accuracy of your position on start-up • Fly and navigate your route visually, only use the GNSS as a secondary aid and cross-check regularly • Maintain adequate lookout for other aircraft and navigation features	• Use the GNSS in isolation • Accept that system accuracy is guaranteed • Embark on a flight without the appropriate charts • Embark on a flight without having carried out adequate pre-flight planning • Embark on a flight with an out of date database • Become totally reliant on the GNSS • Become over reliant on the 'GO TO/DCT' function • Use GNSS as a basis for continuing a flight in marginal or poor weather conditions • Use GNSS for flight in IMC conditions • Use GNSS as a basis for carrying out your own instrument approach procedures

GNSS DRIVEN INCIDENTS

The following are a few examples of how over reliance or inappropriate use of GNSS has resulted in embarasment for the pilot or in some cases accidents or serious incidents:

- A pilot contacted ATC to request permission to enter the CTR. ATC responded that the aircraft had already penetrated the CTR and was on a wide right base.
- The pilot was using a hand held system to navigate when, approximately 10 minutes before arrival, the receiver batteries failed. The pilot, who had no charts on board the aircraft, became disorientated and used up all remaining fuel trying to locate the airfield before carrying out an emergency landing in a car park.
- On departure from a busy airfield the aircraft climbed through the assigned altitude and deviated significantly from the assigned routing. As a result the aircraft was involved in an 'Airprox' with an inbound IFR flight passing within some 200ft and 300m. On investigation the pilot admitted that he had become distractted by trying to resolve an issue with his GNSS unit which had failed.
- The pilot had embarked on a flight in marginal VFR conditions. Some 40 minutes into the route he elected to terminate the flight and use the 'DCT' function to navigate to an alternative destination. After a further 15 minutes of flight the aircraft infringed a Prohibited Area that had recently been established. On investigation it was established that the database was four years out of date.

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