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Global Navigation Satellite Systems Overview

Introduction

From missiles to Mooneys

Satellites have been guiding Australian pilots, from ultralight enthusiasts to heavy metal captains, for more than 15 years. Most Australian aircraft now have some form of global navigation satellite system (GNSS) equipment in the cockpit.

The technology has entered a new phase, with CASA in 2006 giving the go ahead to receivers set to revolutionise satellite navigation, especially for smaller aircraft.

The approval came amid advances in augmentation technology that will boost the accuracy and reliability of GNSS. And it came on the eve of the deployment of a new GNSS system.

GNSS had its roots in the Cold War when the United States and Soviet Union launched the first systems. Designed for military applications, including missile guidance, the first-generation technology of the late sixties and early seventies was crude.

The US later launched its global positioning system (GPS), and the Soviets, GLONASS. Before long the technology was penetrating just about every aspect of civilian life, including aviation.

In 1994, CASA’s predecessor, the Civil Aviation Authority, approved the use of GPS as a supplemental IFR en route navigation aid, putting Australia in the forefront of regulation of GNSS technology. Several other approvals followed, in 1995, 1998, 2002 and 2006.

The development of GPS non-precision approaches (NPAs) began in 1998 when an NPA for Goulburn Airport, near Canberra, got the green light. Fueled by the low cost of GNSS and safety enhancement of straight-in approaches, NPAs proliferated, and now more than 260 Australian airports have them.

The first approvals for GPS approaches were based on technical standard order (TSO) C129 and C129a equipment, but that technology had reached its limits by the turn of the century. It was being superseded by units delivering gains in accuracy, integrity and continuity of service. The new C145 and C146 receivers enabled GA pilots to spend more time riding the radiowaves from satellites 20,000 kilometres above the Earth’s surface.

On the horizon was the next generation of GNSS equipment allowing precision approaches and automatic landing.
How does it work?

GNSS antennas on aircraft pick up signals generated from a constellation of satellites, about 29 of them in the case of the US GPS, the only system available in Australia at the time of writing.

The GPS constellation has been through many permutations since the first satellite went up in 1978. The current generation of satellites, each weighing about a tonne, was deployed between 1989 and 2005.

The satellites, not all of which are always operational, orbit the Earth in six 55-degree planes. The orbital planes, and the spacing of the satellites within them, are optimised to provide a wide coverage of the globe. The satellites complete one revolution, from west to east when viewed from the Earth, every 11 hours and 58 minutes. They pass over any given point on the globe four minutes earlier each day. Sometimes wobbles in their orbits, caused by the gravitational pull of the sun and moon, variation in the Earth’s gravitational field and the pounding of solar radiation, force the activation of on-board thrusters to put wayward satellites back into orbit.

Timing is everything in GNSS, and each satellite has up to four atomic clocks with accuracies measured in the order of thousandths of millionths of a second. A US-based master control station and several monitoring stations around the world track and manage the satellites, relaying critical correctional data to them.

The military and authorised users pick up signals on the L1 frequency (1,575.42 MHz), just above DME band, and on the L2 frequency at 1227.6 MHz. Civilian users receive on the L1 frequency alone. The first L5 (1176.45 MHz) band satellite was due to be launched in 2006/7, but at the time of writing there were no aviation receivers available tuned to this frequency. L5 introduces another civil frequency that can be used with the existing L1 band to reduce errors due to passage of the GPS signal through the ionosphere, a layer of charged particles up to 300 km above the Earth’s surface.

Getting a fix

The satellite broadcasts two codes – the coarse acquisition code, unique to the satellite, and the navigation data message. The codes bear information the receiver needs to work out its latitude, longitude and altitude and to synchronise its quartz clock with ‘GPS’ time, common to the GPS system. The information includes almanac data – the predicted orbital parameters of the satellites beamed up to each satellite from the ground stations – and the more accurate ‘ephemeris’ tracking data divulged by each satellite.
The coarse acquisition code is transmitted in binary form – a series of zeros and ones – and is superimposed on the carrier wave through a method called phase modulation.

GNSS uses the difference in the time of travel of radiowaves from four satellites to fix the position of the receiver and get an accurate value for time.

The unit’s processor computes the distance from a satellite from the time it takes the signal, travelling at 300,000 km/sec – the speed of light – to reach it. The computer deduces the value for time from the degree to which the pattern of zeros and ones in the coarse acquisition code is out of sync with the same pattern retrieved from its own memory and replayed at the same time.

The distance to the receiver is the product of velocity (300,000 km/sec) and time, and the unit’s computer plugs these values into equations, which it solves simultaneously to get the navigation solution. The radiowaves enter the strange realm of relativity in which time slows down, and this is factored in to the receiver calculations.

The GPS unit displays the coordinates as latitude and longitude or as bearing and distance information relative to a known point. (Current approvals for the use of GPS equipment in IFR operations need GPS-derived data to be to WGS-84, or worldwide geodetic datum standard 1984).

**Getting the timing right**
Based on classical mechanics, the principles underlying GNSS are simple, but the system is formidably complex in practice, the main problem being timing errors.

One source of error is the delay in the transmission as the signal passes through the ionosphere. The waves are slowed down as they pass through this electrical maelstrom of ions – atoms stripped of their outer electrons by solar radiation.

Water vapour in the atmosphere also slows the signal down.

And sometimes the satellites’ atomic clocks go haywire, while the receivers’ quartz crystal clocks always carry significant uncertainties.

Yet another source of error is multipath error – caused when obstacles near the GPS receiver reflect the radiowaves. The errors are amplified or annulled, depending on factors including the geometry of the satellites. Together, they could throw the navigation solution out by as much as 10 metres.

Another error was, until 2000, deliberately introduced into the system. A legacy of the Cold War, selective availability.
which skewed the satellite clock and ephemeris data, was designed to prevent hostile forces from using the publicly-available GPS system against the US. The C129 receivers assume selective availability is still switched on, limiting GNSS availability but not accuracy. The C145/C146 units, however, check to see if selective availability is off, and assume no SA.

It is because of the timing error in the receiver clock that it takes data from four satellites – and four equations – to get the position coordinates. Theoretically, three would do if the aircraft also carried an atomic clock, but the fourth equation is needed to obtain the timing error, or user clock bias in the receiver clock. A bonus is a measure of time with an accuracy in the order of a few tens of thousandths of millionths of a second, and this is why GPS has also found applications in fields ranging from telecommunications through physics experiments to electricity generation, as a timepiece. Even the Australian radar systems rely on GPS for a precise readout of time, critical to integrating radar displays when tracking aircraft within multiple radar coverage.

How accurate is GPS?

It is impossible to put a single figure on the accuracy of GPS as it depends on several ever-changing factors, many of which affect the ionosphere, the biggest single source of error. They are:
- position
- time of day
- season and solar activity (which affect the ionosphere)
- the number of operating satellites in the constellation and their angular spacing from the aircraft
- update of satellite clocks and ephemeris data
- reflection from buildings and terrain (multipath)
- receiver performance

Can you trust it?

A way of alerting users that GNSS is underperforming is critical to the safety of the system. GNSS units have software to protect integrity – the measure of trust you can place in the information supplied by the total system. Integrity includes the ability of a system to provide timely warnings to the user when the system must not be used for the intended operation.

There are several ways to ensure integrity. They are aircraft-, ground-, and satellite-based augmentation systems. One of the aircraft-based augmentation systems (ABAS) is familiar to many pilots. It is RAIM, or receiver autonomous integrity monitoring.

RAIM checks up on each satellite by comparing the navigation solutions obtained from data received from various combinations of four satellites in a group of at least five. There are five such combinations in a set of five satellites, and five possible navigation solutions. If all satellites are working, and are in an appropriate geometry, the answers should agree within the limits applicable to the mode of flight. If not, there will be big discrepancies between the five solutions, and this triggers a loss of integrity alarm.

The RAIM limit for en route operations is
2.0 NM, for terminal operations, 1.0 NM, and for non-precision approach, 0.3 NM.

The C129 receivers, which have fault detection (FD) capability only, stop providing a navigation solution when they identify a malfunctioning satellite. The C145/146 receivers are more sophisticated and can exclude data from a faulty satellite from the calculations in a process called fault detection and exclusion (FDE). FDE, which requires six satellites to be in the right place, reduces RAIM alerts, so the flight can continue with integrity.

FDE extends availability – the proportion of time the system is to be used for navigation during which the aircraft gets reliable navigation information – and continuity of service – the capability of the system to perform its function without unscheduled interruptions during the intended operation.

At the time of writing, CASA was keeping a watching brief on moves in the United States to approve C129 receivers upgraded to C145/C146 standards.

RAIM outages, or holes, are times when there are too few satellites with the appropriate spacing for integrity monitoring. This can be anticipated, and you can obtain RAIM predictions from Airservices Australia at www.airservicesaustralia.com. (Do not use your receiver’s prediction for flight planning, as it lacks some of the data forming the basis of the Airservices prediction.)

Meanwhile, many modern transport aircraft use another ABAS system integrating GNSS data with the aircraft’s inertial navigation system data. This boosts the availability of GNSS integrity in all phases of flight.

The GPS signal can also be checked at monitoring stations on the ground, with the resulting corrections and integrity data sent up to geostationary satellites for transmission down to aircraft receivers.

Geostationary satellites, about 40,000 km above the globe, are in orbits timed with the Earth’s rotation so that they appear to stay put with respect to a point on the ground.
Satellite-based augmentation systems (SBAS) comprise:

- A network of ground reference stations to monitor the GPS signals
- Master stations that collect and process reference station data and generate SBAS messages
- Uplink stations that send the messages to the geostationary satellites
- Transponders in the geostationary satellites that broadcast the SBAS messages to the aircraft.

The system delivers error corrections, extra ranging signals (from the geostationary satellite) and integrity information for each GPS satellite being monitored. Four SBAS systems were in place or under development at the time of writing. They were the European Geostationary Navigation Overlay Service (EGNOS), the Indian GPS and Geostationary Earth Orbit Augmentation Navigation System (GAGAN), the Japanese Multi-functional Transport Satellite-based Augmentation System (MSAS) and the US Wide Area Augmentation System (WAAS).

GBAS, or ground-based augmentation systems, provide GPS integrity monitoring through data obtained from the ground. They also boost the accuracy of satellite navigation, clearing the way for GNSS precision approach and landing.

A ground station at the airport transmits locally-relevant corrections, integrity data and approach data to aircraft in the terminal area in the VHF band.

At the time of writing, Australia’s first GBAS system was being trialled at Sydney Airport.

Airservices was also developing a ground-based regional augmentation system (GRAS). This system, a development of GBAS, sends augmentation information to the aircraft receiver via a VHF datalink from one of a group of ground-based transmitters covering a region.

**Galileo**

By 2006, the world’s first dedicated civilian GNSS constellation was under development. The European Union’s Galileo global navigation satellite system for land, sea and air applications was to have a constellation of 30 satellites divided between three circular orbits inclined at 56 degrees to the equator.

Orbiting the Earth at an altitude of around 23,222 km, the satellites would have a bigger footprint than their GPS counterparts, covering the entire surface of the planet.

Nine satellites were to be spread evenly around each orbital plane, with each taking about 14 hours to orbit the Earth. Each plane had an extra, dormant satellite able to cover any ailing satellite in its plane.
Like all automatic systems, GNSS is a double-edged sword: It cuts workload in some areas while increasing it in others. It delivers gains in reliability, accuracy and system monitoring ability but is open to gross mistakes that are difficult to pick up.

Ergonomic problems with the units, a lack of standardisation between them and the effect of the technology on what human factors specialists dub the liveware – you – are among sources of human error.

GNSS can distract you from other tasks, like scanning other instruments and for traffic. And it can lull you into a false sense of security, and take you ‘out of the loop’, at least until you have your first problem with it. It can even erode your basic navigational skills through lack of use.

Cross checking, an appreciation of the technology’s limitations and the ability to revert quickly to traditional navigational techniques are among defences.

The displays of many units are also quite small, creating the possibility of display reading errors. And warnings, including RAIM warnings, are often indicated by relatively small, symbols or lights.

Panel mount your unit in a prominent, central position and familiarise yourself with the displays.

See section 10 (Human factors considerations) of AC 21-36 for more information on receiver installation.

Mode errors also are a risk. GNSS units have different modes of operation, including ‘go-to direct’, nav’, ‘waypoint’, ‘alerts’ and ‘system status’, and the function inputs mean different things in different modes. And some equipment does not make the mode visible, forcing you to remember which one you are in.

Use your company’s standard operating procedures, and, ideally those recommended by the manufacturer.

Display conventions
The diffusion of GNSS technology from the military to GA and, finally, airlines, drove the evolution of diverse software and interfaces as manufacturers moved to differentiate their products from their competitors’.

Manufacturers call the shots on the design of GNSS displays, and a readout on one system might not translate to another.

With their small control keys, GNSS units are prone to data entry errors.
For example, one convention – the display of the active mode (text) in green or magenta (moving map) and the armed mode in white – might not be observed by all manufacturers.

Alert functions like ‘Loss of data integrity’ vary widely between units as well. Exacerbating the problem is the fact that the displays change as the unit progresses from en route, through terminal to approach mode.

GNSS approaches are built from a series of waypoints, all of which are entered into the system as a batch when you load the approach. When you activate the approach, the unit displays the waypoints as you progress through them. You see the next waypoint and the distance to it, not the distance to the missed approach point, unless you are on the last route segment of the approach.

**Liveware**

When you monitor a system like GNSS rather than control it directly, you are less likely to pick up and act on errors. In the long term, being out of the loop can erode skills like map reading, so you should maintain your basic navigation skills.

Another liveware problem is that GNSS can breed complacency, especially among trusting pilots who have never encountered problems with it.

Meanwhile, the brain’s information processing capacity can be exceeded during high workload phases of flight, and pilots sometimes shed tasks to focus on ones they think are more important.

You might lose situational awareness if you are struggling with GNSS technology in flight – flicking through manuals, for example. Familiarise yourself with the technology and do as much preparation as possible, like entering the waypoints for alternates, on the ground to cut the in-flight workload.

**Table 1 GNSS occurrences**

The following cases quoted or paraphrased from reports of occurrences around the world reveal the potential for human error in the use of GNSS equipment at all levels.

- “Due to a discrepancy between the flight plan stored in the GPS unit and the submitted flight plan, the aircraft tracked via a waypoint that was not on the flight plan.”
- “The pilot contacted ATS and requested clearance to enter the CTR. ATS reported the pilot sounded unsure and further questioning revealed the aircraft was already on a wide left base … The pilot claimed the aircraft’s GPS indicated 54nM away from the destination.”
- “ATC queried the pilot regarding navigation aids, to which the pilot reported to have no operable navigation aids on board. The pilot requested a radar heading. However, ATC could not issue a heading as the aircraft was out of radar coverage. Subsequently the pilot reported that the GPS had come back online and indicated a heading of …”
- “… the crew expected to see the selected Initial Approach Fix radial not a changed radial as the IAF … The (operator’s) crew were very familiar with stand alone GPS Approach procedures which they had been using for nearly two years. The reported incident was the first occasion the crew had flown a DME arc procedure and (Location) is the
“(Procedure Name) STAR was granted and programmed into the GPS. The aircraft then tracked normally as required to (Waypoint). From (Waypoint) the aircraft then turned in towards (Destination) instead of tracking via the 1DMe arc onto Final. The error was picked up by the crew and the autopilot was disconnected and at the same time ATC also took corrective action by assigning a radar vector.”

“The crew of an outbound aircraft had climbed through the altitude specified by ATC. Their aircraft was only 500 ft vertically distant and 1.25 nm horizontally distant from an inbound aircraft before ATC advised immediate descent. The investigation report explained that the pilot had given over his attention to the co-pilot who was struggling to reprogram their ‘broken down’ GPS unit.”

“The accident report of a collision between two aircraft stated that the pilot of one of the aircraft became preoccupied with programming his GPS unit and impacted the other aircraft, the pilot of which was practising ground reference manoeuvres at the time.”
Since its inception, GNSS has evolved into one of the principle means of navigation in Australia. There are limitations, depending on the sophistication of the receiver, of which you must be aware. The first limited approvals for GPS were published in 1994, and since then CASA has gradually increased the list of approved operations. Most recently, the appearance of TSO-C145/C146 avionics has eliminated dependence on conventional navaids in some circumstances.

Details of the approvals are in the AIP and current regulations. CASA also publishes advisory material and pilots should refer to CAAP 179 A-1 for the latest information.

**VFR operations**

You can use GNSS under the visual flight rules in the following applications:

- visual navigation
- night VFR RNAV

Pilots operating under the VFR may use GNSS to supplement map reading and other visual navigation techniques. This is not an approval to replace visual navigation techniques with GNSS. Blind faith in GNSS has been blamed for a sharp rise in the number of violations of controlled and restricted airspace by VFR aircraft. You should also be aware of the human factors and technical standards issues associated with different types of receivers and installations, as described in CAAP 179A-1(1).

**Night VFR**

In addition to the use of GNSS to supplement visual navigation, you may train and obtain qualifications to use GNSS equipment as a night VFR navigation aid in Australian domestic airspace.

If GNSS performance degrades to the point at which an alert is raised, or there is other cause to doubt the integrity of GNSS information, the pilot in command must discontinue GNSS use and carry out appropriate navaid failure procedures.

**IFR**

CASA approves the use of GNSS for a variety of IFR applications. These include:

- DR Substitute
- IFR RNAV
- RNAV(GNSS) non-precision approach
- Oceanic RNAV
- GNSS landing system (GLS)

As in the case of VFR, if GNSS performance degrades to the point at which an alert is raised, or there is other cause to doubt the integrity of GNSS information, the pilot in command must discontinue the use of GNSS and carry out appropriate navaid failure procedures.
4

GNSS operations
and requirements

Common GNSS practice is to:
- plan the route using charts
- enter the plan into the GNSS unit or retrieve a saved plan from volatile memory
- check the information in the GNSS database and the user waypoint information against charts or a flight plan containing waypoint names, identifiers, latitude/longitude, tracks and distances. (Cross checking both latitude/longitude information and bearing/distance information will help prevent a charted error being carried over to the GNSS.)
- When entering data manually, get two crew members to check the inputs are accurate and reasonable. If the information is suspect, check it against appropriate documents. If you are flying single pilot, do your own cross checking by comparing GNSS computer tracks and distances against current chart data. Use ‘Flight plan mode’ to compare GNSS-derived distance and bearing information with your own flight plan.
- check each route leg for track and distance as a double check for input errors

Check that manually-entered and database-derived position tracking information is reasonable in the following cases:
- before each compulsory reporting point
- at or before arrival at each en route waypoint
- every hour during area type operations when deviating from established routes
- after insertion of new data, like the creation of a new flight plan.

And
- Check GNSS NOTAMs and other warning information.
- Check that the data are current. This is often displayed at start-up.
- Carry the GNSS operating manual for the unit installed in your aircraft.
You must carry operating instructions for your GNSS unit on board, and, if a commercial operator, incorporate them into your company operations manual.

And you must follow the operating instructions and any additional requirements specified in the approved aircraft flight manual or flight manual supplement.

In addition to GNSS, the aircraft must be equipped with serviceable radio navigation systems as required (Refer AIP).

**GNSS prediction**

Before planning to use GNSS for IFR approaches, get a RAIM prediction from the Airservices Australia briefing website.

RAIM outages are predicted at 1400 UTC each day and when new satellite outage information is received.

RAIM predictions are based on:

- satellite geometry
- differing equipment RAIM capability (FD or FDE)
- certification status (C129 or C146).

The introduction of TSO C146 equipment, which does not necessarily have barometric aiding fitted, created the possibility that RAIM would be unavailable more often. (Barometric aiding provides a position input so that RAIM can be delivered with as few as four satellites.)

For this reason, the predictions are tailored specifically to C129 or C146 installations.

**Selecting operational modes:** TSO-specified GNSS equipment has several different modes used in flight planning and in flight, including:

- ‘nav’ or ‘map’ mode – the primary navigation mode used in flight
- ‘waypoint’ – enabling you to access waypoint information
- ‘flight plan’, in which flight plans can be created, edited, stored and recalled
- other modes that allow you to access information on equipment status, the satellite constellation and other features, such as winds aloft.

**Recalling categories of information from ‘nav’ database:** GNSS navigation databases contain several waypoint types, including: airports, VORs, NDBs, intersections, SIDs, STARS, and approaches. Take care to select the correct waypoint.

You can usually customise the worldwide database within your receiver to access information on the Australasian region only.

**Predicting RAIM in flight:** Most TSO-specified GNSS equipment can predict the availability of RAIM at the destination. You may use this function before commencing an RNAV GNSS approach. The prediction function typically indicates RAIM FD availability at the destination 15 minutes either side of the specified time.

**Entering and checking user-defined waypoints:** You can create user waypoints and store them in the system but you should validate them against published information, like ERSA and charts, or cross check them using bearing and distance information from a known waypoint.

**Entering, retrieving and checking flight plan data:** When you enter or retrieve a flight plan from the GNSS database, cross check each route segment for track and distance with your own flight plan and current charts.

**Interpreting typical GNSS nav displays lat/long, distance and bearing to waypoint,**

**CDI:** GNSS equipment can display navigation information in several formats, including bearing and distance to known waypoints, and latitude and longitude data. It also uses a CDI-style display, which represents a distance, not an angular displacement, from track. For example, full-scale deflection on a GNSS CDI might indicate 5 nautical miles off track rather than 10° off track, as would be the case for a VOR. You can select the sensitivity of the CDI to suit your requirements. Learn how to access the settings to determine the display’s sensitivity and change the scale if necessary.

**Intercepting and maintaining GNSS-defined tracks:** The navigation display includes the current track made good to help you maintain the desired track. Some GNSS displays have a track error graphic to help you intercept the desired GNSS track. Track made good, ground speed, ETA, time and distance to waypoint are in the ‘nav’ or ‘map’ fields. If an air data computer is connected to the unit, wind velocity in-flight is calculated automatically. If you don’t have an air data computer, you will have to enter TAS and present heading manually to enable the unit to compute winds aloft.

**Indications of waypoint passage:** The GNSS display indicates arrival at a waypoint. Monitor it when approaching a waypoint as the indication might be brief. You can change the duration of the indication through the set-up function.
Use of ‘Direct to’ function: You can use the ‘Direct to’ or ‘Go to’ function to navigate directly from your current position to a nominated waypoint. This function is most useful when ATC instructs you to ‘track direct’ from present position or that a weather diversion is required. Beware of the new track’s possible proximity to controlled airspace and restricted area boundaries when using this function, and cross check against current maps, charts and NOTAM information. The ‘direct to’ function will usually take you off a published ERC track, and you will need to reassess lowest safe altitude along the revised track.

‘Nearest airport’ function: GNSS equipment can give you a list of the nearest airports, VORs, NDBs, intersections and approaches. The nearest airport function can be useful in funding a safe haven in an in-flight emergency.

Use of GNSS, and GNSS or DME arrival procedures: When using GNSS for IFR navigation:

- The GNSS database must be current and endorsed by the receiver manufacturer and must be immune to modification by crew.
- RAIM must be available below the LSAAlt/MSA when conducting operations in IMC.
- If there is a contradiction between any sources of information, climb to the LSAAlt/MSA as soon as possible.
TSO-specified GNSS equipment uses internal and external message lights to convey special messages to you. New messages are indicated by a flashing light. Press the message key to access them. The unit will store messages relevant to the current stage of flight, and the message light will remain steadily illuminated. Press the message key to sequence through all messages stored. When the unit no longer deems the messages relevant, it deletes them and the light goes off.

**Loss of integrity:** When the receiver loses the RAIM function, integrity cannot be guaranteed. Different units have different messages to indicate this situation, and you should ensure you are familiar with the receiver before using it in IMC. If RAIM is lost, navigation should not be based on the GNSS solution. This may involve climbing to LSALT or other navaid failure procedures.

**RAIM errors and failures:** Various warnings are displayed when RAIM detects a failure in the navigation solution. Some units disable the navigation display. You must use another means of navigation.

**2D navigation:** The equipment is no longer tracking enough satellites to provide a 3-dimensional navigation solution. RAIM is not available. With aircraft altitude information either automatically or manually entered, the equipment may still provide a very basic navigation function, but the accuracy and integrity cannot be assured and equipment may not be used for IFR navigation.

**Dead reckoning mode:** The receiver has not located enough satellites to make a positive fix. It is possible to enter heading and ground speed data to the receiver which will then provide a DR navigation function. The receiver may continue to display navigation information, but it is not suitable for IFR use.

**Database out of date:** The installed database (ie datacard) has expired. It is possible to acknowledge this message and continue with out-of-date data, but the current database is needed for navigation approvals.

**Database missing:** The database card is missing or not properly installed. Turn the equipment off and install a database card or remove and replace the existing card. Follow the manufacturer’s instructions when handling data cards.

Some GNSS equipment and their data cards may be damaged by attempting to remove or install the card while unit is on.

**GPS file or receiver fail:** These or similar warnings appear when the GNSS electronics has detected an internal failure. It is usually necessary to have the equipment repaired by a manufacturer or authorised service centre.

**Barometric input fail:** The automatic barometric aiding function has failed. The equipment will usually prompt you to input altitude data manually and will then continue to provide navigation information. In this case, the equipment is unable to meet the requirements of IFR navigation.

**Power/battery fail:** Some equipment will continue to function on internal backup batteries. Use aircraft checklists to get the power back.

**Parallel offset on:** You have selected the parallel tracking mode. The equipment is guiding the aircraft along the selected offset track. You may have selected this function to track around a thunderstorm, for example. In controlled airspace, do not use parallel tracking mode without an ATC clearance. In Class G airspace, advise ATS of any intention to operate off track.

**Satellite fail:** The receiver’s RAIM function has detected a satellite failure. If there are enough satellites in view, the receiver can often deselect the faulty satellite and continue to provide navigation with RAIM.
Glossary

**ABAS**
Aircraft-based augmentation system

**Almanac**
A crude set of parameters used to approximate the orbits of satellites in the GNSS constellation.

**Availability**
The proportion of time the system is to be used for navigation during which the aircraft gets reliable navigation information.

**Continuity of service**
The capability of the system to perform its function without unscheduled interruptions during the intended operation.

**Coarse acquisition code (C/A code)**
A satellite-unique sequence of binary pulses transmitted by a GPS satellite and available to all users of the system. Also known as the civilian code.

**CDI**
Course deviation indicator

**DME**
Distance measuring equipment.

**Ephemeris**
The predictions of current satellite position that are transmitted to the user in the satellite data message. Each satellite transmits accurate ephemeris data unique to itself.

**FD**
Fault detection

**FDE**
Fault detection and exclusion

**GBAS**
Ground-based augmentation system

**GLONASS**
Global orbiting navigation satellite system

**GNSS**
Global navigation satellite system

**GPS**
Global positioning system

**ILS**
Instrument landing system

**Integrity**
The ability of a system to provide timely warnings to users when it should not be used for navigation.

**LSALT**
Lowest safe altitude

**PDOP**
Position dilution of precision. A measure of how satellite geometry affects navigation and time accuracy. PDOP multiplies range errors and increases position errors.

**RAIM**
Receiver autonomous integrity monitoring

**Reliability**
The probability of performing a specified function without failure under given conditions for a specified time.

**RNAV**
Area navigation

**SBAS**
Satellite-based augmentation system

**WAAS**
Wide area augmentation system

**WGS**
World Geodetic Survey
CASA CONTACTS

Licensing & Registration Centre
1300 737 032
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• Address updates
• AME licences
• Photo IDs
• Medicals

Service Centre
136 773
• ADCs & CoAs

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131 767
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Moorabbin Airport Mentone Vic 3194
PO Box 26 Moorabbin Vic 3194

Perth
130 Fauntleroy Ave Perth Airport WA 6104
GP Box 1082 Cloverdale WA 6105

Tamworth
Cnr Renatta St & Basil Brown Drive
Tamworth Airport NSW 2340
PO Box 895 Tamworth NSW 2340

Townsville
1 Coral Sea Drive
Townsville Airport QLD 4814
PO Box 7740 Garbutt Qld 4814

Brisbane
39 Navigator Place Hendra QLD 4011

Canberra
Cnr Northbourne Avenue & Barry Drive
Canberra ACT 2600
GP Box 2005 Canberra ACT 2601

Melbourne
Level 11, 505 Little Collins St
Melbourne VIC 3000
PO Box 558 Collins Street West Victoria 8007

Sydney
Building 235
Cnr Qantas Dr & Robey St., Mascot 2020
PO Box 409 Mascot NSW 1460

AIRLINE FIELD OFFICES

Brisbane
39 Navigator Place Hendra
Brisbane QLD 4011

Canberra
CASA Building
Cnr Northbourne Avenue & Barry Drive
Canberra ACT 2600
GP Box 2005 Canberra ACT 2601

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