Australian Government
Civil Aviation Safety Authority
CNS/ATM
Transforming airspace management
Resource guide
CNS/ATM Resource guide

This Resource guide and Workbook have been developed by CASA as a guide to operating in Australian airspace, with particular emphasis on satellite-based navigation and surveillance. They are part of a kit designed for both self- and class-based instruction, providing a foundation level of knowledge for the aviation community.

Who should use this resource kit?

This kit is designed for:
- flying training organisations
- all pilots—civilian and military
- remotely piloted aircraft (drone) operators
- air traffic controllers
- licensed aviation maintenance engineers
- avionics engineers
- aviation management
- human factors specialists.

How to use this resource guide

This guide is part of a resource kit that also includes:
- a practical workbook
- a DVD featuring aviation safety videos on a range of CNS/ATM topics
- electronic copies of this guide, workbook and videos are available from www.casa.gov.au/cnsatm

We encourage members of the aviation community to use the kit as part of their individual professional development. Organisations are encouraged to use it to develop training packages or self-contained sessions.

Additional resources and information

Please visit the CNS/ATM section of the CASA website www.casa.gov.au/cnsatm or email cns@casa.gov.au
## Contents

<table>
<thead>
<tr>
<th>Chapter 1</th>
<th>Overview of CNS/ATM</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>CNS: Don’t be nervous about the acronyms</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Benefits of CNS/ATM</td>
<td>6</td>
<td></td>
</tr>
<tr>
<td>Components of CNS/ATM</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Managing airspace safely and effectively</td>
<td>12</td>
<td></td>
</tr>
<tr>
<td>CNS and human factors</td>
<td>13</td>
<td></td>
</tr>
<tr>
<td>The rules</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Key points</td>
<td>14</td>
<td></td>
</tr>
<tr>
<td>Resources</td>
<td>15</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 2</th>
<th>Communication</th>
<th>17</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voice and data communication</td>
<td>18</td>
<td></td>
</tr>
<tr>
<td>Operations with controller-pilot data link communications (CPDLC)</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>SATCOM voice</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>Key points</td>
<td>20</td>
<td></td>
</tr>
<tr>
<td>Resources</td>
<td>21</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 3</th>
<th>Global navigation satellite systems</th>
<th>23</th>
</tr>
</thead>
<tbody>
<tr>
<td>How does GNSS work?</td>
<td>24</td>
<td></td>
</tr>
<tr>
<td>Augmentation systems</td>
<td>26</td>
<td></td>
</tr>
<tr>
<td>ABAS</td>
<td>27</td>
<td></td>
</tr>
<tr>
<td>SBAS</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>GBAS</td>
<td>31</td>
<td></td>
</tr>
<tr>
<td>En route radio navigation</td>
<td>33</td>
<td></td>
</tr>
<tr>
<td>Finding position using GNSS</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>GNSS performance: accuracy, availability, integrity and continuity</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Navigation databases</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>Key points</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Resources</td>
<td>41</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 4</th>
<th>Surveillance and ADS-B</th>
<th>43</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is ADS-B?</td>
<td>44</td>
<td></td>
</tr>
<tr>
<td>Benefits of ADS-B</td>
<td>47</td>
<td></td>
</tr>
<tr>
<td>Using ADS-B</td>
<td>48</td>
<td></td>
</tr>
<tr>
<td>ADS-B phraseology</td>
<td>53</td>
<td></td>
</tr>
<tr>
<td>Operations</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>Aircraft equipment</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>Key points</td>
<td>58</td>
<td></td>
</tr>
<tr>
<td>Resources</td>
<td>59</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 5</th>
<th>Aircraft equipment</th>
<th>61</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiver standards</td>
<td>62</td>
<td></td>
</tr>
<tr>
<td>Safety first with avionics</td>
<td>63</td>
<td></td>
</tr>
<tr>
<td>Navigational data</td>
<td>64</td>
<td></td>
</tr>
<tr>
<td>Equipment failures</td>
<td>65</td>
<td></td>
</tr>
<tr>
<td>Pre-flight requirements checklist</td>
<td>66</td>
<td></td>
</tr>
<tr>
<td>Key points</td>
<td>67</td>
<td></td>
</tr>
<tr>
<td>Resources</td>
<td>67</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Chapter 6</th>
<th>Performance-based navigation</th>
<th>69</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is PBN?</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>What does performance mean?</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Specifications</td>
<td>70</td>
<td></td>
</tr>
<tr>
<td>Benefits of PBN</td>
<td>72</td>
<td></td>
</tr>
<tr>
<td>How PBN provides more flexibility than conventional navigation</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Instrument approaches</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>Enabling legislation</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>Key points</td>
<td>78</td>
<td></td>
</tr>
<tr>
<td>Resources</td>
<td>79</td>
<td></td>
</tr>
</tbody>
</table>
# Chapter 7

**Flight planning**

- Eight phases of flight 82
- Electronic flight bags 82
- GNSS operations and requirements 84
- RAIM prediction and NOTAMs 87
- Alternate routes 88

**Key points** 90

**Resources** 91

# Chapter 8

**Human factors**

- Don’t be led astray 94
- Influences on people 94
- Situational awareness 98
- Cockpit ergonomics 100
- Airmanship tips 101

**Key points** 102

**Resources** 103

# Chapter 9

**Instrument flight rules operations**

- Transition to performance-based navigation 106
- IFR RNAV 108
- RNAV (GNSS) non-precision approach 109
- Oceanic RNAV 113

**Key points** 114

**Resources** 115

# Chapter 10

**Visual flight rules operations**

- Visual navigation 118
- Night VFR 119
- VFR qualifications 120

**Key points** 120

**Resources** 121

# Appendices

- Abbreviations 124
- Definitions 126
- Rules and information 128
CNS/ATM describes a new approach to integrated air traffic management (ATM) in the satellite age.

It brings together voice, satellite and digital Communications, performance-based Navigation (PBN) and automatic dependent Surveillance broadcast (ADS-B), as well as ground-based systems such as radar and fixed navaids.

This chapter provides an introduction to CNS/ATM, explores its benefits and components and outlines the relevant rules and regulations.
CNS: Don’t be nervous about the acronyms

In the medical world, CNS is the acronym for central nervous system, vital to sustaining life. And so, in a sense, it is in aviation.

Clear Communication, accurate Navigation and Surveillance-based control and guidance have long been important for safe and efficient flying, but as skies become more crowded, any one of them can become a limiting factor in airspace capacity.

As the International Civil Aviation Organization (ICAO) puts it, CNS/ATM is:

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Communications, navigation and surveillance systems, employing digital technologies, including satellite navigation systems together with various levels of automation, applied in support of a seamless global air traffic management system
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Many of these digital technologies have been around for some time. For example, global navigation satellite systems (GNSS) receivers have been in Australian civil aviation use since 1995.

What is new, however, is thinking of these technologies as an integrated system of air traffic management.

In Australia, regulations mandate the fitting of CNS equipment such as Mode S transponders and automatic dependent surveillance-broadcast (ADS-B) to instrument flight rules (IFR)-operated aircraft. These are used in combination to implement performance-based navigation (PBN).

Benefits of CNS/ATM

For pilots and operators, CNS/ATM offers significant efficiencies and improvement in safety, particularly (but not only) for those operating under IFR.

For those involved in airspace management, such as air traffic controllers, it means being able to process more aircraft more efficiently and safely.
The need for change: limitations of legacy technologies

Previous technologies have a number of limitations and effects.

<table>
<thead>
<tr>
<th>Limitation</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radar and VHF have limited range</td>
<td>Over oceans, aircraft are out of radar range and use unreliable and inefficient HF radio for voice communication.</td>
</tr>
<tr>
<td>Transmit limited amount of information</td>
<td>Legacy technologies can be insufficient for automated systems to operate effectively.</td>
</tr>
<tr>
<td>Expensive infrastructure</td>
<td>Legacy technologies require large and costly structures on the ground, each one of which serves only a limited area.</td>
</tr>
</tbody>
</table>

Advantages of modern CNS/ATM technologies

The advantages and benefits of this new system are shown in the following table:

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global</td>
<td>Many operators and pilots are now using a worldwide satellite network.</td>
</tr>
<tr>
<td>High bandwidth</td>
<td>The ability to transmit and receive large volumes of digital data allows position reports and weather forecasts to be transmitted automatically and frequently, rather than relying on the limited information of a voice transmission.</td>
</tr>
<tr>
<td>Accurate</td>
<td>Global navigation satellite systems, such as GPS, the Chinese BeiDou, the Russian GLONASS, and the European Union’s Galileo have accuracies of single metres or less when augmentation systems are used.</td>
</tr>
</tbody>
</table>
Components of CNS/ATM

The relationship between the various components of communication, navigation, surveillance and air traffic management systems can be seen in the following diagram.
Chapter 1: Overview of CNS/ATM

- Radar
- VHF / HFCPD
- ADS-B IN
- ADS-B OUT
- Communication satellite
- SBAS
- GBAS
- Navigation satellites
- Air Traffic Management
- Surveillance
Communication

Radio

Voice communication using very high frequency (VHF) radio remains an essential part of routine and emergency air to ground (and air to air) communication. In emergency operations, voice tone and nuance provide valuable information. Many pilots have spoken of the reassuring effect of hearing a calm controller’s voice. However, VHF can transmit information only as fast as a person can speak coherently, and it cannot handle multiple transmissions on the same frequency. Technology such as controller-pilot data link communications (CPDLC) can significantly reduce the demand for bandwidth and time. Increasingly, routine air traffic management (ATM) air–ground communication services will use data communications, with voice for real-time, critical communication.

Aircraft can reply to ATC with a standard format message or in free text. Messages from a controller normally follow a standard format, with response required to most messages. CPDLC’s advantages include:

- reduced congestion of voice channels
- fewer communication errors
- lower workload for pilots and controllers.

Communication is discussed in more detail in Chapter 2 of this guide.

Navigation

Performance-based navigation (PBN) is the ‘N’ in CNS. PBN standards require a particular level of navigation accuracy. Required navigation performance (RNP) equipment must have on-board performance monitoring and alerting systems to provide assurance the system is working properly. As with all CNS standards, there is no specified technology. However in Australia, GNSS such as GPS is the only practical means of performing en route, terminal and approach operations.

PBN’s accuracy and cost advantages make it hard to justify maintaining an extensive network of old-technology navaids, such as VHF omnidirectional range (VORs) and non-directional beacons (NDBs). About half of these were decommissioned in 2016, but Airservices Australia is maintaining some as a backup navigation network (BNN). Read more about PBN and its practical applications in Chapter 6.

Surveillance

The S in CNS stands for surveillance, such as automatic dependent surveillance-broadcast (ADS-B). This technology uses GNSS equipment and a transponder-like broadcaster to determine the aircraft’s height, position and speed, and broadcasts this, along with its identity, twice per second.

Australia has had an operational ADS-B network since 2009. It uses a network of ground stations to ‘listen’ to these aircraft broadcasts and transmit information to ATC and to aircraft with ADS-B IN equipment. Aircraft fitted with ADS-B IN can also receive aircraft transmissions and display them to the pilot for situational awareness. ADS-B is seamless between countries.

In some parts of Australia, a system known as multilateration (MLAT) uses existing aircraft transponders and a network of ground receivers as an alternative to radar and/or ADS-B.
Air traffic management

The main air traffic management benefit of CNS is reduced aircraft separation in controlled airspace. Aircraft can now be operated closer together with no compromise to safety. Separation standards in oceanic airspace have reduced from 180 nm to 50 nm and then to 30 nm, with the prospect of satellite-based ADS-B systems allowing minimums of less than 15 nm.

Transforming airspace management: the Cold War to hot technology

1960s Global navigation satellite systems (GNSS) had their 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 was crude.

1970s The US launched its global positioning system (GPS), and the Soviets, GLONASS. Before long, the technology was being used in just about every aspect of civilian life, including aviation.

1994 CASA’s predecessor, the Civil Aviation Authority, approved the use of GPS as a supplemental IFR en route navigation aid, putting Australia at the forefront of regulation of GNSS technology.

1998 The development of GPS non-precision approaches (NPAs) began when a non-precision approach (NPA) for Goulburn Airport, near Canberra, was given the green light. Fuelled by the low cost of GNSS and safety enhancement of straight-in approaches, NPAs proliferated and many Australian airports now have them. The first approvals for GPS approaches were based on technical standard order (TSO) C129 equipment, but that technology had reached its limits by the turn of the century.

2000s Superseded by units delivering gains in accuracy, integrity and continuity of service, the TSO C145, C146 and C196 receivers enabled general aviation pilots to spend more time utilising data from satellites 20,000 km above the Earth’s surface. GNSS equipment with augmentation was designed to allow precision approaches and automatic landing.

2002 The US introduced the first satellite-based augmentation system (SBAS) and authorised localiser performance with vertical guidance (LPV) approaches with decision altitudes similar to ILS Cat 1.

2004 ICAO set the global direction for PBN, establishing area navigation (RNAV) and required navigation performance (RNP) specifications.

2007 ADS-B avionics were first used for in flight operations in Australia, with non-complying ADS-B units disabled.

2009 Australia submitted a PBN implementation plan to ICAO and tabled a 2010–2016 timetable for implementation of approaches with vertical guidance.


2016 Mandate requiring all Australian-registered aircraft operating under IFR to be fitted with GNSS avionics came into effect. Airservices Australia turned off around 180 ground-based navigation aids as part of the transition to GNSS-based navigation.
Benefits

The main benefits of CNS/ATM are:

- increased aircraft capacity, especially in congested airspace
- increased schedule flexibility
- better flight path efficiency
- less disruption due to delays and diversions
- increased efficiency from reduced separation minimum.

Managing airspace safely and effectively

Improvements in air traffic management can help reduce aviation fuel burn and as a result, reduce the levels of aircraft engine emissions. This can be achieved by:

- establishing more direct routes
- reducing use of holding patterns
- improving access to optimal cruising levels and constant descent approaches where engines can be throttled back for a steady near-glide to the threshold.

The seamless integration to which ICAO refers is ‘rapid and reliable transmission between ground and airborne system elements’. The promise is that more accurate and reliable navigation systems will also allow aircraft to navigate in all types of airspace and operate closer together with the same or better safety than under current separation standards.

The figure opposite shows the reduction in distance and elevation between aircraft over a 25-year period.

Reduced separation minimums over time

Separation standards refer to the minimum vertical and horizontal distance that aircraft operating in controlled airspace and at airports with an operational control tower must observe. Different separation standards apply to aircraft operating under instrument flight rules (IFR) and visual flight rules (VFR).

Satellite navigation allows an aircraft to navigate to any location using optimum flight paths. It opens up short cuts in the sky and sets aircraft free of the fixed routes required with ground-based navigation aids.

How close can they go—IFR aircraft

In Australia, aircraft flying under IFR in controlled airspace up to flight level (FL)290 must be separated by 1000 ft vertically, unless they are separated horizontally. Above FL290, the vertical separation increases to 2000 ft, except in airspace where reduced vertical separation minimums (RVSM) is applied. When aircraft are separated vertically, horizontal separation can be reduced without compromising safety.

In controlled en route airspace, the horizontal separation standard between aircraft flying at the same altitude is 5 nm. In terminal area airspace, the minimum separation is 3 nm.
Within the confines of an airport control zone, the separation can be as close as practicable as long as the aircraft remain separated. In airspace not monitored by radar or other satellite-based navigation services, aircraft separation is achieved by the use of procedural rules including time and estimated position.

### How close can they go—VFR aircraft

Visual separation depends on where aircraft are flying. For example, over Sydney Harbour, sightseeing helicopters use ‘see and avoid’ principles, where pilots maintain their own separation. For general aviation aircraft outside controlled airspace, separation can be as close as 500 ft vertically and horizontally.

### Loss of separation occurrences

A loss of separation assurance (LOSA) occurs when there has not been a clear application of a separation standard. This can happen for a number of reasons and does not necessarily mean there has been an infringement of separation.

### CNS and human factors

Human factors research seeks the best possible fit between people and the systems in which they operate by applying knowledge of human capabilities and limitations. In aviation, human factors are the social and personal skills, such as communication and decision making, which complement technical skills, and which are important for safe and efficient operations.

The ICAO addressed the importance of human factors considerations in the design of CNS/ATM systems as long ago as 1994 when it looked at the impact of automation and advanced technology on the human operator. ICAO stated that automation must meet the needs and constraints of designers, purchasers and users of the system. Chapter 8 examines GNSS-related human factors issues.
The rules

CASA is moving towards a complete set of operating rules for private operations, and will supplement the rules applicable to corporate/business, air experience, aerial work and air transport operations.

For an updated list of applicable rules see the CASA website at: www.casa.gov.au/landing-page/rules-and-regulations

Key points

- CNS brings together satellite and digital communications, performance-based navigation (PBN) and automatic dependent surveillance broadcast (ADS-B). The advantages of modern CNS technologies are that they are global, high bandwidth and accurate.

- The use of satellite navigation systems where the user performs on-board position determination from satellite information has been adopted as global navigation satellite systems (GNSS).

- The chief air traffic management benefit of CNS is reduced aircraft separation in IFR. Aircraft can now be operated closer together, with no compromise to safety.

- Controller-pilot data link communications (CPDLC), used in Australia since 1998, is a means of communication between air traffic control (ATC) and pilot, using a data link instead of voice. Its three main advantages include reduced congestion of voice channels, fewer communication errors and reduced workload for pilots and controllers.

- Required navigation performance (RNP) equipment must have on-board performance monitoring and alerting systems to provide assurance the system is working properly.

- ADS-B uses a network of ground stations to ‘listen’ to these aircraft broadcasts and transmit information to ATC twice per second and, if they have ADS-B IN equipment, to the aircraft.

When you are ready, please turn to page 6 of the workbook and complete the exercises.
Resources

Further reading


References


The communications element of communication, navigation, and surveillance in air traffic management (CNS/ATM) is evolving with technology. Although emerging communication technology means more use is being made of data link communications, most operations will still use very high frequency (VHF) and high frequency (HF) voice communication.

This chapter will look at emerging trends in communication, en route radio navigation, controller-pilot data link communications (CPDLC), satellite communications (SATCOM) voice and operations in North Atlantic high level airspace.
• Voice and data communication 18
• Operations with controller-pilot data link communications (CPDLC) 19
• SATCOM voice 19
• Key points 20
• Resources 21
Voice and data communication

Airborne radio has been used in Australia for nearly 100 years, and voice communication on VHF and HF remains a vital part of air-to-ground and air-to-air communication. UHF voice is used by the military.

However, there is an increasing emphasis in both civil and military on the transfer of messages via digital codes. These screen-based messages use services such as the controller-pilot data link communication (CPDLC), a technology which emerged in the late 1990s.

As Australian aviation transitions from ground- to satellite-based navigation, communication and surveillance will be transformed by the introduction of four dimensional (4D) trajectories. When fully implemented, air traffic controllers (ATCs) will be able to plot the precise flight path an aircraft will take before an aircraft takes off. This will allow them to map out the projected trajectories of all flights in Australian airspace.

OneSKY Australia program

By 2021, Australia is aiming to provide air traffic control services using one of the most advanced and integrated air traffic control systems in the world. In collaboration with the Department of Defence, Airservices Australia aims to provide a single flight information region for Australian skies under an integrated air traffic management system. The current civilian system, known as The Australian Advanced Air Traffic System (TAAATS) built in the 1990s and commissioned in 2000, will be retired.

One of the key operational and safety benefits from the new system is that an air traffic controller (ATC) at any of the 200 consoles across Australia will be able to access the same flight information simultaneously, reducing the risk of sharing incorrect information. It will place Airservices and the Department of Defence in a position to manage the forecast growth of air traffic movement in Australia.
Operations with controller-pilot data link communications (CPDLC)

CPDLC has been used in Australia since 1998. It uses a two-way data link, instead of voice, to transmit non-urgent information between air traffic control (ATC) and pilots. CPDLC can be used to issue clearances, such as weather deviations, altitude clearances, amended route clearances, speed instructions, as well as secondary surveillance radar (SSR) codes and frequency transfers.

CPDLC is used in a range of operations, including:

- oceanic airspace—instead of the unreliable and interference-prone high frequency (HF) radio
- other airspace at the discretion of the controller.

CPDLC functionality is integrated with the flight data record (FDR). When a CPDLC clearance is uplinked to an aircraft, the FDR is updated on receipt of the ‘will comply’ (WILCO) response from the flight crew. The controller accesses CPDLC message elements via the CPDLC editor.

SATCOM voice

In the 1990s, ICAO determined that future primary long-range communications with aircraft would be by HF or SATCOM data link, and at the time made no provision for satellite voice (SATVOICE). Under ICAO Standards and Recommended Practices (SARPs), SATVOICE is not recognised as an acceptable means of communication for air traffic services (ATS) purposes.

However, the transition to data link communications has not happened as envisioned, and HF voice communication remains a primary means of long-range communication.

Some countries have allowed SATVOICE to be used in lieu of a second HF communications system, providing the aircraft installation and ground segments of the system meet performance standards.

Status in Australia

SATVOICE is not authorised for ATS use in Australia because the Airservices Australia communications infrastructure does not support SATVOICE operations.

However, SATVOICE in North Atlantic high level airspace (NAT HLA) is permitted when authorised by CASA. About 3000 aircraft fly across the North Atlantic airspace daily, with approvals to operate in the ICAO NAT region airspace based on ICAO NAT DOC 007.

For unrestricted operations in the NAT region, operators must have fully functioning HF communications equipment. While SATVOICE and datalink communications are gradually being introduced into NAT operations, operators may still need HF datalink as back-up.
Operators who can demonstrate compliance with the ICAO satellite voice guidance material (SVGM) requirements may be authorised by CASA to use SATVOICE in the NAT HLA region. Aircraft must meet installation requirements and operational procedures must be appropriate.

In transitioning to performance-based navigation (PBN) requirements in this airspace by 30 January 2020, North Atlantic minimum navigation performance specification (NAT MNPS) was redesignated as the North Atlantic high level airspace (NAT HLA).

**Operations**

Aircraft operating in North Atlantic high level airspace require a CASA issued navigation authorisation until 30 January 2020, to coincide with the transition to PBN.

**Key points**

- Communication and surveillance are being transformed by the introduction of four dimensional trajectories which allow air traffic controllers (ATCs) to plot the precise flight path an aircraft will take before an aircraft takes off, allowing them to map out the projected trajectories of all flights in Australian airspace.
- CPDLC, used in Australia since 1998, is a means of communication between ATC and pilot, using a data link instead of voice. Its main advantages include reduced congestion of voice channels, fewer communication errors and reduced workload for pilots and controllers.
- Aircraft operating in North Atlantic high level airspace require a CASA issued navigation authorisation until 30 January 2020, to coincide with the transition to PBN.
Resources

Further reading

References
Australians have been early adopters of satellite navigation, using it for many activities and applications including aviation. The global nature of the technology is suited to Australia’s large land mass and low population density.

Many charter operators operating under visual flight rules (VFR), especially in remote areas, use panel-mounted or portable GNSS units.

Satellite-guided tracking and approach guidance are commonplace in instrument flight rules (IFR) operations.

This chapter will look at how GNSS works, what augmentation systems are in place and how to use these systems in aircraft operations.

It’s important to remember that the use of GNSS is no substitute for thorough flight planning—you can read up on this in Chapter 7.
How does GNSS work?

GNSS units receive signals generated from constellations of satellites, and have been guiding Australian pilots for more than two decades. The first approvals for GNSS approaches were based on technical standard order (TSO) C129 in the 1990s.

GNSS satellites orbit the Earth in several included planes. The orbital planes, and the spacing of the satellites within them, are optimised to provide a wide coverage of the globe. Signals from at least four satellites are required to determine a position, one for each of the three spatial dimensions, and one for accurate time. Australia has particularly good coverage: GNSS receivers can normally ‘see’ more than eight satellites at any given time.

The satellites complete one revolution, from west to east when viewed from the Earth, about twice a day. On-board thrusters are used to correct 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.

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. Master control stations and monitoring stations around the world, track and manage the satellites, relaying critical correctional data to them.

The GNSS signals are transmitted on multiple frequencies. For example, the US GPS transmits the civil signal on the L1 frequency (1,575.42 MHz), just above the distance measuring equipment (DME) band. Military and authorised users can get more accurate measurements on the encrypted ‘L2’ frequency (1,127.60 MHz).

The L5 frequency (1,176.45 MHz) band is reserved for aviation safety services. It features higher power, greater bandwidth and an advanced signal design which reduces errors caused by passage of the GPS signal through the ionosphere—a layer of charged particles up to 1000 km above the Earth’s surface.

GNSS constellations

There are four major GNSS constellations:

- the USA’s NavStar Global Positioning System (GPS)
- the Russian Federation’s GLObal NAvigation Satellite System (GLONASS)
- the European Union’s Galileo GNSS
- China’s BeiDou Navigation Satellite System.

Although ICAO standards have been published for all four constellations, and standards for multi-constellation avionics are under development, the only GNSS permitted for IFR flight in Australia is GPS.

Each system comprises a constellation of orbiting satellites supported by ground stations and aircraft receivers. These orbiting systems need to be complemented or ‘augmented’ by additional systems to produce the performance required by certain operations.

Developments in satellite technology and its use for aircraft navigation suggest that new satellite navigation systems will evolve in the future, each with unique characteristics. The four major GNSS constellations are outlined in the following table.
<table>
<thead>
<tr>
<th>GNSS</th>
<th>Global Positioning System</th>
<th>BeiDou Navigation Satellite System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational satellites</td>
<td>30+</td>
<td>20+</td>
</tr>
<tr>
<td>Owner/operator</td>
<td>United States Government system operated by the Department of Defense (DOD)</td>
<td>China National Space Administration</td>
</tr>
<tr>
<td>Service</td>
<td>The two levels of service provided are known as the standard positioning service (SPS) and the precise positioning service (PPS). SPS is available to all users and provides horizontal positioning accuracy of 36 metres or less, with a probability of 95 per cent. PPS is more accurate than SPS, but is available only to the US military and a limited number of other authorised users.</td>
<td>The service aims to provide global coverage with positioning, navigation and timing services, including an open and authorised service. The open service provides free location, velocity and timing data, with positioning accuracy of 10 metres, velocity accuracy of 0.2 metres/second and timing accuracy of 10 nanoseconds. The authorised service provides a more secure position, velocity, timing, communications services and level of integrity.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GNSS</th>
<th>Galileo</th>
<th>GLONASS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operational satellites</td>
<td>11+</td>
<td>24+</td>
</tr>
<tr>
<td>Owner/operator</td>
<td>European Union</td>
<td>Russian Federation’s MOD and managed by the Russian Space Forces</td>
</tr>
<tr>
<td>Service</td>
<td>The constellation is planned to have a bigger footprint than GPS, with 30 satellites. Galileo’s observed dual-frequency positioning accuracy is an average 8 metres horizontal and 9 metres vertical, 95 per cent of the time.</td>
<td>GLONASS shares the same principles of data transmission and positioning methods that are used in GPS and is also based on a constellation of orbiting satellites and a ground control segment. At peak efficiency, the standard-precision signal offers horizontal positioning accuracy within 5–10 metres and vertical positioning within 15 metres.</td>
</tr>
</tbody>
</table>
Augmentation systems

Having a way of alerting users that GNSS is underperforming is critical to the safety of the system. GNSS avionics have software to protect integrity—the measure of trust 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 cannot be used for the intended operation.

Aircraft based, satellite-based and ground-based augmentation systems can ensure integrity. A number of augmentation systems can be used to improve the navigational performance provided by the GNSS constellations.

### ICAO recognised augmentation systems used in Australia

<table>
<thead>
<tr>
<th>Type of augmentation</th>
<th>Benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>ABAS (Aircraft-based)</td>
<td>Resolves integrity deficiencies.</td>
</tr>
<tr>
<td>SBAS (Satellite-based)</td>
<td>Provides third-party monitoring of GNSS ranging signals and broadcasts corrections over a wide area from a communications satellite, with a moderate improvement in accuracy.</td>
</tr>
<tr>
<td>GBAS (Ground-based)</td>
<td>Provides third-party monitoring of GNSS ranging signals and broadcasts corrections over a local area from a ground station. GBAS provides a large improvement in accuracy and clears the way for GNSS precision approach and landing.</td>
</tr>
</tbody>
</table>
ABAS

Aircraft-based augmentation systems (ABAS) use on-board equipment designed to overcome performance limitations of the GNSS constellations. Current ABAS stand-alone receivers are designed to resolve integrity deficiencies. Highly integrated systems may use other aids such as inertial navigation.

The two ABAS currently in use are receiver autonomous integrity monitoring (RAIM) and the aircraft autonomous integrity monitor (AAIM).

RAIM

RAIM ensures that:

• an erroneous ranging signal from a satellite will not adversely affect the accurate navigation of the aircraft
• the constellation geometry is good enough to provide an accurate position—that is, the satellites are spread evenly across the sky
• if an error is detected within the constellation, pilots are notified that they cannot rely on GNSS for navigation.

RAIM calculates the worst error that might exist in the satellite that is most difficult to detect it in. GNSS avionics compare the navigation solutions from at least six satellites with the solution using all satellites except one. If there is a substantial difference between the two solutions, it is reasonable to assume an error in one satellite.

Upon detection of an error, some avionics can continue to operate by removing the erroneous satellite from the navigation solution—this is called fault detection and exclusion (FDE). However, if a second satellite is detected with a faulty ranging signal, the avionics will notify the pilot that GNSS cannot be relied upon for navigation. If the avionics cannot remove the satellite, it has fault detection (FD) only.

All TSO-C145, TSO-C146, and TSO-C196 GNSS receivers have FDE.

Some TSO-C129 GNSS receivers have FDE, while others have FD only.

The effect of constellation geometry depends on the phase of flight. As long as the horizontal protection level (HPL)—the measure of how good the geometry is—remains less than the required navigation performance (RNP) value for the phase of flight, the operation can continue. Some examples of RNP values for different phases of flight are:

• en route: RNP 2 (2 nm)
• terminal: RNP 1 (1 nm)
• approach: RNP 0.3 (0.3 nm)
• missed approach: RNP 1 (1 nm).

If GNSS avionics cannot provide a navigation solution with RAIM, they usually have two other modes of operation:

• 2D or 3D navigation solution without RAIM, or
• dead reckoning (DR), or loss of navigation solution.
Aircraft-based augmentation system positioning with six satellites to support fault detection and exclusion

Requirements for ground-based navais with different types of GNSS receivers (ref: AIP-GEN 1.5)

<table>
<thead>
<tr>
<th>C129 receiver</th>
<th>Other requirements</th>
<th>C145, C146 or C196 receiver*</th>
<th>Other requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Night VFR</td>
<td>1</td>
<td>Nil</td>
<td>1</td>
</tr>
<tr>
<td>IFR airwork</td>
<td>1</td>
<td>ADF or VOR</td>
<td>1</td>
</tr>
<tr>
<td>and private</td>
<td></td>
<td>If alternate required, there</td>
<td></td>
</tr>
<tr>
<td>operations</td>
<td></td>
<td>must be ground-based en-route</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>navigation to it.</td>
<td></td>
</tr>
<tr>
<td>IFR RPT</td>
<td>1</td>
<td>Ground-based approach navaid</td>
<td>1</td>
</tr>
<tr>
<td>and charter</td>
<td></td>
<td>with a suitable approach</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>required unless the alternate</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>is suitable for an approach</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>in VMC.</td>
<td></td>
</tr>
</tbody>
</table>

* or a later version
RAIM outages

RAIM outages, or holes, are times when there are too few satellites with the appropriate spacing for integrity monitoring. This can be anticipated with 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.

The figure below is an example of RAIM outages (holes) across Australia. The holes move in time and space, so you need a new prediction each time you fly.

Example of RAIM outage map of Australia

<table>
<thead>
<tr>
<th>RAIM hole outage duration in minutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-10</td>
</tr>
<tr>
<td>11-20</td>
</tr>
<tr>
<td>21-30</td>
</tr>
<tr>
<td>31-45</td>
</tr>
<tr>
<td>45-60</td>
</tr>
<tr>
<td>61-75</td>
</tr>
<tr>
<td>76-90</td>
</tr>
<tr>
<td>91+</td>
</tr>
</tbody>
</table>
AAIM

Aircraft autonomous integrity monitor (AAIM) uses the redundancy of position estimates from multiple sensors, including GNSS, to provide integrity performance that is at least equivalent to RAIM. AAIM uses inertial navigation solutions as an integrity check of the GPS solution when RAIM is unavailable, but GPS positioning information continues to be valid.

SBAS

Satellite-based augmentation systems (SBAS) support wide-area or regional augmentation by using additional satellite-broadcast messages—ranging, integrity and tracking signals.

Geostationary satellites about 40,000 km above the globe are in orbits timed with the Earth’s rotation. As the name suggests, they appear stationary with respect to a point on the ground. These geostationary satellites are owned and operated independently of the GNSS constellations.

*Satellite-based augmentation system transmitting integrity*
The SBAS system comprises:
- a network of ground reference stations that monitor satellite signals
- master stations that collect and process reference station data and generate SBAS messages
- uplink stations that send the messages to geostationary satellites
- transponders on these satellites that broadcast the SBAS messages.

By providing differential corrections, extra ranging signals via geostationary satellites and integrity information for individual constellation satellites, SBAS delivers a much higher availability of service than the core satellite constellations with RAIM alone.

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.

Operational SBAS and their launch dates include:
- FAA’s wide area augmentation system (WAAS) in 2003
- Japanese multi-function transport satellite (MTSAT) satellite-based augmentation system (MSAS) in 2007
- European geostationary navigation overlay service (EGNOS) in 2009
- Indian global positioning system (GPS) aided geostationary Earth orbit (GEO) augmented navigation (GAGAN) in 2016
- Russian Federation’s System for Differential Corrections and Monitoring (SDCM) is under development
- the Chinese Satellite Navigation Augmentation System (SNAS) is expected to be operational by 2020.

Other SBAS are being developed in South Korea and Africa.

**GBAS**

Ground-based augmentation systems (GBAS) 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.

An airport ground station transmits locally relevant corrections, integrity data and approach data to aircraft in the terminal area in the VHF band.
A system meeting ICAO’s GBAS requirements provides two services:

- precision approach service
- GBAS positioning service.

The **precision approach service** provides deviation guidance for GNSS landing system (GLS) approaches. A GBAS installation will typically provide GNSS corrections that support precision approaches to multiple runways at a single airport.

A GBAS **positioning service** could provide horizontal position, velocity and time information to support area navigation (RNAV) operations in terminal areas, though no such services are currently in use.

GBAS infrastructure includes electronic equipment which can be installed in any suitable airport building, and antennas for both the data broadcast and to receive the GNSS satellite signals. The cost and flexibility of GBAS has resulted in more runway ends having electronic precision approach guidance, resulting in significant safety and efficiency benefits.

GBAS can also provide multiple approaches to the same runway end with different touchdown points (during runway threshold repairs) and different glide path angles (reduce noise under the flight path).

See Chapter 9 for information about the use of GNSS in IFR operations, and Chapter 10 for its use in VFR and night VFR.
En route radio navigation

The AIP specifies that ‘aircraft must be navigated by the most precise means of track guidance with which the aircraft is equipped and the pilot is qualified to use. The order of precision is localiser (LLZ), GNSS, VOR, then NDB’.
(ENR 3.3.4.3).

Ground-based systems

Navigation by radio aids includes navigation mainly by reference to indications of bearing and distance indicated on VHF omnidirectional ranges (VOR), distance measuring equipment (DME) and automatic direction finding (ADF) equipment located on the aircraft. This information is derived from ground radio beacons (VOR, DME and non-directional beacons [NDBs]) or broadcast stations in the AM band.

Radio navigation aids and systems can be used by pilots to:
• determine aircraft position fix solely with reference to navigation aids and systems
• intercept tracks to and from navigation aids and systems
• maintain tracks within specified tolerances
• record, assess and revise timings as required
• recognise station passage
• undertake instrument approaches.

From ground- to satellite-based navigation

Airservices Australia has implemented the Navigation Rationalisation Project (NRP) in conjunction with CASA’s Civil Aviation Order (CAO) 20.18. This requires that all aircraft operating under IFR must be equipped with a TSO-C129, C145, C146 or C196 GNSS receiver.

The GNSS mandate of 4 February 2016 enabled Airservices Australia to implement the NRP. The project involved decommissioning about 180 ground-based aids, including NDBs, VORs and DMEs. For more information, go to: http://www.airservicesaustralia.com/projects/nrp/

This means that GNSS is now the primary means of navigation for all IFR aircraft. The backup navigation network (BNN) serves as a contingency in the case of failure in the GNSS constellation or in the aircraft receiver. However, because of the limited number and wide geographical spacing of remaining nav aids, the BNN alone may not be capable of sustaining navigation services to flight-planned destinations.
Finding position using GNSS

Getting a fix

GPS satellites broadcast two codes—the coarse/acquisition (C/A) code which is unique to the satellite and the navigation data message.

The codes contain information the receiver needs to determine latitude, longitude and altitude, and to synchronise its quartz clock with GPS time used through 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 from each satellite.

The C/A 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.

The GNSS receiver computes its distance from a satellite from the time it takes the signal from each satellite, 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 C/A 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.

GPS navigation solution

Four pseudo-range ($\hat{R}_i$) values

\[
\begin{align*}
SV1 & \quad X_1, Y_1, Z_1 \\
SV2 & \quad X_2, Y_2, Z_2 \\
SV3 & \quad X_3, Y_3, Z_3 \\
SV4 & \quad X_4, Y_4, Z_4 \\
\end{align*}
\]
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 require GPS-derived data to be in the WGS-84 coordinate system, or worldwide geodetic datum standard 84.

**A GPS unit display**

**Getting the timing right**

The principles underlying GNSS are simple, but the system is very complex in practice. The main problem is timing errors.

The main 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 whirlpool of ions—atoms stripped of their outer electrons by solar radiation. The rate to which they are slowed down depends on the thickness of the ionosphere, which changes continuously and cannot be predicted by the avionics.

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.

Multipath error, caused when obstacles near the GPS receiver reflect the radio waves, 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** (SA), which skewed the satellite clock and ephemeris data, was designed to prevent hostile forces using the publicly-available GPS system against the US.

This is important for aircraft fitted with C129 receivers, because these receivers assume SA is still switched on. This limits the availability, but not the accuracy, of GNSS. The newer C145/C146/C196 units, however, check to see if SA is off, or assume it is.
It takes data from four satellites—and four equations—to get position coordinates. The fourth satellite is needed to obtain the timing error, or user clock bias, in the receiver clock.

GPS measures time with an accuracy in the order of a few tens of thousandths of millionths of a second, and for this reason is used as a timepiece in fields ranging from telecommunications, through physics experiments, to electricity generation. 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.

**GNSS performance: accuracy, availability, integrity and continuity**

GNSS performance may be measured in a number of ways. While accuracy is the most obvious quality of a navigation system, other measures, such as system availability, data integrity and continuity of service, are also important.

**How accurate is GPS?**

It is impossible to put a single figure on the accuracy of GPS as it depends on several constantly changing factors, many of which affect the ionosphere—the largest single source of error. Common causes of reduced accuracy include:

- **Ephemeris software** calculates the position of planets and their satellites, asteroids or comets. Although the satellite orbits are extremely stable and predictable, they can be disturbed by gravitational effects of the Earth and Moon, and the pressure of solar radiation. This can generate errors of up to 3 metres.

- **Clock (timing)** errors due to inaccuracies in both the satellite and receiver clocks, as well as relativity effects, can result in position errors of up to 3 metres.

- **Receiver**—pseudo-random noise codes are at a lower level than the receiver ambient noise, due to the low signal strength of GNSS transmissions. This results in a fuzzy correlation of receiver code to the satellite code, and produces some uncertainty in the relationship of one code to another. The position error that results from this effect is about 1.5 metres.

- **Ionosphere error** is one of the most significant—up to 10 metres—with pseudo-range calculations from the passage of the satellite signal through the Earth’s ionosphere. It varies depending on the time of day, solar activity and a range of other factors. Ionospheric delays can be predicted and an average correction applied to the GPS position, although there will still be some errors introduced by this phenomenon.
ICAO standards and recommended practices (SARPs) specify the accuracy requirements for various phases of flight. Current technology can use the GNSS constellations to meet the IFR accuracy requirements for oceanic and domestic en route use, as well as for terminal area and non-precision (dive) approaches. Precision (glide) approaches require some form of GNSS augmentation to overcome the known limitations of the constellation systems.

**Availability**

Availability is defined as the percentage of time the services of a navigation system are accessible. It’s a function of both the physical characteristics of the environment and the technical capabilities of the transmitter facilities.

GNSS availability is the system’s capacity to provide the number of satellites required for position fixing within the specified coverage area. Theoretically, at least three satellites need to be in view to determine a two-dimensional (2D) position. In practice, four are required to establish an accurate three-dimensional (3D) position.

As mentioned on page 35, selective availability (SA) was, until 2000, used by the US Department of Defense to limit the accuracy of GPS to other than approved users. It artificially created a significant clock or ephemeris error. Many early GPS receivers were ‘hard-wired’ for SA in the expectation that civil use would need to assume that SA was active.
For receivers that cannot take advantage of SA being discontinued, average receiver autonomous integrity monitoring (RAIM)—fault detection (FD)—availability is 99.7 per cent for non-precision approach operations for a 24-satellite GPS constellation.

By contrast, receivers that can take advantage of SA having been discontinued have 99.99 per cent availability of RAIM (FD) for non-precision approaches. These percentages will vary depending on which satellites are out of service at any given time. Currently, the US maintains the constellation in a 27-satellite configuration, further improving availability.

**Integrity**

Integrity is the ability of a system to provide timely warnings to the user when the equipment is unreliable for navigation purposes. The concept of integrity includes both a failure to alarm and a false alarm.

In Australia, conventional ground-based navigation aids incorporate monitoring equipment at the ground site. Should the equipment detect an out-of-tolerance condition, the transmitter is shut down, and the user alerted by means of a flag or loss of aural identification.

GNSS integrity relates to the trust that can be placed in the accuracy of the information supplied by the total system. This includes the ability of the system to notify the pilot if a satellite is transmitting erroneous signals.

Individual GNSS satellites are not continuously monitored, and several hours can elapse between the onset of a failure and its detection and correction. Without some additional integrity monitoring, a clock or ephemeris error, for example, can have a significant effect on any navigation system using that satellite.

RAIM is the most common form of integrity monitoring and is discussed in more detail earlier in this chapter. Many non-aviation and non-TSO GPS receivers do not monitor integrity and will continue to display a navigation solution based on erroneous data.
Continuity

Continuity is the probability that the performance of a system, comprising all elements needed to maintain an aircraft’s position within a defined area), will be maintained from the beginning to the end of an operation.

**How many GNSS satellites does your aircraft receiver need to ‘see’ for various operations?**

<table>
<thead>
<tr>
<th>Number of satellites</th>
<th>Type of navigation</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-3</td>
<td>Nil</td>
<td>Not sufficient for navigation</td>
</tr>
<tr>
<td>4</td>
<td>3D</td>
<td>Position solution but no integrity monitoring</td>
</tr>
<tr>
<td>5</td>
<td>3D + RAIM</td>
<td>Can detect faulty satellite data (integrity) and will stop providing navigation solution</td>
</tr>
<tr>
<td>6 or more</td>
<td>3D + fault detection and exclusion</td>
<td>Capable of detecting and excluding faulty satellite data, and continuing to supply valid navigation solution. (TSO 145, 146 and 196 receivers only)</td>
</tr>
</tbody>
</table>

Navigation databases

RNP approaches require the use of a valid and current database.

The data on the GNSS approach extracted from the database includes other parameters for the approach, not just the waypoint positions. This information is used by the receiver to alter the course deviation indicator (CDI) scaling and change the RAIM protection limits.

The approaches are coded as a series of waypoints which the receiver can retrieve and automatically sequence during an approach. Included with the waypoint coordinates in the database is information about the waypoint type. This information includes whether the waypoint is a fly-over point, or a fly-by point, and whether it is an initial, intermediate, final or missed approach point.

Under the requirements of CAO 20.91:

- the database must be valid for the current aeronautical information regulation and control (AIRAC) cycle
- all terminal routes—standard instrument departures (SIDs), standard terminal arrival routes (STARs) and approaches—must be loaded from the database and may not be modified by the pilot except as provided for in the CAO.
Key points

- The four major GNSS constellations are the USA’s NavStar Global Positioning System (GPS), the Russian Federation’s GLObal NAvigation Satellite System (GLONASS), European Union’s Galileo GNSS and China’s BeiDou navigation satellite system.

- GNSS antennas on aircraft pick up signals generated from constellations of satellites. It is expected that about 120 satellites will be available once all four major systems are fully deployed by 2020.

- GNSS uses the difference in the time of travel of radio waves from at least four satellites to fix the position of the receiver and get an accurate value for time.

- Aviation 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.

- RAIM outages, or holes, are times when there are too few satellites with the appropriate spacing for integrity monitoring. The holes move in time and space, so you need a new prediction from Airservices Australia each time you fly.

- GNSS is now the primary means of navigation for all instrument flight rules aircraft, and is supported by the backup navigation network (BNN).
Resources


The surveillance component of CNS/ATM, GNSS-based automatic dependent surveillance-broadcast (ADS-B) has evolved from radar.

ADS-B offers a substantial increase in the areas covered by surveillance.

This chapter will introduce ADS-B, discuss airspace changes and cover installation and operation of equipment. Human factors in ADS-B is covered in Chapter 8.
CHAPTER 4
Surveillance and ADS-B

• What is ADS-B? 44
• Benefits of ADS-B 47
• Using ADS-B 48
• ADS-B phraseology 53
• Operations 55
• Aircraft equipment 57
• Key points 58
• Resources 59
What is ADS-B?

ADS-B is a broadcast surveillance system in which an aircraft automatically transmits to a ground station and other air traffic its identity, precise location, altitude, velocity and other information. The system requires an aircraft to be fitted with systems such as a barometric encoder and global navigation satellite system (GNSS) equipment. While ADS-B is required only for aircraft operating under instrument flight rules (IFR), it also offers substantial benefits for visual flight rules (VFR) pilots.

ADS-B ground stations comprise a receiver unit, an antenna and a site monitor. Ground stations across Australia are connected to the Airservices Australia digital communication infrastructure and, combined with radar, provide continent-wide, line-of-sight surveillance coverage above 30,000 ft, as well as significant coverage at lower levels.

ADS-B uses the same transponder as, but operates independently of, the aircraft radar and traffic collision alerting and avoidance (TCAS) systems. Most modern Mode S secondary surveillance radar (SSR) transponders are capable of transmitting SSR and ADS-B (also termed extended squitter) data. However Mode A/C and some older Mode S transponders do not support ADS-B.

Australia, Europe, the US, and the rest of the world have implemented ADS-B on the Mode S frequency band of 1090 MHz—most commonly called ten-ninety ES (extended squitter). In the USA, the FAA has deployed a redundant ADS-B system on 978 MHz called universal access transponder (UAT) for aircraft that operate below 18,000 feet. This system is not deployed in Australia and the avionics will not work—when importing an aircraft from the US, ensure it has the correct ADS-B equipment on board.

Combined radar and ADS-B coverage with initial ADS-B rollout
ADS-B transmission and display
On-board ADS-B equipment can consist solely of a transmission system to send ADS-B information (ADS-B OUT). Aircraft can also be equipped with ADS-B IN—a cockpit display of traffic information (CDTI).

**ADS-B OUT**
An ADS-B transmitter enables the identity, position and altitude of an aircraft to be determined and displayed to an air traffic controller. The signal is broadcast from the aircraft approximately every half second and, provided the aircraft is within the coverage volume of an ADS-B ground station, the data can be fed to the ATC facility and used to provide air traffic services.

**ADS-B transmission**
Information includes: position, altitude, identity, velocity vector and vertical rate. Typically broadcast twice per second.
**ADS-B IN**

Aircraft may also be equipped with a cockpit display of traffic information (CDTI) and associated receiver to display the broadcast positions of ADS-B OUT aircraft. CDTI may be combined with other systems, such as moving map navigation displays.

Aircraft fitted with transmitter only

Aircraft fitted with transmitter and receiver. Information displayed on display panel-mounted CDTI

Aircraft fitted with ADS-B transmitter only
**Benefits of ADS-B**

Australia’s adoption of ADS-B for air traffic surveillance across the continent outside conventional radar coverage offers a range of benefits to commercial and general aviation pilots flying using IFR. These are:

- Position reports by voice no longer required for identified ADS-B aircraft.
- Ability to approve continuous rather than stepped climbs and descents to and from cruising level.
- Greater flexibility in allocating appropriate flight levels at the request of pilots. (That is, to climb to optimum flight level, as aircraft weight decreases with fuel burn.)
- Airspace which previously had no radar, and only procedural separation services, can now have an ATC surveillance service.
- Greater ability for ATC to grant clearances to fly requested routes or levels.
- Aircraft are easier to locate for search and rescue (SAR).
- Giving priority to ADS-B equipped aircraft is Airservices’ policy (when doing so lowers the workload of ATC, thereby improving safety).
- Ability to replace radar.
What the air traffic controller sees

The ongoing rollout of ADS-B ground stations significantly improves surveillance coverage of aircraft across the continent, including at lower altitudes. By allowing controllers to more precisely ‘see’ aircraft, rather than relying on estimated position reports, ADS-B increases the level of service ATC can provide while increasing safety for everyone in the sky.

The control panel provides controllers with an integrated air situation display, showing positions from ADS-B and other sources on a single screen.

Assistance in-flight

Aircraft fitted with ADS-B experiencing any kind of in-flight incident or emergency will have their location more accurately pinpointed, meaning search and rescue operators will be able to respond more rapidly, particularly in remote areas.

Controllers routinely provide pilots with navigation assistance if they lose their position due to instrument failure, weather, or if they become incapacitated. This availability is enhanced by the precise accuracy of ADS-B.

There are many reasons to request altitude or flight level changes during flight, including avoiding poor weather, and reducing fuel burn and carbon dioxide emissions by improving the efficiency of your engine. Fitting ADS-B in your aircraft will raise the likelihood of ATC granting altitude or flight level changes during your flight, as they will more accurately ‘see’ your position in the air in relation to other aircraft nearby.

Using ADS-B

Before you fly with ADS-B, find out what you have to do. In most cases, this will be very little other than entering the correct fields in the flight plan, as the ADS-B broadcast is automatic. However, safe flight relies on you understanding what ATC might require of you, how to handle emergencies, and how to use the cockpit interface effectively.

ADS-B systems typically broadcast two means of identifying the transmitting aircraft:

- the aircraft address (also known as the 24-bit code), and
- the flight identification (FLTID)—the visual equivalent of a call sign—used to identify targets on a display and link them to their flight plans.

Aircraft address

Each aircraft has a unique aircraft address, which consists of a 24-bit code allocated by CASA. This code is usually entered into the unit by a licensed aviation maintenance engineer (LAME) at installation and may be expressed in either binary or hexadecimal format. The code is on the aircraft registration letter sent to aircraft owners by CASA. If your aircraft is not registered by CASA, you can get a code from the aircraft registry. See the CASA website www.casa.gov.au for more information.

The 24-bit aircraft address is safety critical information, so ensure it is correct before flying. An incorrect address could lead to traffic collision and avoidance systems (TCAS) on your or other aircraft not functioning correctly, to ATC confusing your aircraft with another, or not being able to ‘see’ it at all.
Flight identification

The FLTID is used in both ADS-B and Mode S secondary surveillance radar (SSR) technology. Up to seven characters long, it is usually set in airline aircraft by the flight crew via a cockpit interface. It enables air traffic controllers to identify an aircraft on a display and to correlate a radar or ADS-B track with the flight plan data.

Aircraft identification is critical information, so enter it carefully; punching in the wrong characters could lead to ATC confusing your aircraft with another. It is important that the identification exactly matches the aircraft identification (ACID) entered in the flight notification.

Air traffic control might ask you to change your FLTID if possible, so you must know if you can do so and how (see below). They might also ask you to stop transmitting an ADS-B signal because they have detected an error, such as altimeter failure, in your equipment. If you cannot do this, notify ATC immediately. (See ADS-B phraseology on page 53 for more detail.)

If the ADS-B transmitter and SSR transponder are combined, switching ADS-B off may also make the aircraft invisible to SSR and TCAS.

Intuitive correlation between an aircraft’s flight identification and radio call sign enhances situational awareness and communication. Airline aircraft will use the three-letter ICAO airline code used in flight plans, not the two-letter IATA codes.

Check the manual

Procedures for use of ADS-B transponders are likely to be different from those for older Mode C types. It is therefore important that pilots of ADS-B equipped aircraft ensure that their transponders are switched to the correct mode.

Case study—Which button would you push?

The VFR pilot of an aircraft which had recently been fitted with an ADS-B transponder selected the unit’s ON button (see illustration) before undertaking some circuits in class C airspace. Once airborne, the pilot was advised by air traffic control that the aircraft was not returning altitude information.

On the unit in question, a Garmin 335, the ON button powers the transponder, but disables altitude reporting. The pilot’s guide for the transponder says that the unit should always be in ALT mode (altitude reporting enabled) on the ground and in the air, unless instructed otherwise by ATC.
Setting the FLTID

Your call sign normally dictates the applicable option:

(a) the flight number using the ICAO three-letter designator for the aircraft operator if a flight number call sign is being used (e.g. QFA1 for Qantas 1, VOZ702 for Virgin 702)

(b) the nationality and registration mark (without a hyphen) of the aircraft if the call sign is the full version of the registration (e.g. VHABC for international operations)

(c) the registration mark alone of the aircraft if the call sign is the abbreviated version of the registration (e.g. ABC for domestic operations)

(d) the designator corresponding to a particular call sign approved by Airservices Australia or the Australian Defence Force (e.g. SPTR3 for Firespotter 3, ROLR45 for Roller 45)

(e) the designator corresponding to a particular call sign in accordance with the operations manual of the relevant recreational aircraft administrative organisation (e.g. G123 for Gyroplane 123). Don’t add any leading zeros, hyphens, dashes or spaces to the FLTID.

Sometimes an aircraft may need to use an aircraft identification and call sign other than that corresponding to the FLTID. Air traffic control may approve or direct the use of an alternative FLTID.

Correction of FLTID in flight

• If FLTID has been entered incorrectly, ATC will instruct you to re-enter ADS-B aircraft identification.

• If you are able to, you must then re-set the FLTID to exactly match the aircraft identification in the ATS flight notification.

• If you are unable to re-set the FLTID in flight (for example if the FlightID was configured by LAME) advise ATC that you are unable to comply.

Failure to enter your FLTID correctly means information from your ATS flight plan is not automatically linked to your ADS-B information. This causes:

• screen clutter on air traffic control displays—two different labels are displayed instead of one

• distraction

• increased controller and pilot workload to resolve FLTID error.

Incorrect FLTID entry by an air transport operator is a reportable event, and ATC is required to raise a safety incident report.
Flight planning and ATC displays

The flight planning format requires pilots to indicate the surveillance equipment carried and operated on the aircraft. Field 10b of the flight plan provides the following options for ADS-B equipped aircraft:

- E: Mode S transponder with Flight ID, pressure altitude and extended squitter (ADS-B) capability
- L: Mode S transponder with Flight ID, pressure altitude, extended squitter (ADS-B), and enhanced surveillance capability.

And for ADS-B fitment one of:

- B1: ADS-B OUT using 1090MHz, or
- B2: ADS-B IN and OUT using 1090MHz.

There are also other codes for ADS-B installations complying with other international standards, i.e. UAT.

Complete guidance on notifying surveillance equipment and capabilities in flight plans can be found in AIP ENR 1.10.

A typical field 10b flight plan entry for an ADS-B equipped aircraft will be: (Field 10a content)/EB1.

An aircraft address code is not usually needed on flight plans. However, if ATC has approved the use of a FLTID different from the ACID, the aircraft address will be needed to correlate the flight plan to the aircraft. Enter the aircraft address in item 18 of the flight notification as hexadecimal code (e.g. CODE/7C81CB).

Hexadecimal code is complex and non-intuitive, and easy to enter incorrectly, so use it only when necessary and check it carefully. If you lodge flight notification by radio, tell air traffic services the aircraft FLTID if it differs from the call sign.

Common errors in FLTID entries

| ABC_123 ✗ | ABC123 ✓ | 123 ✗ | ABC123 ✓ |
| Added spaces designator omitted | ICAO airline |

| AB123 ✗ | ABC123 ✓ | ABC0123 ✗ | ABC123 ✓ |
| IATA airline designator used | Additional zero inserted |

| AB0123 ✗ | ABC123 ✓ | BNEMEL ✗ | ABC123 ✓ |
| Zero added and one letter of ICAO airline designator dropped | DEP/DEST/Alternate details used instead of Flight ID |
How the FLTID must exactly match aircraft in your ATS flight plan

 exemplo: (FPL-ABC123-IS -B738/M-SADE2E3FGHIRWYZ/LB1 -YSSY0905 -M077F370 DCT ENTRA Y245 BANDA H185 CG/NO452F360 Q69 ITIDE DCT HBA DCT -YHBA0121 -PBN/A1S2T1 NAV/GPSRNAD DDF/121225 REG/VHABC EET/YBBB0013 OPR/ ABACUS AIRLINES PER/C RMK/TCAS)

Flight plan procedures

Operators who meet the Australian requirements for ADS-B operations must indicate ADS-B capability in the flight notification (ATS flight plan) of all approved ADS-B equipped aircraft when planning to operate in Australian airspace.

Example:
(FPL-ABC123-IS -B734/M-SDHIRWZ/C -YBBN0735 -M074F360 DCT LAV H62 CORKY H39 SY DCT -YSSY0106 -REG/VHAUS PER/B RMK/ADSB NAV/ GPSNAVSATPHONE)
ADS-B performance requirements for ATC

Airservices uses a hierarchy system on The Australian advanced air traffic system (TAAATS) displays. Radar is displayed first, followed by ADS-B, followed by ADS-C and then the flight plan track of the aircraft if there is no surveillance coverage.

In the future, however, ADS-B will be displayed first, then radar.

Loss or degradation of GNSS integrity in the airborne receiver is transmitted to air traffic control in the ADS-B messages. ADS-B services may be terminated if GNSS integrity is inadequate.

ADS-B phraseology

Specific and generic radio phraseology is used for ADS-B and radar services. You should use specific phraseology when it is necessary to differentiate between radar and ADS-B. The ADS-B equivalent of ‘squawk’ is ‘transmit’ and ADS-B is pronounced ‘ay-dee-ess-bee’ over the radio.

Otherwise, you can use generic phraseology when it is not necessary to differentiate between a service provided by radar and one provided by ADS-B. In many of these cases, no change to existing phraseology is required. For example, ‘identified’ and the various vectoring instructions apply to either technology.

The following table lists some examples, but users should check the AIP for the current terminology.
### Circumstance

<table>
<thead>
<tr>
<th>Termination of radar and/or ADS-B service</th>
<th>Identification terminated (due [reason]) (instructions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radar or ADS-B ground equipment unserviceability</td>
<td>Secondary radar out of service or Primary radar out of service (appropriate information as necessary)</td>
</tr>
<tr>
<td>Identification terminated (due [reason]) (instructions)</td>
<td>ADS-B out of service (appropriate information as necessary)</td>
</tr>
<tr>
<td>To request the aircraft’s SSR or ADS-B capability</td>
<td>Advise transponder capability</td>
</tr>
<tr>
<td>To advise the aircraft’s SSR or ADS-B capability</td>
<td>Transponder (Alpha, Charlie or Sierra as shown in the flight plan) or Negative transponder</td>
</tr>
<tr>
<td>To request reselection of FLTID*</td>
<td>Re-enter Mode S aircraft identification</td>
</tr>
<tr>
<td>To request the operation of the IDENT feature*</td>
<td>Squawk ([code]) (and) Ident</td>
</tr>
<tr>
<td>To request termination of SSR transponder or ADS-B transmitter operation*</td>
<td>Stop squawk (transmit ADS-B only)</td>
</tr>
<tr>
<td>To request transmission of pressure altitude*</td>
<td>Squawk Charlie</td>
</tr>
<tr>
<td>To request termination of pressure altitude transmission due to faulty operation*</td>
<td>Stop squawk Charlie Wrong indication</td>
</tr>
</tbody>
</table>

* Some older ADS-B installations may not provide for entry of FLTID, transmission of Ident, or isolation of pressure altitude by the pilot. Such systems are no longer compliant with CAOs. Some ADS-B installations may share controls with the SSR transponder, so that you cannot operate the two systems independently. If you cannot comply with a particular instruction, advise ATC and ask for other instructions.
Operations

Emergency codes

The method for notifying ATC of an emergency depends on the type of equipment carried and the surveillance coverage available, so make sure you know which equipment is on board. Does the aircraft have an ADS-B emergency function? Or an on/off switch only? Is it linked to the transponder, so that squawking 7600 also sends an ADS-B communications failure message?

Selection of an emergency transponder code, e.g. 7600, automatically generates an emergency indication in the ADS-B message. However, many transponders transmit only a generic ADS-B emergency indication. That means the specific type of emergency, such as communications failure, may not be conveyed to controllers in an ADS-B environment. Some general aviation installations may not broadcast any form of ADS-B emergency indication.

Required emergency procedures

If an emergency indication is received from an aircraft in ADS-B airspace and the flight crew does not verbally communicate the nature of the emergency, the controller will initiate procedures for suspected unlawful interference.

Phraseology: `<call sign>` CONFIRM SQUAWKING ASSIGNED CODE

If no response from the pilot is received within a reasonable time, the controller will assume the possibility of unlawful interference.

Note: Some transponders cannot transmit an ADS-B 'IDENT' (SPI) while an emergency transponder code is selected.

Does your transponder transmit discrete emergency codes, or does it transmit a generic emergency code only?

In an emergency, use all available means to signal your status, regardless of expected surveillance and communications coverage.
Traffic awareness with cockpit displays

Before flying, you must understand the capabilities of your cockpit display of traffic information (CDTI) and how to best use it for traffic awareness.

CDTIs will help you spot other ADS-B traffic more easily by showing you where to look. However:

- depending on the unit’s filtering capability, your CDTI might not show all ADS-B traffic
- CDTIs will not display non-ADS-B traffic
- don’t try to second-guess ATC instructions with CDTI information
- do not attempt to take evasive action, or to separate your aircraft from other traffic, using a CDTI. It is there to enhance situational awareness, not to replace separation procedures.

Cockpit display of traffic information does not replace see-and-avoid. You still have to look out the window for other traffic.

Radar or ADS-B?

You may not always know which surveillance system is being used and how you are being controlled. You may be told only that you have been ‘identified’, but it may not be clear whether you have been identified with radar, ADS-B or both. Unless ATC uses specific phraseology, use both ADS-B and transponder equipment to give the controller the best surveillance picture.

Surveillance coverage and controlled airspace often have different boundaries.
Aircraft equipment

In Australia, ADS-B is transmitted on the 1090 MHz extended squitter datalink, also known as 'Ten Ninety'. Standards for the extended squitter avionics are defined in Civil Aviation Order 20:18. CASA has also published Australian TSOs C1004 and C1005.

What are the rules?

- Non-compliant ADS-B transmissions must be disabled.
- Operation at/above FL290 requires ADS-B.
- All aircraft flying IFR must be equipped for GNSS navigation and be fitted with ADS-B.

**GNSS provides the positioning information for ADS-B, so if you turn the GNSS receiver off, your aircraft will become invisible to ADS-B surveillance.**

ADS-B equipment can have various pilot interfaces, ranging from a simple on/off switch for the transmitter to a pilot control interface with advanced features, such as a cockpit display of traffic information.

It may also be combined with other systems, such as a secondary surveillance radar (SSR) transponder, traffic collision avoidance system (TCAS) or multifunction display (MFD). In most aircraft installations, the SSR transponder control module in the cockpit also controls the ADS-B transmitter; operating the SSR system will also operate the ADS-B system.

International variations

A number of states around the world are implementing ADS-B. While harmonised as much as possible, there are some differences in equipment requirements and fitment. For example, the USA requires either DO260B (also accepted by Australia) or universal access transceiver (UAT) technology, which is not used in Australia.

Anyone importing a GA category aircraft from the United States should make sure the ADS-B fitted is the 1090MHz system, not the UAT system. Anyone who has imported an IFR aircraft since February 2014 should make sure it is ADS-B and Mode S capable.

What to do when something goes wrong?

Chapter 5 explores installation and recovery procedures for aircraft equipment.
Key points

- ADS-B avionics broadcast identification, position, altitude, velocity and other data automatically about every half second, with air-to-ground and air-to-air applications.

- Aircraft fitted with ADS-B experiencing any kind of in-flight incident or emergency will have their location more accurately pinpointed, meaning search and rescue operators will be able to respond more rapidly, particularly in remote areas.

- Operators who meet the Australian requirements for ADS-B operations must indicate ADS-B capability in the flight notification (ATS flight plan) of all approved ADS-B equipped aircraft when planning to operate in Australian airspace.

- If the ADS-B transmitter and SSR transponder are combined, switching ADS-B off may also make the aircraft invisible to SSR and TCAS.

- GNSS provides the positioning information for ADS-B, so if you turn the GNSS receiver off, your aircraft will become invisible to ADS-B surveillance.

- In most aircraft installations, the SSR transponder control module in the cockpit also controls the ADS-B transmitter; operating the SSR system will also operate the ADS-B system.
Resources

Further reading


References


Integrated systems, training requirements and data management are providing operators and pilots with a more complex operating environment.

PBN requires not only that the pilot is suitably trained and qualified, but also that the aircraft is appropriately equipped.

This chapter covers receiver standards, use of avionics, navigational data, troubleshooting equipment failures and recaps on the requirements checklists.
CHAPTER 5
Aircraft equipment

- Receiver standards 62
- Safety first with avionics 63
- Navigational data 64
- Equipment failures 65
- Pre-flight requirements checklist 66
- Key points 67
- Resources 67
Receiver standards

Aircraft equipment certified for different operations is measured against a technical standard. These standards are developed by regulators across the globe including:

- US Federal Aviation Administration as a technical standard order (TSO)
- European Aviation Safety Agency as a European technical standard order (ETSO)
- CASA as an Australian technical standard order (ATSO).

Pilots can identify the TSO status of GPS equipment by referring to the compliance stamp on the receiver, or by referring to the operating handbook in the aircraft. Reference to a manufacturer’s model number is not a guarantee of TSO certification.

Non-TSO

Non-TSO GPS receivers do not have to meet any regulatory standards for power supply, installation, lighting, database, integrity monitoring or performance. For example, many hand-held units not identified as suitable for aviation purposes are unable to operate when the aircraft groundspeed exceeds 99 knots.

Navigation information from non-TSO equipment should be treated with extra care until verified by another source.

Day VFR

CASA does not prescribe any required equipment standards and both panel-mount and hand-held equipment may be used for day VFR operations. Non-TSO equipment can be used to supplement visual navigation under VFR.

Night VFR

For night VFR operations you can also use a non-TSO receiver to supplement visual navigation, but such equipment cannot be used to meet alternate aerodrome, mandatory aircraft equipment, or flight crew qualification requirements.

IFR

A non-TSO receiver does not meet any of the requirements for IFR navigation.
## Safety first with avionics

To ensure safety, pilots must use GNSS properly. Here are some safety tips:

<table>
<thead>
<tr>
<th>Advice</th>
<th>Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Use appropriate standard avionics equipment</td>
<td>Hand-held and panel-mount VFR equipment does not ensure the integrity and reliability needed for IFR and some night VFR applications.</td>
</tr>
<tr>
<td>✓ Use a database valid for the operation</td>
<td>Many non-aviation databases lack accuracy, and currency is critical for operations relying on GNSS for navigation clear of terrain, obstacles and airspace boundaries.</td>
</tr>
<tr>
<td>✓ Check that all procedures that could be required are present in the database</td>
<td>Data storage limitations have resulted in some manufacturers omitting certain data, such as small aerodromes, from the receiver database.</td>
</tr>
<tr>
<td>✓ Always carry and use current VFR charts, as they are the primary reference for navigation</td>
<td>VFR receivers can be used to supplement map reading in visual conditions. Some VFR units show airspace boundaries and terrain, but there is no standard for this data and no guarantee that the depiction is correct.</td>
</tr>
<tr>
<td>✓ Portable receivers and related cables should be positioned carefully in the cockpit</td>
<td>Avoid the potential for electromagnetic interference (EMI), and to avoid interfering with aircraft controls.</td>
</tr>
<tr>
<td>✗ Don’t rest the GPS on the glareshield near the magnetic compass</td>
<td>This can create electromagnetic interference. Be aware also of the potential for EMI from mobile phones and other personal electronic devices.</td>
</tr>
<tr>
<td>✗ Do not be tempted to design your own approach</td>
<td>Approach designers receive special training and use specific tools. There are many levels of validation before an approach is commissioned.</td>
</tr>
<tr>
<td>✗ Never fly below published minimum altitudes while in instrument conditions</td>
<td>Accidents have resulted from pilots placing too much reliance on the accuracy and integrity of GNSS.</td>
</tr>
<tr>
<td>✗ Don’t rely on a backup battery to give a navigation solution following an electrical failure</td>
<td>The backup battery may also fail, so additional redundancies should be employed. Pilots should continue to use and practise navigation skills by running a basic plot at all times.</td>
</tr>
<tr>
<td>✗ Resist the urge to fly into marginal weather when navigating VFR</td>
<td>The risk of becoming lost is small when using GNSS, but the risk of controlled flight into terrain or obstacles increases in low visibility.</td>
</tr>
</tbody>
</table>
Directions for GNSS use

There are various requirements for the use of GNSS in an aircraft. Details are in CAO 20.91 but in summary:

- If a GNSS database contains details of waypoints and navigation aids that are published in maps and charts required to be carried in the aircraft, those details must not be capable of modification by the aircraft operator or flight crew. This does not prevent the storage of ‘user-defined data’ within the equipment.
- The database must also be current and provided by an approved supplier.
- The manufacturer’s operating instructions for the GNSS receiver must be carried in the aircraft, in a place easily accessible to the pilot.
- If the aircraft is engaged in commercial operations, the operating instructions must be incorporated in the aircraft’s operations manual.
- GNSS equipment must be operated in accordance with its operating instructions.
- Additional requirements relating to the operation of GNSS equipment may be incorporated in an aircraft’s flight manual, if they are consistent with the operating instructions.
- Manually-entered data must be cross-checked by at least two flight crew members for accuracy.
- In the case of a single-pilot operation, manually entered data must be checked against other aeronautical information, such as current maps and charts.

Navigational data

Data integrity

A significant number of data errors in general applications occur as a result of human error during manual data entry. Whenever possible, navaid and waypoint positions should be derived from a commercially prepared aviation database which cannot be modified by the operator or crew.

In some situations, it may be necessary to create ‘user’ waypoints by manual entry. In this situation, pilots are responsible for the integrity of the data and must follow CASA’s directions for cross-checking. Manually entered data must not be used for navigation below the lowest safe altitude (LSALT) or minimum sector altitude (MSA), unless specifically authorised by CASA.

Stored user waypoints and stored flight plans are considered manually entered data and must be checked prior to use.

Database currency

Many VFR databases do not have an expiry date, as the VFR equipment is intended only to supplement visual navigation using current charts and documents.
All IFR databases have an expiry date, as data currency (integrity) is critical to safe navigation without visual reference.

The principal requirements relating to GNSS navigation data are:

- GNSS navigation requires a current database appropriate to the operation
- only data from a current database should be used for IFR flight.

**GNSS navigation database maintenance**

Quality control of the navigation database includes the maintenance required to update it. Some equipment may require a maintenance authority from CASA. They can also provide advice for particular GNSS units.

**WGS84 coordinate system**

Waypoint coordinates, particularly those used for approach and landing, must be based on the same geodetic reference system used by satellite positioning systems. ICAO and Australia have adopted the coordinate system known as the World Geodetic System of 1984 (WGS84) as the common geodetic reference datum for civil aviation.

> Pilots and operators should ensure that WGS84 is selected as the default geodetic reference in their GPS receivers.

**Equipment failures**

**Potential operating failures for GNSS units**

Although very unlikely to occur, potential errors include:

- GNSS constellation failure—pilots can revert to use of ground-based navaids
- single satellite failure within a constellation failure—if FDE is functioning, the GNSS unit should locate a new satellite. If no FDE is operating, revert to ground-based navaids
- electrical failure or distortion in screen display—reboot device.

Commercial operators will have a second GNSS unit fitted, which will likely still be operational.

**Common installation problems for ADS-B transponders**

Over the past years the following installation faults have repeatedly occurred. It is strongly recommended that the LAME use an ADS-B capable transponder test set.
### Fault Advice

<table>
<thead>
<tr>
<th>Fault</th>
<th>Advice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incorrect setting of ‘SIL’ value for DO260A/B transponders</td>
<td>Needs to be 2 (10E-5) or 3 (10E-7).</td>
</tr>
<tr>
<td>Incorrect 24-bit address</td>
<td>Ensure ICAO 24-bit address matches the CASA-assigned code.</td>
</tr>
<tr>
<td>Incorrect Flight ID</td>
<td>Domestic aircraft should not include ‘VH’ unless on international flight leg. Not ‘N’ as can easily be entered for a common GA transponder.</td>
</tr>
<tr>
<td>Incorrect software version in GPS or transponder</td>
<td>Regularly update software and navigation database.</td>
</tr>
<tr>
<td>NUC or NIC set to 0</td>
<td>NUC or NIC should not be 0, because it indicates the data has no integrity.</td>
</tr>
<tr>
<td>Non-compliant ADS-B transponder installed</td>
<td>It MUST be disabled.</td>
</tr>
</tbody>
</table>

### Pre-flight requirements checklist

All pilots (VFR and IFR) must have checked and completed the following:

- **Battery**
  - power supply

- **Database**
  - must be current

- **Pilot operating handbook (POH)**

- **NOTAMs**
  - check RAIM and planned outages

- **Flight review**
  - check if current

- **EFB, maps and charts**
  - packed and accessible in cockpit

- **SARTIME**
  - lodged

- **Personal administration**
  - up-to-date licences, medicals and required memberships

IFR requirements in addition to those for all pilots include:

- **Approach**
  - appropriate instrument rating

- **Currency**
  - 90 days

- **Receiver**
  - must be correct TSO for the type of operations

- **Installation**
  - IFR with baro-aiding if available

- **Manual**
  - must be on the aircraft

- **RPS**
  - RAIM prediction service (RPS) must be used for planning

- **Report**
  - any GNSS interference or database errors
Key points

- For day VFR operations, CASA does not prescribe any required equipment standards and both ‘panel-mount’ and ‘hand-held’ equipment may be used. Non-TSO equipment can be used to supplement visual navigation under VFR.

- For night VFR operations you can also use a non-TSO receiver to supplement visual navigation, but such equipment cannot be used to meet alternate aerodrome, mandatory aircraft equipment or flight crew qualification requirements.

- Portable receivers and related cables should be positioned carefully in the cockpit to avoid the potential for electromagnetic interference (EMI), and to avoid interfering with aircraft controls.

- For IFR operations, GNSS navigation data must be drawn from a current database appropriate to the operation and only data from a current validated database may be used for navigation below the LSALT or MSA.

Resources

Further reading

References


The navigational component of CNS/ATM is performance-based navigation or PBN, which is becoming more common worldwide. For more than 15 years, Australian aviation has been adopting GNSS-based area navigation in place of ground-based navigation aids such as non-directional beacons (NDB) and VHF omni-range (VOR) for the en route, terminal and approach phases of flight.

This chapter will introduce PBN, discuss PBN-based approach designs and look at deeming provisions for GNSS-equipped aircraft.
• What is PBN? 70
• What does performance mean? 70
• Specifications 70
• Benefits of PBN 72
• How PBN provides more flexibility than conventional navigation 75
• Instrument approaches 75
• Enabling legislation 77
• Key points 78
• Resources 79
What is PBN?

Performance-based navigation (PBN) is the internationally recognised regulatory framework for implementing area navigation, with an emphasis on GNSS as the enabling technology.

PBN includes the definition of navigation specifications in terms of the accuracy, integrity, continuity and functionality required for various types of operations. It uses on-board equipment such as global navigation satellite systems (GNSS) receivers, stand-alone navigators, and integrated navigation systems.

PBN is absolute navigation—the aircraft determines its current latitude and longitude, and where it is in relation to the intended flight path. As long as the aircraft has a means of determining its current position, it can operate anywhere within coverage of the relevant GNSS system.

This contrasts with traditional relative navigation, based largely on fixed ground-based navigation aids which guide aircraft along published routes via waypoints defined by the aids.

What does performance mean?

Under PBN, airspace and route design take into account the aircraft operations in the region, and the capability of aircraft flying in it.

Both aircraft and flight crew must meet performance standards for the route, which may change with the flight phase (en route, approach etc.) and the class of airspace in which the aircraft is flying.

Specifications

PBN encompasses two types of navigation specifications:

- RNAV (area navigation), and
- RNP (required navigation performance).

The difference between the two specifications is that on-board performance monitoring and alerting is required for RNP but not for RNAV. RNAV requires independent performance monitoring of an aircraft’s position.

RNP has parallel lateral performance requirements and can be supported by a variety of technologies. In Australia, RNP operations require GNSS but can be supplemented by inertial systems.
RNAV
The RNAV family of navigation specifications were created by ICAO to consolidate the disparate approvals developed by countries around the world, including:
- US RNAV Type A & B
- European B-RNAV and P-RNAV
- Australian AUSEP and GPS OCEANIC

While it remains possible to operate using RNAV based on DME/DME, DME/VOR or inertial navigation systems, Australia lacks the substantial infrastructure required to do so. For this reason, GNSS will be the basis of navigation for most aircraft.

RNAV defines fixes by name, latitude and longitude. These area navigation fixes allow planning of routes which are less dependent on the location of navaisds.

RNP
In an aircraft using a stand-alone GNSS, the functionality requirements of RNP are achieved through the use of receiver autonomous integrity monitoring (RAIM).

Integrated area navigation systems employ several sources of information, such as inertial and GNSS, to provide highly accurate navigation. They use aircraft autonomous integrity monitoring that are equivalent to RAIM.

Further information on augmentation systems is available in Chapter 3.
RNAV specifications, except oceanic and remote RNAV 10 (RNP 10), are not implemented or used in Australian airspace.

**Australia is implementing the following navigation specifications**

<table>
<thead>
<tr>
<th>Navigation specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNP specifications (requires on-board performance monitoring and alerting)</td>
</tr>
<tr>
<td>RNAV specifications (no requirement for on-board performance monitoring and alerting)</td>
</tr>
<tr>
<td>En route and terminal specifications: RNP 2, RNP 1, RNP APCH, RNP AR APCH, RNP 0.3</td>
</tr>
<tr>
<td>Oceanic and remote specifications: RNP 4, RNP 2, RNAV 10 (RNP 10)</td>
</tr>
</tbody>
</table>

Although RNP 10 is a commonly used specification, it actually belongs in the RNAV family. This is a product of history.

**Benefits of PBN**

Performance-based navigation allows pilots, operators and air traffic control to make the best use of advances in navigation technology and brings increased safety, efficiency and environmental benefits.

The International Civil Aviation Organization (ICAO) says that PBN helps the aviation community by reducing congestion, helping to maintain reliable all-weather operations at even the most challenging airports, conserving fuel, protecting the environment, and reducing the impact of aircraft noise. The benefits can be seen in the table below.

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Development</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced separation standards for all phases of flight</td>
<td>As the skies become busier, PBN allows the most efficient use of available airspace, through appropriately managed reductions in separation standards during the en route, approach and landing phases. Australia’s airways system can handle more aircraft and do this more safely within time and airspace constraints.</td>
</tr>
<tr>
<td>PBN and GNSS allow straight-in approaches</td>
<td>ICAO data shows that straight-in approaches are 25 times safer than circling approaches. Adding vertical guidance to the approach brings a further safety gain.</td>
</tr>
</tbody>
</table>
### The importance of accurate position estimates

Technologies such as ADS-B help overcome some of the limitations of ground-based navigation aids in en route position finding. But they are not a substitute for good communication practices.

A number of safety incident reports have involved pilots either not arriving at a reporting point within two minutes of their estimate, or not updating their estimate when it was outside the two minutes, as required in the Aeronautical Information Package (AIP).

The majority of these reports involved aircraft in a climb, descent, regaining track after a diversion, or around the Australian flight information region boundary.

In areas outside radar or ADS-B coverage, air traffic controllers use the aircraft track, altitude and position estimates advised by the pilot to provide separation from other aircraft or airspace. This means that if your tracking, altitude or estimates provided to ATC are not accurate, it is possible that your separation with other aircraft or airspace may also be compromised.

Further information is available from the Airservices Australia website: [www.airservicesaustralia.com](http://www.airservicesaustralia.com)

<table>
<thead>
<tr>
<th>Reduced reliance on radio-navigation aids through widespread use of GNSS-enabled PBN</th>
<th>Most airports are served by satellite-based approaches. In many cases, these have replaced approaches using NDB and VOR radio-navigation aids. These ground-based aids are 70-year-old technology, which is becoming increasingly expensive to install and maintain. About 180 ground-based navaids were switched off from May 2016 as part of Airservices Australia’s navigation rationalisation project. The remaining aids are retained for contingency navigation only.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reduced track miles/fuel burn/ carbon dioxide emissions during landing approaches</td>
<td>PBN reduces unproductive flight time, unnecessary delays and fuel burn, providing obvious economic benefits to operators and the environment. Advanced PBN applications now under development will deliver further efficiencies through time-of-arrival control and continuous descent arrivals (CDFA). Four dimensional air traffic management will bring even more efficiency, with aircraft operating on direct routes at optimum altitudes, thus avoiding the congested arrival holding pattern.</td>
</tr>
<tr>
<td>Global harmonisation</td>
<td>ICAO’s PBN navigation standards are being applied worldwide for use by any authorised operator from any ICAO state. This means that certifying both operators and aircraft will be much easier, and aircraft will be operating to global standards.</td>
</tr>
</tbody>
</table>
Potential sources of error with area navigation

The RNAV and RNP specifications define the accuracy required in both the cross-track (lateral) and along-track (longitudinal) dimensions.

**Lateral navigation.** Aircraft tracking and positioning errors may lead to navigation being less accurate than required. Three errors in on-board performance monitoring and alerting contribute to the total system error (TSE), and are shown in the illustration below:

- **path definition error (PDE).** This occurs when the path defined in the RNAV system does not correspond to the desired path i.e. the path expected to be flown over the ground.
- **flight technical error (FTE).** This relates to the autopilot’s ability to follow the defined path or track, including any display error.
- **navigation system error (NSE).** This refers to the difference between the aircraft’s estimated position and its actual position.

**Longitudinal navigation** specifications define requirements for along-track accuracy, which includes navigation system error (NSE) and path definition error (PDE).

There is no flight technical error (FTE) in the longitudinal dimension, and PDE is considered negligible.

The along-track accuracy affects position reporting (e.g. ‘10 nm to ABC’) and procedure design (e.g. minimum segment altitudes, where the aircraft can begin descent once crossing a fix).

The on-board performance monitoring and alerting requirements in the RNP specifications are defined for the lateral dimension for the purpose of assessing an aircraft’s compliance. However, NSE is considered as a radial error so that on-board performance monitoring and alerting is provided in all directions.
How PBN provides more flexibility than conventional navigation

Standard instrument departure (SID) and standard terminal arrival route (STAR)

SIDs are designated IFR departure routes linking an airport or runway with a significant point, normally on a designated air route, at which the en route phase of flight commences.

STARs are designated IFR arrival routes linking a significant point, normally on an air route, with a point from which a published instrument approach procedure can be commenced. Major airports typically have a ‘family’ of STARs which link major air routes to instrument approach procedures.

Leg types

A leg type describes the desired path proceeding, following, or between waypoints on a procedure. Tracks are intercepted to and from stations and waypoints with reference to navigation aids/systems using ground-based and satellite-based navigational systems.

Leg types are identified by a two-letter code that describes the path (e.g. heading, course, track, etc.) and the termination point (e.g. the path terminates at an altitude, distance, fix, etc.). Leg types used for procedure design are included in the aircraft navigation database, but not normally provided on the procedure chart. The path and terminator concept defines that every leg of a procedure has a termination point and some kind of path into that termination point.

Instrument approaches

ICAO has introduced a method of classifying instrument approaches—Type A and Type B. Details are contained in ICAO Annex 6 Part 1 Chapter 4.

Approaches are then flown using either a two dimensional (2D) or a three dimensional (3D) methodology.

Use of GNSS for instrument approaches

ICAO recognises GNSS and augmented GNSS signal in space (SIS), and traditional ground-based aids, as suitable technologies to support a range of 2D and 3D approaches.

The official ICAO term for RNAV(GNSS) approaches (previously called GPS APPROACH in Australia) is now RNP APCH, although RNAV(GNSS) will be around for some time until charts and databases are updated to the new ICAO charting standards.

2D approaches

Two dimensional approaches use lateral guidance only. Examples are NDB, VOR, localiser (LLZ) or GNSS (required navigation performance—RNP).

With 2D approaches it is the pilot’s responsibility to adhere to all step-down altitudes and use the minimum descent altitude (MDA) procedure.
With the advent of GNSS, including its various augmentations, a range of different 2D approaches are possible. These include:

<table>
<thead>
<tr>
<th>Approach</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNP APCH–LNAV</td>
<td>The superseded RNAV/GNSS approach (APCH) is replaced by the new RNP APCH lateral navigation (LNAV) approach definition. The aircraft must be equipped with an appropriately authorised TSO-C129 sensor or navigator, a TSO-C145 GNSS sensor, or a TSO-C146 stand-alone GNSS system. This equipment must be installed correctly as described in CASA Advisory Circular 21-36.</td>
</tr>
<tr>
<td>LP</td>
<td>Localiser performance (LP) uses satellite-based augmentation (SBAS)-provided lateral guidance to tolerance similar to ILS LOC.</td>
</tr>
<tr>
<td>LNAV+V</td>
<td>Modern GNSS receivers may have the capability to present an ‘advisory’ vertical profile for the final segment. These are often called LNAV+V. This profile is generated by the receiver and is not based on an underlying approach design. While using this form of guidance, pilots are responsible for any step-down altitudes and must use the MDA procedure.</td>
</tr>
</tbody>
</table>

### 3D approaches

Three dimensional approaches use both lateral and vertical guidance, with the vertical profile provided by the guidance system. A **decision altitude** (DA) minimum procedure is used.

Instrument landing systems (ILS), microwave landing systems (MLS) and ground-based GNSS augmentation landing systems (GLS) can provide Cat I, II or III level of minimums.

There are several types of RNP APCH with 3D vertical guidance, and they differ in the way in which they source their vertical guidance information.

<table>
<thead>
<tr>
<th>Approach</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNP APCH–LNAV/VNAV (baro-VNAV)</td>
<td><strong>Barometric vertical navigation (baro-VNAV)</strong> uses a combination of lateral guidance and a vertical profile generated by on-board equipment from the instrument approach design database. A suitable aircraft pitot static and barometric system is required. The flight management system (FMS) calculates the descent path using this barometric information. An important limitation of baro-VNAV is that the actual path flown by the aircraft is dependent on the ambient air density. A temperature higher than ISA will result in a steeper approach path and temperatures lower than ISA will result in a lower descent profile. Baro-VNAV approaches may have published temperature limits and will not be available should the ambient temperature lie outside the permitted range.</td>
</tr>
<tr>
<td>LPV</td>
<td><strong>Localiser performance with vertical guidance (LPV)</strong> requires a satellite-based augmentation system (SBAS) service and currently provides approaches equivalent to an instrument landing system (ILS) Cat 1. LPV can only be conducted in a defined SBAS service area, such as the US wide area augmentation system (WAAS), or the European geostationary navigation overlay service (EGNOS).</td>
</tr>
<tr>
<td>RNP AR APCH</td>
<td><strong>Required navigation performance—authorisation required (RNP-AR)</strong> is a type of RNP operation that allows for defined curves in the flight path and uses baro-VNAV for vertical guidance. Special authorisation is required—see ICAO Doc 9905.</td>
</tr>
<tr>
<td>Overlay approaches</td>
<td>Some aircraft equipment is authorised to fly approaches for which the aircraft is not technically fitted. For example, while in an SBAS service area, the receiver may be able to be used to conduct (or overlay) a baro-VNAV approach. However, without SBAS, the aircraft may not be fitted to fly a stand-alone baro-VNAV procedure.</td>
</tr>
</tbody>
</table>

**Approach plates**

A single instrument approach plate may contain a mix of 2D and 3D approaches. Care must be taken to ensure that correct piloting procedure is used including recognition of the type of minimums presented.

**Enabling legislation**

Civil Aviation Order (CAO) 20.18 (Aircraft equipment—basic operational requirements), deals with the equipment required for PBN and ADS-B and affects all IFR operators in Australia.

Civil Aviation Order (CAO) 20.91 (Instructions and Directions for Performance-based Navigation) allows for this equipment to be used for PBN, both in Australia and overseas.

CAO 20.91 contains deeming provisions which mean that:

- aircraft equipped with stand-alone GNSS systems with aircraft flight manual entries for RNP 1, RNP 2, or RNP APCH-LNAV, or installed in accordance with CASA advisory circular 21-36, and flown by suitably qualified pilots, meet the equivalent PBN requirements
- aircraft equipped with integrated avionics systems using GNSS only for area navigation are also covered by the deeming provisions.

Aircraft with flight management systems (FMS), such as some newer commuter/regional aircraft, will need to obtain navigation authorisations from CASA. The PBN standards also provide for IFR helicopter-specific operations, such as in metropolitan areas and for offshore support.

CAO 20.91 and its associated advisory circular provide operating instructions and airworthiness requirements for IFR pilots flying aircraft using PBN.
Pilot and operator obligations

Pilots in command of IFR flights must only use RNAV or RNP if they are qualified to do so.

The aircraft operator must also:

- hold, or be deemed to hold, a navigation authorisation for the relevant PBN specification
- ensure that each member of the flight crew satisfies the requirements in the relevant appendix (1–13)
- ensure that each member of the flight crew conducts the flight according to the authorisation.

Navigation databases

Since navigation under PBN relies on area navigation, the aircraft navigation system must carry a navigation database. Under the requirements of the CAO:

- the database must be valid for the current AIRAC cycle (refer to AIP GEN 3.1 for further information)
- all terminal routes (SIDs, STARs and approaches) must be loaded from the database and may not be modified by the pilot except as provided for in CAO 20.91.

Aircraft equipment

Information on aircraft equipment is available in Chapter 5.

Key points

- PBN has two requirements—the pilot must be suitably trained and qualified and the aircraft must be appropriately equipped.
- The introduction of PBN allows pilots, operators and air traffic control to make the best use of recent advances in navigation technology, and brings increased safety, efficiency and environmental benefits.
- The difference between the RNAV and RNP navigation specifications is that on-board performance monitoring and alerting is required for RNP but not for RNAV operations.
- Area navigation operates by first determining the aircraft’s present position in terms of latitude and longitude, and then where this position is in relation to the intended flight path.
- In Australia, if you have a GNSS-equipped aircraft approved for IFR operations, you do not need to make any changes.
Resources

Further reading


References


An important aspect of any flight away from home base is thorough flight planning. Having a well thought-out plan before you get airborne will help you enjoy the flight, arrive refreshed and return alive.

Even if you are going somewhere familiar, have some key details worked out beforehand. Getting the most up-to-date weather and NOTAMs is a must.

This chapter will cover the eight phases of flight, use of electronic flight bags, GNSS operations and requirements, applying RAIM predictions and use of alternate routes.
• Eight phases of flight 82
• Electronic flight bags 82
• GNSS operations and requirements 84
• RAIM prediction and NOTAMs 87
• Alternate routes 88
• Key points 90
• Resources 91
Eight phases of flight

There are eight phases in every flight for every aircraft. Each phase has its own significance in flight planning and each must be managed successfully.

As Benjamin Franklin once said, ‘If you fail to plan, you are planning to fail.’ As technology becomes more sophisticated, it becomes even more critical to plan your flights carefully. Where will your flight go, what route will you follow, what will the weather be like at your destination and along your route, how much fuel will you carry, what potential diversions or delays might you encounter, and are you fit to fly?

While technology needs to be considered in all phases of flight, remember that technology is not a substitute for proper planning.

Complete a quick review of the eight phases of flight below.

1. **Planning:** make decisions and calculations about your route: the weather; how much fuel to carry; your load; and any potential diversions, delays or emergencies.
2. **Pre-flight:** inspect the aircraft: analyse any faults or conditions and if these will affect the flight plan.
3. **Pre-departure:** check the operation of the aircraft: set systems for take-off and climb, assess if you are fit to fly.
4. **Post-departure:** commence navigation procedures: configure the aircraft for cruise flight, fly accurately on your outbound route.
5. **En route:** monitor navigation, weather, fuel management and consumption, other traffic.
6. **Pre-approach:** fly a stable and accurate descent, obtain ATIS or AWIB information.
7. **Approach:** sight the airport, communicate with ATC or other traffic, assess airport and wind conditions.
8. **Landing:** land, exit the runway, taxi, shut down the aircraft.

Electronic flight bags

Electronic flight bags (EFBs) can store and retrieve documents required for flight operations, such as maps, charts, the flight crew operations manual, minimum equipment lists and other control documents.

Physical EFB displays may use various technologies, formats and forms of communication. The capabilities of electronic flight bags increase, almost by the month, but even their developers warn that these computer programs are no substitute for basic flight-planning skills.

Australia has two major EFB providers for general aviation: OzRunways and AvPlan EFB. Both are available for Apple iOS and Android tablets and both offer the ability to plan a flight, get weather and NOTAMs and navigate, with maps, *En route supplement Australia* (ERSA), *Departure and approach procedures* (DAPs) and Aeronautical Information Package (AIP) at the pilot’s fingertips. Both allow the pilot to fetch or enter winds, store aircraft profiles, submit to National aeronautical processing system (NAIPS) and create custom waypoints.
Some EFB products display nearby traffic, derived either from a portable ADS-B IN receiver carried on board or uploaded from the provider’s ground system, in which case the traffic displayed may be limited to aircraft that use the same EFB provider. The ability of EFBs to provide a range of information to and from aircraft is expected to continue to improve in future. Pilots should contact their EFB service provider for information about specific current capabilities.

**Screens**

The screen size and resolution needs to display information in a manner comparable with the paper aeronautical charts and data it is intended to replace.

The recommended minimum size of the screen is about 200 mm measured diagonally across the active viewing area. If the intent of the installation is to display charts and maps, the device should be suitably sized to display the image without excessive scrolling.

*The paperless cockpit is now a reality—screen size does matter*

**Mounting devices**

EFBs which use temporary mounts that attach to the aircraft, such as suction mounts and Velcro pads, are regarded as class 1 devices and must be stowed during take-off and landing. They should also be stowed during periods of turbulence.

Temporary mounts are not considered to be airworthy and may constitute a hazard on the flight deck in certain circumstances. The equipment, when mounted and/or installed, must not present a safety-related risk or associated hazard to any flight crew member. EFBs attached to kneeboard holders do not need to be stowed.

The mounted EFB must not obstruct:

- external vision
- physical access to aircraft displays or controls, or
- visual access to aircraft displays or controls.

The required cabling for an EFB should be a sufficient length to prevent damage or hazards.
Pilots need to consider stowage for EFBs which are not mounted to the aircraft or to a kneeboard. They must be designed and used in a way which prevents the device from jamming flight controls, damaging flight compartment equipment or injuring flight crew members.

All EFB mounts attached to the aircraft structure will require airworthiness approval. See Subpart 21.M of the Civil Aviation Safety Regulations 1998.

Software

The operator should ensure the operating system and programs meet the intended function. Unauthorised modification of any database or the loading of any new or additional software is not permitted unless the software complies with the manufacturer’s specifications.

Information provided to the pilot needs to be a true and accurate representation of the charts or documents they replace.

**GNSS operations and requirements**

- 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 check both latitude/longitude information and bearing/distance information to prevent a charted error being carried over to the GNSS.
- Where available, get two crew members to check the inputs are accurate and reasonable when entering data manually. 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.
- Examine 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, such as the creation of a new flight plan.
And ensure that you:

- check GNSS NOTAMs and other warning information
- check that the data is current—this is often displayed at start-up
- carry the GNSS operating manual for the unit installed in your aircraft.

**Don’t take off without it!**

You must carry operating instructions for your GNSS unit on board, and, if a commercial operator, incorporate them into your company operations manual.

You must also 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.

**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, equipment RAIM capability (fault detection or fault detection and exclusion) and certification status (C129 or C146).

**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.

See RAIM prediction and NOTAMs later in this chapter for more information.

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, such as 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—course deviation indicator (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 nm 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 to ‘track direct’ from present position or that a weather diversion is required.
Be aware 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 en route chart (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 finding 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 LSALT/MSA when conducting operations in IMC
- if there is a contradiction between any sources of information, climb to the LSALT/MSA as soon as possible.

**RAIM prediction and NOTAMs**

There are three sources of RAIM prediction generally available to civil aviation users.

1. **Receiver**: TSO receivers have a built-in approach RAIM prediction function available to the pilot. This is useful for in-flight use. However, these systems are usually not capable of FDE prediction and use the last issue of the constellation almanac to predict RAIM. The resulting prediction therefore becomes progressively less accurate over time and is thus unsuitable for flight planning purposes.

2. **Software**: GPS oceanic and remote area approval requires an appropriate en route RAIM prediction, using the software provided by the receiver manufacturer, to be conducted prior to flight. This analysis takes into account the required navigation performance for the route or centreline spacing. Australian operators must retain a record of the GPS prediction analysis.

3. **NOTAM**: Having the latest NOTAMs is very important. Read the NOTAMs carefully, highlighting the ones that will affect your flight.

**GPS Status reports**

Airservices Australia makes GPS status reports available via the AVFAX system. These reports are issued by the US Coast Guard and contain details of the satellites in orbit, notice advisory to NavStar users (NANU) and other general remarks.
RAIM prediction service

The Airservices Australia RAIM prediction service (RPS) uses NANU and the current almanac to provide GPS NOTAMs for flight planning purposes. Approach RAIM outages are given for 72 hours from the UTC prediction time shown in the first line of the prediction message. RPS has been upgraded to facilitate the differences between TSO-C129 and TSO-C146 equipment.

Sample text of the RAIM prediction output is:

```
BUTLER (YBUT)
GPS RAIM PREDICTION 071401 YBUT
TSO-C129 (AND EQUIVALENT) FAULT DETECTION
  03080610 TIL 03080615
  03090606 TIL 03090611
  03100602 TIL 03100607
GPS RAIM FD UNAVBL FOR NPA
TSO-C146A (AND EQUIVALENT) FAULT DETECTION ONLY
NO GPS RAIM FD OUTAGES
FAULT DETECTION AND EXCLUSION 03080610 TIL 03080613
GPS RAIM FDE UNAVBL FOR NPA
```

Alternate routes

While in the preliminary flight-planning phase, you should make provision for at least one other safe alternate route—a plan B. In planning this route, take the same level of care as you do with your primary route. Having a well-researched plan B takes a lot of pressure off if the weather deteriorates and you have to use it.

IFR

The approvals for use of GPS under IFR in the AIP specify that GPS may be used to satisfy any of the IFR requirements for provision of an alternate aerodrome provided that it is certified to TSO-C145a or C146a, and a valid prediction of approach FDE availability is used. This applies to the requirements for navais at both the destination and the alternate aerodrome.

When using a TSO-C129 receiver, or a C146a receiver with a prediction that FDE will not be available, and the forecast weather is below the alternate weather minimums, the alternate must be suitable for visual approach or an instrument approach using ground-based navigation aids.

The following table gives examples of alternate requirements for aircraft fitted with TSO GNSS receivers with and without fault detection and exclusion (FDE).
### Flight Planning

#### Operation: CHTR/AWK/PVT

<table>
<thead>
<tr>
<th>Onboard navaids</th>
<th>Weather at destination</th>
<th>Approaches at destination</th>
<th>Alternate required?</th>
<th>Alternate requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 TSO C146 or later GPS (FDE available)</td>
<td>Above alternate minimums</td>
<td>RNP APCH LNAV VOR NDB</td>
<td>No</td>
<td>None</td>
</tr>
<tr>
<td>1 ADF</td>
<td>1 VOR</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### Operation: AWK/PVT

<table>
<thead>
<tr>
<th>Onboard navaids</th>
<th>Weather at destination</th>
<th>Approaches at destination</th>
<th>Alternate required?</th>
<th>Alternate requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 TSO GPS (no FDE available)</td>
<td>Above alternate minimums</td>
<td>RNP APCH LNAV</td>
<td>Yes—due navaids</td>
<td>Must have an NDB and/or VOR IAL and forecast weather above alternate minimums, or By day only, have no IAL and forecast weather better than LSALT + 500 ft and 8 km visibility</td>
</tr>
<tr>
<td>1 ADF</td>
<td>1 VOR</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Night VFR

When both pilot and aircraft meet the AIP requirements, a pilot may not need to provide for an alternate aerodrome to a ‘no-aid’ destination under night VFR.

AIP requires that the pilot provides for an alternate within one hour’s flight time of the destination unless:

- the destination is served by a radio navigation aid (NDB or VOR) and the aircraft is fitted with the appropriate radio navigation system capable of using the aid, or
- the aircraft is fitted with a GNSS receiver appropriate for an aircraft operated at night under VFR and the pilot is appropriately qualified.
Key points

- If you fail to plan, you are planning to fail. As technology becomes more and more sophisticated, it is critical to plan your flights carefully.
- The role of CNS technology needs to be considered in all phases of flight. When assisted by technology—seen with the adoption of GNSS and ADS-B—even experienced pilots can forget important steps.
- Establish key details beforehand, then get the most up-to-date weather and NOTAMs.
- Electronic flight bags (EFBs) can electronically store and retrieve documents required for flight operations, such as maps, charts, the flight crew operations manual, minimum equipment lists and other control documents.
- There are generally three sources of RAIM prediction available to civil aviation users: TSO receivers, the NAIPS website and NOTAMs.
- While in the preliminary flight-planning phase, you should make provision for at least one other safe alternative route—a plan B.
Resources

Further reading

References
The original goals of human factors (HF) were to optimise human and system efficiency and effectiveness. As such, the term human factors, refers to the many issues whether personal, social, environment or organisational that affect how people perform tasks in their work and non-work environments. Within aviation, HF has been focused predominantly on error reduction, either through engineering in safety and efficiencies or through training and monitoring (checklists).

The intention of this chapter is to highlight some of the HF that may impact those operating a GNSS, explore situational awareness, managing errors and discuss the human-machine interface. Pilots and engineers may also wish to read the human factors resource kits produced by CASA.
• Don’t be led astray 94
• Influences on people 94
• Situational awareness 98
• Cockpit ergonomics 100
• Airmanship tips 101
• Key points 102
• Resources 103
Don’t be led astray

Many of us have heard stories about people ending up in the wrong suburb, town or even country because they tried to follow directions from a GPS in their car or mobile phone mapping application.

- **March 2015:** A group of Belgian tourists are sent on a detour of close to 1200 km (750 miles) after a GPS navigation error by their bus driver saw them arrive at La Plagne in the Pyrenees rather than La Plagne in the Tarentaise Valley.
- **June 2013:** A woman follows her GPS right into the path of an oncoming train in Belmont, US.
- **January 2013:** A woman leaves her home in Belgium intending to pick up a friend in Brussels, 144 km (90 miles) away. After switching on her GPS, she ends up in Zagreb, Croatia.
- **March 2012:** Japanese tourists drive a rental car into the Pacific Ocean as they follow GPS instructions down a road toward Australia’s North Stradbroke Island.

Pilots have also had accidents to which their GPS units have contributed. Cockpit recordings indicate that a lack of familiarity with the GPS units’ functions, distraction and over-reliance were some of the error-producing influences on the pilots. These potential threats to performance from technology make clear the importance of understanding your strengths and shortcomings, and of the technology you are using.

An awareness of the limitations in the design, controls, displays and software logic of GPS units can avoid potentially dangerous errors such as:

- incorrect data entries
- incorrect interpretation of data
- inadequate cross-checking from alternative sources
- inappropriate decisions based on GPS output.

Influences on people

Interaction

A number of factors influence the way that people interact with technology associated with CMS/ATM, such as GPS receivers, ADS-B transponders and cockpit display of traffic information (CDTI) units.

The ‘dirty dozen’ concept, originally designed in the 1990s to improve human performance in maintenance, refers to the most common factors which influence people to make mistakes. In the CNS/ATM context some of the ‘dirty dozen’ provide guidance on how to get the best of from the technology while avoiding the pitfalls.

Communication

Most human communication is obtained visually, with 55 per cent from body language, 38 per cent through tone and pitch and only seven per cent the actual words. People normally remember about 20 per cent of what they hear if all they have is sound, which is why aviation radio procedures require readback of essential information such as frequencies, turning instructions and radar codes.
Listening to directions from your GPS tends to be less effective than a passenger giving you the same information, since the passenger provides cues such as tone of voice and possibly gestures.

While technology can reduce pilot workload, the examples above show that interactive systems have limited means of communication with the human interface—so it’s not a matter of ‘set and forget’.

For example, ADS-B surveillance reduces the need for air-ground voice communications for position reports, reducing some pilot and controller workloads. When out of range of an ADS-B ground station, ADS-B IN receiver capability provides the pilot with local airspace information and thus a real-time air traffic picture. This additional information should significantly enhance a pilot’s situational awareness.

However, the additional information being presented creates workload for the pilots because it has to be:

- observed in a timely manner, thus increased scanning
- interpreted correctly and
- used to contribute to the pilot’s decision-making process.

For example, instead of being instructed to change course or altitude by the ATC, the onus is on the pilots to come to a consensus. And there is an assumption the other aircraft in the vicinity are ADS-B OUT equipped and that the equipment is operating.

**Complacency**

Just as using cruise control in a car doesn’t mean that you can travel at a constant speed regardless of other traffic, so there is no such thing as a routine flight. Your GPS may have worked well last time—but what if there’s an in-flight power failure, or it’s a different model this time?

As noted previously, ADS-B assists pilots through providing information, but what if there is more information than the system can provide? An over-reliance on the system to inform may lead to complacency with visual scans. Remember, if you only look for one thing, you may miss important signals because your perception is biased by your expectations and information filtering.

Furthermore, the displays of many GPS units are quite small, with the potential for display reading errors. Warnings such as RAIM are often indicated by small symbols or lights and if the screen is being dimmed by bright light the washout can limit what is actually seen.

A last comment on over-reliance is the old adage ‘use it or lose it’. Drivers in a simulator who follow satellite navigation instructions find it more difficult to work out where they have been than those who use maps. Instructed drivers also fail to notice that they have been led past the same point twice.

Roger McKinlay, the former president of the Royal Institute of Navigation in the UK suggests that our natural sense of navigation diminishes over time if we constantly outsource the responsibility to machines.

And skills need be practised. For example, flight planning and map-reading skills are likely to deteriorate for VFR pilots who routinely rely on the direct-to function on a GPS as their primary means of navigation.
Current knowledge

If dependency increases on ‘outsourced’ knowledge systems, than there is potential for any changes to the systems and procedures to be left to the device to update, rather than on the operator to keep current. The good practice of asking others, rather than assuming the automation is up-to-date, may lapse. To ensure correct procedures are followed, always use checklists and avoid working from memory.

For IFR pilots familiar with ground-based navigation aids, there will be some significant differences in an RNAV environment. These include the display of distance to the next waypoint, cross-track error measured in distance rather than degrees, and absence of slant range. This means that some old rules of thumb and situational awareness techniques may no longer apply. Be absolutely clear about the minimum descent requirements for the approach segment you are in.

A lack of equipment standardisation may cause problems when pilots move between aircraft. For example some CDTIs allow traffic on the ground to be filtered out while others don’t.

An ADS-B OUT interface in the cockpit will not display traffic or terrain, but may let the pilot enter the FLTID.

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. Some equipment does not display the mode, which means pilots need to remember which one they are in.

Distraction

Distraction is anything which draws a person’s attention away from the task at hand. It’s also the main cause of forgetting things. There is a tendency, when returning to a task after being distracted, to think we are further ahead than we actually are.

Concentrating on only one thing while flying can be dangerous, leading to loss of situational awareness and control. Using interactive equipment can capture your attention for longer than you think.

For example, it’s easy to become fixated trying to find a function hidden deep in the menu structure of a GPS. Familiarise yourself with the technology and do as much preparation as possible, such as entering the waypoints for alternates on the ground to cut the in-flight workload.

GNSS can distract pilots from other tasks, such as monitoring other instruments and scanning for traffic. It can also lull pilots into a false sense of security.
Teamwork
This is particularly, but not only, applicable to multi-crew operations. For example, it’s important to make sure that the information which goes into the GPS and ADS-B units is checked and double-checked, both for accuracy and for common sense. Accidents have happened because crews faithfully input data which was incorrect or ambiguous.

Fatigue
Fatigue is a natural physiological reaction to prolonged physical and/or mental stress. After 17 hours of wakefulness, you are functioning as if you had an equivalent blood alcohol level of 0.05 per cent. After 24 hours the level increases to 0.1 per cent. The more fatigued you are, the lower your cognitive processing speed and memory capacity, which detract from your ability to concentrate and make you more easily distracted.

An area near the front of the brain responsible for logical reasoning and complex thought seems particularly vulnerable to sleep deprivation. This may be why people typically have such a hard time recognising their own fatigue and level of impairment. We tend to underestimate our level of fatigue and overestimate our ability to cope with it. Don’t be pressured into flying if you are fatigued.

Stress
Stress can have many causes, and can result in a pilot being less attentive, or making a decision without considering all the information available. It can cause a narrowing of attention, or tunnel vision, making information-gathering (scanning) scattered and poorly organised.

Acute stress from too much work (overload) can be bad for situational awareness. But so can too little stress, or underload.

If a lot of information needs to be prioritised quickly, situational awareness will ultimately suffer. Real-time demands, such as dealing with an in-flight emergency, can cause acute stress to our senses, mental processing and body.

Conversely, during periods of low workload such as in long-haul flying, reduced vigilance may affect your motivation to actively find out what is going on around you. Automation in the cockpit can leave a pilot with little to do, and the lack of stimulation can lead to complacency.

Chronic stress is cumulative, and the result of life events such as family relations, finances, illness, bereavement or divorce can mean our threshold of reaction to demands and pressure at work is lowered. We may over-react inappropriately, too often and too easily.

Norms
Norms are unwritten rules or behaviors, dictated and followed by the majority of a group. They can be positive or negative, but most have not been designed to meet all circumstances. Don’t feel pressured into doing something a particular way just because ‘that’s the way it’s done around here’.
The following extracts from reports of occurrences around the world show the potential for human error in the use of GNSS equipment is.

- '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 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 ran into the other aircraft, the pilot of which was practising ground reference manoeuvres at the time.'
- 'The pilot of an aircraft, which was destroyed when it struck trees on departure from an airport, told the investigator that his hand-held GPS receiver had fallen from the instrument panel during the take-off roll and jammed the flight controls.'
- 'The pilot was using a GPS receiver to navigate when, about 10 minutes before arrival, the receiver batteries failed. Becoming disoriented, the pilot then used up the remaining fuel trying to locate the airport, eventually making a forced landing into a parking lot.'

Situational awareness

The complexity of aviation operations means that there is potential for even small errors to cause serious problems. A key to avoiding them is to understand the consequences of particular actions.

Safe use of GPS in aviation requires:
- sound theoretical knowledge
- operational proficiency with the equipment
- awareness of both system and human vulnerabilities
- standardisation of systems and procedures wherever possible.

Ten clues to loss of situational awareness

These clues can warn of an error chain in progress—a series of events that may lead to an accident. Most accidents involving human error include at least four of these clues.

1. **Ambiguity**: information from two or more sources that doesn’t agree.
2. **Fixation**: focusing on any one thing to the exclusion of everything else.
3. **Confusion**: uncertainty about a situation (often accompanied by anxiety or psychological discomfort).
4. **Failure to fly the plane**: you are focused on non-flying activities.
5. **Failure to look outside**: you are looking down.
6. **Failure to meet an expected checkpoint on flight plan or profile**.
7. **Failure to adhere to standard operating procedures**.
Failure to comply with limitations, minimums, regulations etc.

Failure to resolve discrepancies: contradictory data or personal conflicts.

Failure to communicate fully and effectively: vague or incomplete statements.

How to maintain and improve situational awareness

Here are some simple tips to help maintain an adequate level of situational awareness in your flying activities.

• **Learn and recognise the symptoms that indicate you are losing situational awareness.** For instance, you may be losing situational awareness if you are struggling with GNSS technology in flight, such as flicking through manuals or cycling through control menus.

• **Be well informed.** Learn everything you can about the situation. In order to make sound decisions as a pilot, it is vital that you have appropriate and current information available and that it is used as much as is operationally useful.

• **Plan well in advance.** ‘Know before you go’ by properly researching flight plans and obtaining the timeliest data possible. Pre-flight planning can start days before a flight and includes knowing everything you can about the aircraft’s capabilities, the weather and the airports at which you will operate.

• **Brief yourself and others on the plan.** Take a few minutes to review your flight plan and to brief yourself and your passengers and/or crew on each phase of the upcoming flight. Cover the necessities such as airports, fuel planning, emergencies and anything else that might be useful for that flight.

• **Fly to your plan.** Continually monitor the flight’s progress against the original plan that you briefed prior to departure. Always know exactly where you are and be prepared for the tasks that are required next.

• **Use an easily repeatable scanning technique.** Make sure that it takes in engine instrument indications, flight instrument indications, aircraft heading, flight path, time, charts and the ground. Develop a scan that covers key items without distracting you too much. The scan should be well-rehearsed and second nature; be careful not to fixate on any one item.

• **Think ahead and rehearse your actions at key points.** For example, rehearse your actions should the engine fail in cruise flight, or immediately after take-off.

• **Communicate clearly when operating at, or in the vicinity of, airports.** Listen for key words that indicate the positions and intentions of other aircraft. Be aware that not all aircraft will be radio equipped, and even those which are, may not be listening on the appropriate frequency. Think ahead and have a plan for safe and orderly traffic separation.

• **Fly the plane within your limits** and the aircraft’s performance limits.

• **Avoid locking on to a problem or task for too long**—for instance, your intended landing point. Don’t keep looking only in one direction; keep the scan going, be aware of the relative position and movement of other traffic. Hold the heading and fly at a safe airspeed appropriate to current atmospheric conditions, maintaining your height above the surface.
Cockpit ergonomics

Many aircraft have been fitted with GNSS receivers some years after the aircraft was designed and built. As a result, displays are not necessarily in the ideal location in the cockpit, although IFR installations require the displays to be in the pilot’s field of view. Reflected sunlight can cause problems with both screen displays and annunciator lights and pilots should ensure familiarity with the illumination of the particular receiver installation before night flight.

Many GNSS receivers are coupled to the horizontal situation indicator (HSI) or the primary navigation display. Mode awareness is critical with these installations as different switching and logic arrangements are used to display data from GNSS, VOR, ILS and other sources. Pilots should also be aware of the attentional dominance of the HSI when navigating by a system not displayed on the HSI, and avoid this configuration where possible.

Where does my coffee cup go?

Donald Norman in The Design of Everyday Things (1988, revised 2013)

‘Even the comfort of the flight crew is ignored. Only recently have decent places to hold coffee cups emerged. In older planes, the flight engineer has a small desk for writing and for holding manuals, but the pilots don’t. In modern planes, there are still no places for the pilots to put their charts, their maps, or in some planes, their coffee cups. Where can the crew stretch their legs or do the equivalent of putting the feet up on the desk? And when it is mealt ime, how does one eat without risking spilling food and liquids over the cockpit? The lighting and design of the panels seem like an afterthought, so much so that a standard item of equipment for a flight crew is a flashlight.’

Norman says the cramped, inconsiderate design of cockpits is a symptom of a more serious problem. ‘If comfort is ignored, think how badly mental functioning must be treated.

‘Why hasn’t this need been recognised? The need for mental, cognitive assistance should be recognised during the design of the cockpit. Why don’t we build in devices to help the crew? Instead, we force them to improvise, to tape notes here and there, or even to wedge pieces of paper at the desired locations, all to act as memory aids. The crew needs external information, knowledge in the world, to aid them in their tasks. Surely we can develop better aids than empty coffee cups?’

Norman’s proposed solution is user-centred design, meaning it puts the needs of the user before other considerations.
Data entry in GNSS units

Both manually entered and database-derived information should be checked for reasonableness with a confidence check in the following cases:

- prior to each compulsory reporting point
- prior to or at arrival at each en route waypoint
- at hourly intervals during area type operations when operating off established routes
- after insertion of new data; for example, creation or amendment of a flight plan.

Many similar or identical waypoint names exist in a database and it is possible for pilots or software producers to load the wrong waypoint into a sequence inadvertently. Confidence checks should compare tracks and distances against charted information rather than simply scroll through a list of waypoints. Pilots should refer to their company operations manual and to CAO 20.18 for additional information regarding data entry.

Airmanship tips

A lack of mode awareness is a common hazard in computerised flight systems. You must be able to recognise the correct mode of operation for each phase of flight, particularly during instrument approach.

- Ensure you are familiar with the operating procedures before using the GPS in instrument meteorological conditions (IMC).
- Check the receiver operation, the database validity and your approach chart before flight.
- Make sure the receiver is set up with the required navigation settings—distances in nautical miles, QNH in hectopascals etc. Also check the CDI scaling for en route operation.
- Ensure the GPS is included in your instrument scan but avoid fixating on the receiver.
- Review the functions of the GPS receiver before each flight by entering the complete flight plan, including the instrument approach procedure to your destination.
- Do a confidence check of all tracks and distances.
- As you become more familiar with the unit, guard against complacency, and use all navigation information available to cross-check GPS information.

Design should:

- make it easy to determine what actions are possible at any moment
- make things visible, including the conceptual model of the system, the alternative actions, and the results of actions
- make it easy to evaluate the current state of the system
- follow natural mappings between intentions and the required actions; between actions and the resulting effect; and between the information that is visible and the interpretation of the system state.
Key points

- GPS can deliver gains in reliability, accuracy and system monitoring ability, but training and system familiarity is essential.
- The lack of standardisation of equipment can cause problems when pilots move between aircraft with different displays.
- You might lose situational awareness if you are struggling with a GPS in flight, such as flicking through manuals or cycling through controls.
- The amount of information humans can deal with at any one time is limited and at times, particularly in the IFR environment during high workload phases of flight, it is possible to exceed individual processing capacity.
- Modern challenges in the human machine interface include cockpit design, which covers how to present information to the pilot; and automation design, covering the question of who should do what, in dividing the task of flying between humans and computers.
- A lack of mode awareness is a common hazard in computerised flight systems. You must be able to recognise the correct mode of operation for each phase of flight, particularly during instrument approach.

When you are ready, please turn to page 22 of the workbook and complete the exercises.
Resources

Further reading


References


Harvard University Get Sleep website retrieved April 2017 from http://healthysleep.med.harvard.edu/need-sleep/

In February 2016, GNSS became mandatory for all aircraft flying IFR. This chapter explores the transition to performance-based navigation and how GNSS is used in IFR operations through a number of area navigation (RNAV) applications, providing guidance on operating safely and addressing common issues. GNSS may also be used in VFR operations—see Chapter 10.

Pilots flying IFR must hold the applicable instrument rating aircraft endorsements.
CHAPTER 9
Instrument flight rules operations

- Transition to performance-based navigation 106
- IFR RNAV 108
- RNAV (GNSS) non-precision approach 109
- Oceanic RNAV 113
- Key points 114
- Resources 115
CASA approves the use of GNSS for a variety of IFR applications. These include:

- DR substitute
- en route RNAV
- required navigation performance (RNP) approach (also known as RNAV[GNSS] non-precision approach)
- oceanic RNAV
- GNSS landing system (GLS).

**Transition to performance-based navigation**

The number associated with an RNP or RNAV specification includes the navigational accuracy required (in nautical miles).

While both RNAV and RNP specify accuracy, RNP also specifies integrity. Australian operational navigation specifications include:

- RNP 1—for standard instrument departures (SIDs) and standard terminal arrival routes (STARs)
- RNP 2—en route
- RNP-APCH—LNAV approach.

Under GNSS-RNAV, these types of operations were previously known as terminal, en route and non-precision approach.
### Navigation authorisations for typical IFR operations

The table below shows how operations have transitioned under advisory circular (AC) 91.U-01 Navigation authorisations.

<table>
<thead>
<tr>
<th>Operation</th>
<th>Applicable navigation specifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australian continental operations not entering oceanic airspace that include en route, terminal and:</td>
<td>• RNP 2&lt;br&gt;• RNP 1&lt;br&gt;• RNP APCH-LNAV&lt;br&gt;• baro-VNAV</td>
</tr>
<tr>
<td>• RNAV (GNSS) approach&lt;br&gt;• RNAV (GNSS) approach with Baro-VNAV</td>
<td></td>
</tr>
<tr>
<td>Operations entering oceanic airspace as well as continental operations that include en route, terminal and RNAV (GNSS) approach.</td>
<td>• RNAV 10 (RNP 10)&lt;br&gt;• RNP 2&lt;br&gt;• RNP 1&lt;br&gt;• RNP APCH-LNAV&lt;br&gt;• RNP APCH-LP and LPV</td>
</tr>
<tr>
<td>Operations entering oceanic airspace as well as continental operations that include en route, terminal and RNAV (GNSS) approach that will also be operating in airspace with use of a satellite-based augmentation system (SBAS).</td>
<td>• RNAV 10 (RNP 10)&lt;br&gt;• RNP 2&lt;br&gt;• RNP 1&lt;br&gt;• RNP APCH-LNAV&lt;br&gt;• RNP APCH-LP and LPV</td>
</tr>
<tr>
<td>Operations entering oceanic airspace with reduced separation (30 nm lateral and longitudinal separation) as well as continental operations that include en route, terminal and RNAV (GNSS) approach.</td>
<td>• RNAV 10 (RNP 10)&lt;br&gt;• RNP 4&lt;br&gt;• RNP 2&lt;br&gt;• RNP 1&lt;br&gt;• RNP APCH-LNAV</td>
</tr>
<tr>
<td>Note: There are likely to be additional requirements for aircraft to be equipped with CPDLC and ADS-C to support reduced separation operations in oceanic airspace.</td>
<td></td>
</tr>
<tr>
<td>Aircraft that operate in B-RNAV airspace in Europe.</td>
<td>• RNAV 5</td>
</tr>
<tr>
<td>Aircraft that operate in North Atlantic high level airspace (NATHLA).</td>
<td>• NAT MNPS&lt;br&gt;• NAT HLA MNPS</td>
</tr>
<tr>
<td>Aircraft that operate in European P-RNAV airspace or US RNAV Type A or Type B airspace.</td>
<td>• RNAV 1&lt;br&gt;• RNAV 2</td>
</tr>
</tbody>
</table>
IFR RNAV

Pilots flying IFR in Australian domestic airspace may use GPS for position fixing and long-range navigation in accordance with Airservices Australia’s Aeronautical Information Package (AIP). This applies to operations on designated RNAV routes, application of RNAV-based LSALT, deriving distance information for en route navigation, traffic information and air traffic control (ATC) separation. ATC may apply RNAV-based separation standards to aircraft meeting the requirement for IFR RNAV.

Position fix (PF) is determined with reference to navigation aid and systems using ground-based and/or satellite-based navigational systems.

GPS may also be used as a navigation aid to determine distance information for standard instrument departures (SIDs), standard terminal arrival routes (STARs) and instrument approach procedures where the use of GPS is specified on the instrument approach and landing (IAL) chart. GPS may be used to meet the IFR requirements for radio navigation systems specified in Airservices Australia’s AIP Part 1-General (GEN) 1.5.

If your GNSS performance degrades to the point at which an alert is raised, or you have any other cause to doubt GNSS information integrity, you should stop using GNSS and carry out appropriate navaid failure procedures.

**Common Australian operational navigation specifications under PBN**

- RNP 1 SIDs
- RNP 2 STARs
- RNP 1 APCH or RNP APCH
**GNSS arrivals**

Although classed as instrument approach procedures, GNSS arrivals and DME or GNSS arrivals (DGA) are included in the RNP 1 application and approval. Additional competency and recent qualifications apply to flying DGA.

For these procedures, the destination navaid (VOR or NDB) nominated on the approach chart must be used to provide primary track guidance during the arrival procedure and the distance information must be based on the ‘reference waypoint’ navaid nominated on the chart.

**Lowest safe altitude (LSALT)**

AIP GEN 3.3 permits IFR LSALT to be determined by GNSS capability. LSALT printed on terminal area and en route charts assumes RNP 2 capability and takes into account an area of 5 nm surrounding and including the departure point, destination and nominal track. (see diagram).

For other routes and route segments, the obstacle clearance to be considered must be within an area of 5 nm surrounding, and including, an area defined by lines drawn from the departure point not less than 15 degrees each side of the nominal track to a maximum of 7 nm, thence paralleling track to abeam the destination and converging by a semicircle of 7 nm centred on the destination.

**RNAV (GNSS) non-precision approach**

Pilots operating under IFR may use GPS as an approach navigation aid to determine distance and track information for RNAV(GNSS), also known as RNP APCH-LNAV, non-precision approach procedures. As with other IFR applications, TSO-C129 is the minimum standard of approved receiver.

Overlay and T-pattern GNSS approaches are used in some other countries. Pilots should familiarise themselves with the design, procedures and naming conventions used before flying these approaches under IFR.

There are no published overlay approaches in Australian domestic airspace, as the TSO-C129 receiver is unable to accurately fly the base turn reversal procedure of the teardrop design commonly used in Australia.
Australian approach design

The Australian-developed Y-pattern runway aligned design has been adopted by ICAO and is published in PANS-OPS. The approaches are essentially ‘straight-in’ to the runway and can usually be joined at any of three initial approach waypoints without the need for a reversal or base turn manoeuvre.

Naming conventions

The approach name is based on airport identification and the runway used for alignment, or in some cases the direction of the approach in relation to the airport.

In general, waypoint names use the first three letters to identify the aerodrome, the next letter to identify the compass quadrant from which the approach is flown, and the final letter for the approach waypoint.

For example, the Runway 24 GNSS approach for Paraburdoo, WA (YPBO) uses ‘PBO’ as the first three letters, and ‘E’ as the fourth letter, of all waypoints.

Runway 24 GNSS approach for Paraburdoo
GPS non-precision approaches

The missed approach
- You must manually select the missed approach mode if required.
- If not visual at the MDA, track to the missed approach point before selecting the missed approach.
- If RAIM is available, the system can be used for guidance through the missed approach.
- If RAIM is unavailable, or a warning is displayed, another means of guidance (including DR) must be used.

On the intermediate segment
- The CDI begins transition to 0.3 nm full-scale deflection 2 nm from the final approach waypoint.
- If the system fails to transition to approach mode by the final approach waypoint, a missed approach must be flown.

Enable approach when ready.
Select desired approach and initial approach waypoint.

The system will enter terminal mode within 30 nm of the aerodrome.

You may be prompted to enter the aerodrome QNH.

Waypoint designators
- H: Missed approach holding waypoint
- T: Missed approach turning waypoint (where required)
- M: Missed approach waypoint
- F: Final approach waypoint
- I: Intermediate approach waypoint
- A: Initial approach waypoint
- C: Initial approach waypoint
- D: Initial approach waypoint

During the final approach segment
- CDI full-scale deflection and the RAIM protected area are each 0.3 nm.
- Should a RAIM warning or loss of RAIM message appear, the pilot must execute a missed approach.
Vertical navigation

GNSS does not provide accurate altitude guidance and all altitudes must be obtained from the aircraft altimeter. At runways where visual approach slope indicators are not provided, pilots should take extra care to maintain the correct approach angle at runways where visual slope indicators are not provided.

A distance altitude scale is usually provided on the approach plate to give a 3° approach profile, and a corresponding altitude may be included on the profile view at selected points.

Flying the approaches

GNSS receivers are essentially navigation management computers and require more pilot attention than ILS, VOR and ADF receivers, particularly during approach. Pilots should take advantage of receiver simulation modes and ground training prior to undertaking airborne training.

Prior to flight, the receiver should be set to the required aviation parameters—nautical miles, knots, altitude in feet, pressure in hectopascals and WGS84 reference system. The nominal en route CDI scaling is 5 nm full-scale deflection.

The database must be current and contain the relevant approach. The approach should first be retrieved from the database and then selected along with the desired initial approach waypoint. The intermediate, final and missed approach segments must be flown only in that sequence. Select the desired approach and the initial approach waypoint and add this to the flight plan. Check waypoint sequence, tracks and distances against the approach chart.

Approach design
Pilot identification of each waypoint is essential for situational awareness during the approach, and to ensure compliance with limiting altitudes. The distance provided by the receiver is to the next approach waypoint (not to the airport) and the receiver will adjust the CDI scaling through the approach. The tracking tolerance is half of full-scale deflection regardless of the CDI scale.

An aircraft that is not required to hold or to lose height in a holding pattern may commence the approach without entering the holding pattern for procedures using GPS, provided the aircraft is tracking to an initial approach waypoint from within the capture region for that waypoint. Capture regions ensure that the radius of turn will permit interception of the approach segment prior to the next waypoint.

Should a missed approach be required, the missed approach mode must be manually selected. This expands the CDI scale to the terminal mode of 1.0 nm.

**Oceanic RNAV**

CASA may issue an approval for an operator to use GNSS as an en-route navigation aid in oceanic and remote areas outside the boundaries of Australian domestic airspace. The oceanic RNAV approval is based on FAA Notice 8110.60 and designed for operations over the high seas and in remote areas such as Antarctica.

**Equipment requirements**

The GPS equipment requirements include dual installations of FDE-capable receivers to ensure adequate redundancy and navigation performance. Installations in Australian registered aircraft must be approved and equipment capable of carrying out an appropriate en route RAIM prediction analysis for the route to be flown must use avionics manufacturer-specified software.

**Operational requirements**

You must operate GPS navigation equipment in accordance with the operating instructions and any additional requirements specified in the approved aircraft flight manual or flight manual supplement. These instructions must be carried on-board the aircraft.

In addition to GPS, aircraft must also be equipped with serviceable radio navigation systems as specified at GEN1.5 Section 2, or the operator’s minimum equipment list.

Before each flight, you must do an appropriate en route GPS prediction analysis, using the software provided by the GPS manufacturer. For this analysis, you must use the following parameters or equivalents:

- the route or airspace RNP, where published, or
- a centreline space of 20 nm for flight in classes A, C, D & E airspace or 50 nm for flight in OCA, and
- for Australian operators, a record of the GPS prediction analysis must be retained as required by the instrument of approval.
Oceanic lateral offsets

ICAO has analysed the technical safety issues associated with the use of lateral offsets when flying in oceanic areas. Parallel offset tracking is only approved for oceanic operations. The current separation standards, safety height calculations and tracking requirements for IFR aircraft are based on the requirement that the pilot will attempt to maintain track as closely as possible. Offsets are not approved for non-oceanic IFR aircraft.

Authorisation from AIP ENR 2.2 states that aircraft operating in oceanic controlled airspace in the Australian flight information region (FIR) are authorised to use lateral offsets in accordance with certain requirements. This approval is no longer specific to operations with GNSS and full details of the requirements are listed in AIP. Contact your local CASA field office to apply for an oceanic approval.

Key points

- GNSS must not be used as navigation reference for flight below the lowest safe altitude (LSALT) or minimum safe altitude (MSA), except as specified in IFR applications or as authorised by CASA.
- Pilots operating under IFR may use GPS in lieu of dead reckoning (DR) navigation techniques for that part of the flight that is outside the rated coverage of terrestrial navigation aids.
- Pilots operating in Australian domestic airspace under IFR may use GPS for RNAV—position fixing and long range navigation—in accordance with Airservices Australia’s AIP en route (ENR) documentation.
- Pilots operating under IFR may use GPS as an approach navigation aid to determine distance and track information for RNAV(GNSS) non-precision approach procedures.
- CASA may issue an approval for an operator to use GNSS as an en-route navigation aid in oceanic and remote areas outside the boundaries of Australian domestic airspace.
Resources

Further reading


References


Not sure whether you’re ready to apply for the instrument rating exam but still want to use GNSS and ADS-B when you fly? The good news is GNSS may be used in visual flight rules (VFR) operations for visual navigation and night VFR—you will just need to demonstrate competency in GNSS use in night VFR operations.

Installation of an ADS-B unit is the responsibility of an aircraft operator, but pilots need to be aware of how to operate a unit and respond to air traffic controller instructions. You can review ADS-B operations in Chapter 4 and also make sure you are ready to fly with thorough flight planning—see Chapter 7 on flight planning. You can also order a copy of the flight planning kit from the CASA online store—go to shop.casa.gov.au
CHAPTER 10
Visual flight rules operations

- Visual navigation 118
- Night VFR 119
- VFR qualifications 120
- Key points 120
- Resources 121
GNSS can be used under visual flight rules for:

- visual navigation
- night VFR RNAV.

**Visual navigation**

VFR pilots 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.

**At night**

As well as using GNSS to supplement visual navigation, you can train and obtain qualifications to use GNSS equipment for night VFR navigation in Australian domestic airspace.

If your GNSS performance degrades to the point at which an alert is raised, or you have any other cause to doubt GNSS information integrity, you should stop using GNSS and carry out appropriate navaid failure procedures.

---

**178 seconds to live—VFR into IMC**

Flights operating under VFR flying into IMC remains a prominent safety issue, with the Australian Transport Safety Bureau recording an average of 11 occurrences a year, including serious incidents and accidents.

In 1999, a pilot was conducting a VFR flight from Walgett to an airstrip near Merriwa. The Piper Archer had departed from Walgett earlier in the day, but returned a short time later when it was reported that weather at the destination was not suitable for VFR flight.

However, the pilot felt under pressure to complete the flight that day. He continued to monitor the weather by telephoning for weather reports from an automatic Bureau of Meteorology outlet and by contacting a friend near the destination airfield.

The aircraft departed again at 1415, but the pilot never reached Merriwa.

Read the full story and watch the ‘178 seconds to live’ safety video on the Flight Safety Australia website: http://www.flightsafetyaustralia.com/2016/01/178-seconds-to-live-vfr-into-imc/
VFR parallel offsets

International and Australian studies indicate there is some increased risk of head-to-head collision because of the increased navigation accuracy provided to aircraft using GNSS equipment. The following provides guidance to pilots using GNSS for VFR navigation in class E and class G airspace.

- Pilots should use known waypoints to determine tracks and, when broadcasting, give position information in relation to those waypoints to provide meaningful alerted ‘see and avoid’ positions to any possibly conflicting traffic.
- When operating clear of class C and class D, pilots flying VFR using a GNSS navigation source may offset 1.0 nm RIGHT of track. The offsets must not be used in proximity to controlled or restricted airspace because their use could infringe aircraft segregation.
- Prior to entering class C, class D or when changing to IFR, this offset must be cancelled. Offsets should not be included in default receiver settings and pilots should ensure that they are removed from the CDI settings after use.
- Pilots using the offset procedure while operating under VFR at night must ensure that LSALT calculations are based on the offset track.

GNSS as a supplement to visual navigation techniques

Continuing improvements to the accuracy, affordability and usability of GNSS and its flying-related applications have led to an increasing number of VFR pilots using it as a navigation aid. As with most new technologies, some safety issues have arisen and improper use of, or overreliance on, GNSS have been identified as contributing to a number of safety occurrences discussed in Chapter 8.

Night VFR

In addition to the use of GNSS to supplement visual navigation, pilots may undertake training and become qualified to use GNSS equipment as a night VFR navigation aid in Australian domestic airspace.

The following descriptions provide a general summary for educational purposes. Refer to AIP for full details of the approvals.

RNAV approval

GNSS may be used under VFR at night as a navigation aid and RNAV system for the following purposes:

- position fixing
- operations on designated RNAV routes and application of RNAV-based LSALT
- deriving distance information for en route navigation, traffic information and ATC separation
- meeting the night VFR requirements for carriage of radio navigation systems and alternate aerodromes.
Lowest safe altitude

Night VFR LSALT can be determined by a number of different methods, including on the basis of GNSS RNAV capability.

Mandatory navigation equipment

GNSS systems used by appropriately qualified pilots may satisfy the night VFR requirements for serviceable radio navigation systems.

Alternate aerodromes

GNSS equipment may be used to satisfy the navigation aid aspects of night VFR alternate aerodrome requirements.

VFR qualifications

Day VFR operations

There are no GNSS qualifications issued for the use of GPS as a supplement to visual navigation. Pilots should review the competency requirements of the day VFR syllabus in regard to the use of navigation aids.

Night VFR operations

Pilots must be competent to use their GNSS unit and comply with a licensing requirements of CASR Part 61.

Key points

- GPS may be used in visual flight rules (VFR) operations for visual navigation and night VFR—you will just need to demonstrate competency in GNSS use in night VFR operations.
- Under VFR you cannot fly in cloud and must also stay a specified distance away from cloud, regardless of supplementary GNSS guidance available.
- ‘Blind’ faith in GNSS is often blamed for a sharp rise in the number of violations of controlled and restricted airspace by VFR aircraft.

When you are ready, please turn to page 29 of the workbook and complete the exercises.


**Resources**

**Further reading**


**References**


APPENDICES

• Abbreviations 124
• Definitions 126
• Rules and information 128
<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>AAIM</td>
<td>Aircraft autonomous integrity monitor</td>
</tr>
<tr>
<td>ABAS</td>
<td>Aircraft-based augmentation system</td>
</tr>
<tr>
<td>ACID</td>
<td>Aircraft identification</td>
</tr>
<tr>
<td>ADC</td>
<td>Air data computer</td>
</tr>
<tr>
<td>ADS</td>
<td>Automatic dependent surveillance</td>
</tr>
<tr>
<td>ADS-B</td>
<td>Automatic dependent surveillance-broadcast</td>
</tr>
<tr>
<td>ADS-C</td>
<td>Automatic dependent surveillance-contract</td>
</tr>
<tr>
<td>AFCS</td>
<td>Automatic flight control system</td>
</tr>
<tr>
<td>AFM</td>
<td>Aircraft flight manual</td>
</tr>
<tr>
<td>AFMS</td>
<td>Aircraft flight manual supplement</td>
</tr>
<tr>
<td>AIP</td>
<td>Aeronautical Information Package</td>
</tr>
<tr>
<td>AIRAC</td>
<td>Aeronautical information regulation and control</td>
</tr>
<tr>
<td>AIS</td>
<td>Aeronautical information services</td>
</tr>
<tr>
<td>AMM</td>
<td>Aircraft maintenance manual</td>
</tr>
<tr>
<td>AP</td>
<td>Autopilot</td>
</tr>
<tr>
<td>APCH</td>
<td>Approach</td>
</tr>
<tr>
<td>AR</td>
<td>Authorisation required</td>
</tr>
<tr>
<td>ASECNA</td>
<td>Agency for security of aerial navigation in Africa</td>
</tr>
<tr>
<td>ATC</td>
<td>Air traffic control</td>
</tr>
<tr>
<td>ATIS</td>
<td>Automatic terminal information service</td>
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<tr>
<td>ATS</td>
<td>Air traffic services</td>
</tr>
<tr>
<td>AWIB</td>
<td>Aerodrome weather information broadcast</td>
</tr>
<tr>
<td>BARO</td>
<td>Barometric</td>
</tr>
<tr>
<td>Baro-VNAV</td>
<td>Barometric vertical navigation</td>
</tr>
<tr>
<td>BNN</td>
<td>Backup navigation network</td>
</tr>
<tr>
<td>B-RNAV</td>
<td>Basic area navigation</td>
</tr>
<tr>
<td>CAAP</td>
<td>Civil Aviation Advisory Publication</td>
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<tr>
<td>CAO</td>
<td>Civil Aviation Order</td>
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<tr>
<td>CASA</td>
<td>Civil Aviation Safety Authority</td>
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<tr>
<td>CDFA</td>
<td>Continuous descent final approach</td>
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<tr>
<td>CDI</td>
<td>Course deviation indicator</td>
</tr>
<tr>
<td>CDTI</td>
<td>Cockpit display of traffic information</td>
</tr>
<tr>
<td>CPDLC</td>
<td>Controller to pilot data link communication</td>
</tr>
<tr>
<td>DA</td>
<td>Decision altitude</td>
</tr>
<tr>
<td>DB</td>
<td>Database or data block</td>
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<tr>
<td>DME</td>
<td>Distance measuring equipment</td>
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<tr>
<td>DOD</td>
<td>US Department of Defense</td>
</tr>
<tr>
<td>EGNOS</td>
<td>European geostationary navigation overlay service</td>
</tr>
<tr>
<td>ERSA</td>
<td>En route supplement Australia</td>
</tr>
<tr>
<td>ESIR</td>
<td>Electronic safety incident report</td>
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<tr>
<td>FAA</td>
<td>Federal Aviation Administration</td>
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<td>FAR</td>
<td>Federal aviation regulation</td>
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<tr>
<td>FD</td>
<td>Fault detection</td>
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<tr>
<td>FDE</td>
<td>Fault detection and exclusion</td>
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<td>FDR</td>
<td>Flight data record</td>
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<td>FIR</td>
<td>Flight information region</td>
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<tr>
<td>FLTID</td>
<td>Flight identification</td>
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<td>FMS</td>
<td>Flight management system</td>
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<tr>
<td>FTE</td>
<td>Flight technical error</td>
</tr>
<tr>
<td>GBAS</td>
<td>Ground-based augmentation system</td>
</tr>
<tr>
<td>GEO</td>
<td>Geostationary Earth orbit</td>
</tr>
<tr>
<td>GLONASS</td>
<td>Global orbiting navigation satellite system</td>
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<tr>
<td>GNSS</td>
<td>Global navigation satellite system</td>
</tr>
<tr>
<td>GPS</td>
<td>Global positioning system</td>
</tr>
<tr>
<td>GRAS</td>
<td>Ground-based regional augmentation systems</td>
</tr>
<tr>
<td>IATA</td>
<td>International Air Transport Association</td>
</tr>
<tr>
<td>ICAO</td>
<td>International Civil Aviation Organization</td>
</tr>
<tr>
<td>IFR</td>
<td>Instrument flight rules</td>
</tr>
<tr>
<td>ILS</td>
<td>Instrument landing system</td>
</tr>
<tr>
<td>IMC</td>
<td>Instrument meteorological conditions</td>
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<tr>
<td>Abbreviation</td>
<td>Description</td>
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<tr>
<td>--------------</td>
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</tr>
<tr>
<td>INS</td>
<td>Inertial navigation system</td>
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<td>IREX</td>
<td>Instrument rating exam</td>
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<tr>
<td>IRS</td>
<td>Inertial reference system</td>
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<tr>
<td>ISA</td>
<td>International standard atmosphere</td>
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<tr>
<td>LAME</td>
<td>Licensed aircraft maintenance engineer</td>
</tr>
<tr>
<td>LNAV</td>
<td>Lateral navigation</td>
</tr>
<tr>
<td>LNAV/VNAV</td>
<td>Lateral navigation with vertical navigation</td>
</tr>
<tr>
<td>LOC</td>
<td>ILS localiser</td>
</tr>
<tr>
<td>LOI</td>
<td>Loss of integrity</td>
</tr>
<tr>
<td>LP</td>
<td>Localiser performance</td>
</tr>
<tr>
<td>LPV</td>
<td>Localiser performance with vertical guidance</td>
</tr>
<tr>
<td>LSALT</td>
<td>Lowest safe altitude</td>
</tr>
<tr>
<td>MNPS</td>
<td>Minimum navigation performance specification</td>
</tr>
<tr>
<td>NAIPS</td>
<td>National aeronautical information processing system</td>
</tr>
<tr>
<td>NATHLA</td>
<td>North Atlantic high level airspace</td>
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<tr>
<td>ND</td>
<td>Navigation display</td>
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<tr>
<td>NDB</td>
<td>Non-directional beacon</td>
</tr>
<tr>
<td>NPA</td>
<td>Non-precision approach</td>
</tr>
<tr>
<td>NRP</td>
<td>Navigation rationalisation project</td>
</tr>
<tr>
<td>NSE/PEE</td>
<td>Navigation system error/position estimation error</td>
</tr>
<tr>
<td>NVFR</td>
<td>Night visual flight rules</td>
</tr>
<tr>
<td>OEM</td>
<td>Original equipment manufacturer</td>
</tr>
<tr>
<td>PBN</td>
<td>Performance-based navigation</td>
</tr>
<tr>
<td>PDE</td>
<td>Path definition error</td>
</tr>
<tr>
<td>PIC</td>
<td>Pilot-in-command</td>
</tr>
<tr>
<td>P-RNAV</td>
<td>Precision area navigation</td>
</tr>
<tr>
<td>QZSS</td>
<td>Quasi-zenith satellite system</td>
</tr>
<tr>
<td>RAIM</td>
<td>Receiver autonomous integrity monitoring</td>
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<tr>
<td>RF</td>
<td>Constant radius to a fix</td>
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<tr>
<td>RNAV</td>
<td>Area navigation</td>
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<tr>
<td>RNP</td>
<td>Required navigation performance</td>
</tr>
<tr>
<td>RNP APCH</td>
<td>RNP approach</td>
</tr>
<tr>
<td>RNP AR</td>
<td>RNP AR approach</td>
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<tr>
<td>APCH</td>
<td>RNP AR departure</td>
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<tr>
<td>RPS</td>
<td>RAIM prediction service</td>
</tr>
<tr>
<td>RVSM</td>
<td>Reduced vertical separation minimum</td>
</tr>
<tr>
<td>SA</td>
<td>Selective availability</td>
</tr>
<tr>
<td>SARPS</td>
<td>Standards and recommended practices</td>
</tr>
<tr>
<td>SATCOM</td>
<td>Satellite communications</td>
</tr>
<tr>
<td>SBAS</td>
<td>Satellite-based augmentation system</td>
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<tr>
<td>SDCM</td>
<td>Refers to the Russian system of differential correction and monitoring</td>
</tr>
<tr>
<td>SID</td>
<td>Standard instrument departure</td>
</tr>
<tr>
<td>SIS</td>
<td>Signal-in-space</td>
</tr>
<tr>
<td>SMS</td>
<td>Safety management system</td>
</tr>
<tr>
<td>SSR</td>
<td>Secondary surveillance radar</td>
</tr>
<tr>
<td>STAR</td>
<td>Standard terminal arrival route</td>
</tr>
<tr>
<td>TCAS</td>
<td>Traffic collision alerting and avoidance system</td>
</tr>
<tr>
<td>TF</td>
<td>Track to a fix</td>
</tr>
<tr>
<td>TOAC</td>
<td>Time of arrival control</td>
</tr>
<tr>
<td>TSE</td>
<td>Total system error</td>
</tr>
<tr>
<td>TSO</td>
<td>Technical standard order</td>
</tr>
<tr>
<td>VFR</td>
<td>Visual flight rules</td>
</tr>
<tr>
<td>VHF</td>
<td>Very high frequency</td>
</tr>
<tr>
<td>VMC</td>
<td>Visual meteorological conditions</td>
</tr>
<tr>
<td>VNAV</td>
<td>Vertical navigation</td>
</tr>
<tr>
<td>VOR</td>
<td>VHF omnidirectional range</td>
</tr>
<tr>
<td>WAAS</td>
<td>Wide area augmentation system</td>
</tr>
<tr>
<td>WGS</td>
<td>World geodetic survey</td>
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<tr>
<td>WILCO</td>
<td>‘will comply’</td>
</tr>
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</table>
Definitions

**Airspace:** an area, route or procedure (the designated environment) in respect of which all, or any, of the following requirements must be satisfied, before an aircraft to which an order applies, is able to use it:

- navigation specifications (RNAV or RNP) applicable in the designated environment, for which the aircraft must hold an authorisation or approval
- aircraft navigation equipment requirements that the aircraft must satisfy
- aircraft navigation system functional and performance requirements that the aircraft must satisfy
- aircraft navigation equipment installation requirements that the aircraft must satisfy.

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

**Alternate means of navigation:** the use of information from an area navigation system in lieu of that from conventional navigation aids and navigation equipment that is installed, operational and compatible with conventional navigation aids.

**Augmentation systems:** GNSS supplemental systems used to augment core satellite constellation signals to meet safety and reliability requirements. These systems may include ranging, integrity or differential elements in any combination. There are three categories of augmentation systems:

- aircraft-based augmentation systems (ABAS)
- ground-based augmentation systems (GBAS)
- satellite-based augmentation systems (SBAS).

**Automatic direction finder (ADF):** equipment on the aircraft that detects a non-directional beacon’s (NDB) signal and the NDB transmitter.

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

**CNS/ATM:** airspace capacity is determined by the combined capabilities of the communications, navigation, surveillance and air traffic management systems (CNS/ATM) in place. These include ground- and aircraft-based systems and requirements vary according to the airspace being considered.

**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.

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

**Continuous descent final approach (CDFA):** a technique, consistent with stabilised approach procedures, for flying the final approach segment of a non-precision approach (NPA) procedure as a constant descent, without level-off, from an altitude at, or above, the final approach fix altitude to a point approximately 15 m (50 ft) height above the landing runway threshold or the point where the flare manoeuvre should begin for the type of aircraft flown.
Ephemeris: software which generates the position of planets and their satellites, asteroids or comets.

ETSO: European technical standard order and/or FAA technical standard order.

GAGAN: refers to the Indian global positioning system (GPS) aided geostationary Earth orbit (GEO) augmented navigation.

Instrument landing system localiser (LOC): a system of horizontal guidance in the instrument landing system, which is used to guide aircraft along the axis of the runway.

Instrument meteorological conditions (IMC): an aviation flight category that describes weather conditions that require pilots to fly primarily by reference to instruments.

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

Localiser performance with vertical guidance (LPV) approach: similar to an instrument landing system (ILS) approach, it requires an SBAS-enabled GPS receiver.

Long range navigation system: a navigation system comprising an INS, an IRS or a GNSS capable of use in oceanic or remote airspace.

MSAS: multi-function transport satellite (MTSAT)—a satellite-based augmentation system.

Navigation specification: a set of aircraft and aircrew requirements needed to support PBN operations within a defined airspace.

Operator: the individual or entity responsible for flight operation of the aircraft. This may or may not be the registered operator for maintenance purposes.

Path terminator: a specific type of flight path along a segment of a route or a procedure along with a specific type of termination of that flight path, as assigned to all area navigation routes, SIDs, STARs and approach procedure segments in an aircraft navigation database.

Performance-based navigation: area navigation based on performance requirements for aircraft operating along an ATS route, on an instrument approach procedure, or in a designated airspace.

Positional dilution of precision (PDOP): a measure of how satellite geometry affects navigation and time accuracy. PDOP multiplies range errors and increases position errors.

Receiver autonomous integrity monitor: a form of ABAS whereby a GNSS receiver processor determines the integrity of the GNSS navigation signals using only GPS signals or GPS signals augmented with altitude (baro-aiding). This determination is achieved by a consistency check among redundant pseudo-range measurements. For the receiver to perform the RAIM function, at least one additional satellite needs to be available with the correct geometry, over and above the requisite GNSS satellites needed for the position estimation.

Reliability: the probability of performing a specified function without failure under given conditions for a specified time.
Restricted aerodrome: an aerodrome for which an operator restricts operations to aircraft with certain equipment, or flight crew with a certain combination of training, qualifications and experience, as set out in the operations manual.

RNAV specification: a navigation specification based on area navigation that does not include the requirement for on-board performance monitoring and alerting, designated by the prefix RNAV, e.g. RNAV 5, RNAV 1.

RNP specification: a navigation specification based on area navigation that includes the requirement for on-board performance monitoring and alerting, designated by the prefix RNP, e.g. RNP 4, RNP APCH.

Standard instrument arrival (STAR): a designated instrument flight rule (IFR) arrival route linking a significant point, normally on an ATS route, with a point from which a published instrument approach procedure can be commenced.

Standard instrument departure (SID): a designated instrument flight rule (IFR) departure route linking the aerodrome or a specified runway of the aerodrome with a specified significant point, normally on a designated ATS route, at which the en route phase of a flight commences.

Visual meteorological conditions (VMC): an aviation flight category in which visual flight rules (VFR) flight is permitted—that is, conditions in which pilots have sufficient visibility to fly the aircraft maintaining visual separation from terrain and other aircraft.

Rules and information

Please go to the CASA and Airservices Australia websites for current rules and further information on the topics covered in this Resource guide.

CASA

Aviation safety rules are contained in the:

- Civil Aviation Act 1988
- Civil Aviation Regulations 1988 (CAR)
- Civil Aviation Safety Regulations 1998 (CASR) and associated legislative instruments.

Links to the act and regulations are available at https://www.casa.gov.au/landing-page/rules-and-regulations

Airservices Australia

The Aeronautical Information Package (AIP) can be downloaded from the Airservices Australia website at www.ariservicesaustralia.com.au/aip/aip.asp

It includes:

- The AIP book
- AIP supplements and aeronautical information circulars (AIC)
- Departure and approach procedures (DAP)
- Designated airspace handbook (DAH)
- En route supplement Australia (ERSA)