Australian Government
Civil Aviation Safety Authority
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PBN Implementation Plan

Australia

ICAO Resolution 36-23, Implementation of Performance Based Navigation and Approaches with Vertical Guidance

Version 1, March 2010

Contents

Executive Summary

Background

Australia is a signatory of the Convention on International Civil Aviation; the Chicago Convention. The convention is administered by the International Civil Aviation Organisation (ICAO), an entity of the United Nations.

ICAO has recommended to member States the implementation of Performance Based Navigation (PBN), the regulatory framework for Area Navigation and Approach Procedures with Vertical guidance (APV) for all instrument runway ends, either as the primary approach or as a back-up for precision approaches by 2016. Australia has agreed to these recommendations.

The PBN concept links the Area Navigation application to Oceanic, Continental En route, Terminal Area, Approach and Departure navigation specifications and supporting technologies. Adoption of PBN ensures worldwide harmonisation of Area Navigation. The PBN Area Navigation (PBN/RNAV) specifications harmonise the various existing forms of area navigation and the PBN Required Navigation Perforamance (RNP) specifications add new navigation capability.

Australia is a world leader in applying area navigation; it has been used for over two decades as it is extremely well suited to the Australian operational environment which has significant airspace volume, limited surveillance capability and low radio navigation aid density. Area Navigation is the standard navigation capability of the majority of passenger carrying aircraft in service today and is widely used in many other types of aircraft. Using the Global Navigation Satellite System (GNSS) PBN/RNP specifications include on board navigation performance monitoring which improves pilot situation awareness, removes Air Traffic Control (ATC) navigation monitoring requirements and permits the introduction of smaller separation standards thus further improving operational safety and efficiency.

Australia's fleet of passenger carrying aircraft are typically fully RNAV capable with many RNP capable aircraft, particularly for en route flight operations. RNP approaches to land capabilities vary but are still quite high relative to the rest of our region. Australia's present fleet capabilities, and those within the Asia Pacific region, dictate a requirement to maintain support for RNAV only capable aircraft for some considerable time. Australia therefore intends to maintain its area navigation capability harmonised as PBN/RNAV and simultaneously build an RNP capability through the parallel availability of PBN RNAV and RNP navigation specifications in all classes of airspace.

Australia operates a terrestrial radionavigation aid network that provides aircraft with approach to land guidance in adverse weather. Of the 300 aerodromes in Australia that have radionavigation aids, only around 10% have a vertically guided approach using Instrument Landing Systems (ILS); approaches at the majority (90%) of aerodromes are flown with lateral guidance only using Non Directional Beacons (NDB) and VHF Omni Range (VOR) radionavigation aids. These navigation aids are 70 year old technology and are becoming increasingly expensive to install and maintain. APV procedures supported by GNSS and/or Barometric Vertical Navigation (Baro-VNAV) provide continuous lateral and vertical guidance without the need for terrestrial radionavigation aids. APV approaches are recognised internationally as being up to 8 times more safe than procedures using lateral guidance only. Lack of vertical guidance during instrument approach to land operations is a major contributing factor to accidents involving Controlled Flight into Terrain (CFIT) and such accidents almost always result in 100% fatalities. Recent accidents in Australia or involving Australians include Lockhart River; Queensland, 2005, 15 fatalities and Kokoda; PNG, 2009, 13 fatalities.

Bureau of Infrastructure Transport and Regional Economics (BITRE) Aviation Statistics Document 158 Australian Domestic Airline Activity 2008-2009 lists the Top Competitive air routes (city pairs) in the country. Of the top 50 routes 21 or 42% are flown into aerodromes not serviced by an APV. These services carried 9.3M passengers in the 08/09 FY and include such aerodromes as Gold Coast, Mackay, Rockhampton, Maroochydore, Broome, Kalgoorlie, Albury, Ballina, Coffs Harbour, Dubbo, Mildura and Wagga Wagga.

APV are an ICAO safety initiative directed at reducing the rate of high fatality CFIT accidents that are typical in approach to land operations without vertical guidance. ICAO recognises Baro-VNAV and augmented GNSS as suitable technologies to support vertical guidance. Baro-VNav is available in modern jet and regional aircraft and augmented GNSS is suitable for older and smaller aircraft. Australia does not have a GNSS augmentation system eg: a Space Based Augmentation System (SBAS) such as North America's Wide Area Augmentation System (WAAS) or the European Geostationary Overlay Navigation Service (EGNOS). Unless/until an SBAS service is acquired, Australia can only implement APV though Baro-VNAV. Due to aircraft navigation system fitment limitations APV will have only have maximum safety benefit if both Baro-VNAV and SBAS are adopted:

- By implementing Baro-VNAV Australia will be able to provide APV protection to 97% of fare paying passengers but only 15% of aircraft
- By implementing Baro-VNAV *and* augmented GNSS Australia will be able to provide APV protection to 100% of fare paying passengers and 100% of aircraft

The National Aviation Policy White Paper December 2009 recognises and supports implementation of ICAO resolutions relating to the introduction of new technologies.

Benefits

The introduction of PBN enables significant safety, efficiency and environmental benefits. High accuracy lateral guidance and universal use of vertical guidance for arrival and approach operation greatly enhances safety. Optimised flight paths (lateral and vertical) increase operating efficiency and minimise fuel consumption and emissions. Examples of PBN benefits include:

- Oceanic operations
  - RNP is a necessary enabler to transition from navigation along fixed routes to more efficient Flex tracks and User Preferred Routes (UPR) where effects of head wind can be minimised and benefits of tail wind maximised
  - Australia has implemented UPR across the Pacific and one operator is trialling UPR domestically. Flex Tracks are used between Australia and Asia and across the Indian Ocean
  - Savings of 3 to 4 tonnes of fuel and 10 to 13 tonnes of CO2 emissions on a 14 hour flight are typically achieved.
- Arrival and approach operations
  - Continuous Descent Operations (CDO) during arrival and approach where the aircraft engines are placed at idle from top of descent and the aircraft "glides" to the runway

- Reduced aircraft noise (engines at idle and later deployment of flaps and landing gear during approach) plus curved paths allow greater flexibility in placement of residual noise (eg: over rivers, freeways and/or industrial areas)
- During the Brisbane operational trial of RNP Authorisation Required Approach (RNP AR APCH) operations some 4,900 approaches resulted in average savings of 11.4 track miles, 143Kg of fuel and 486Kg of CO2 per approach were achieved.

- Reduced cost of regulatory oversight through inter-State recognition of internationally adopted global standards thus avoiding multiple aircraft approvals of State specific area navigation specifications
- Reduced reliance on terrestrial radionavigation aid infrastructure through widespread use of GNSS enabled PBN thus permitting the widespread reduction of ground navigation aids

Concept

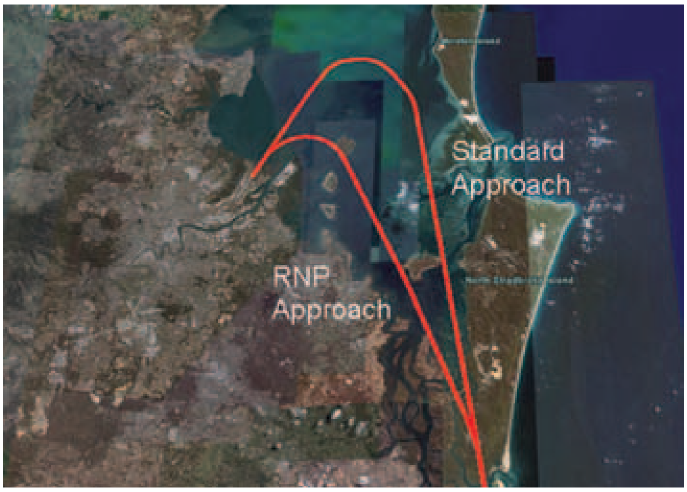
Australia's concept for the transition to PBN is:

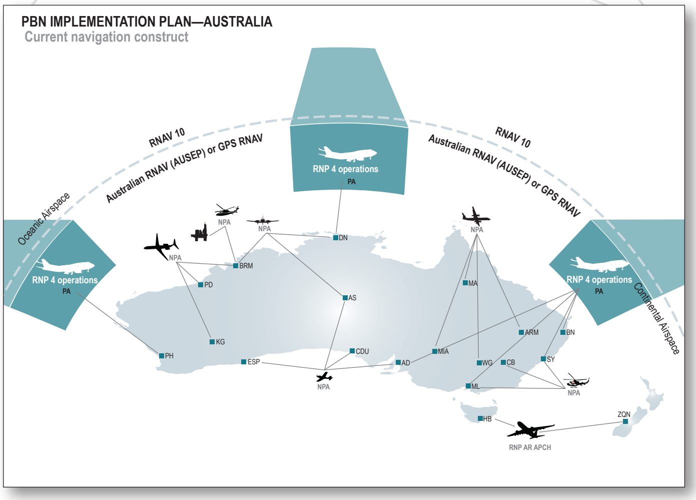
- Parallel availability of RNAV and RNP specifications in all classes of airspace
- APV enabled through barometric vertical navigation (Baro VNav)

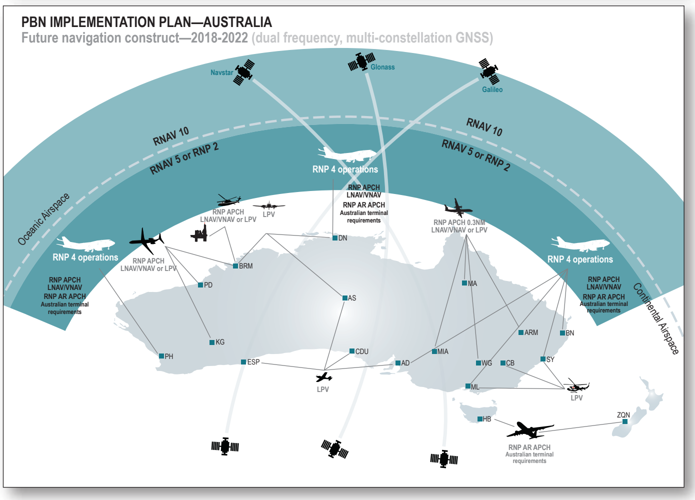
Methodology

Australia's methodology for the transition to PBN is:

- Maintenance of present area navigation capability
- Transition of Australian unique specifications to ICAO PBN specifications (RNAV and RNP)
- Introduction of limited APV capability through barometric vertical navigation
- Utilise the GNSS as the enabling technology for the implementation of PBN
- Utilise a reduced network of terrestrial radionavigation aids (the backup network) to support non PBN arrivals and non precision approaches at selected aerodromes.







About the Plan

Background

ICAO Assembly Resolution A36-23 resolved that:

- Each State to develop a national PBN implementation plan by 2009 to achieve
  - implementation of RNAV and RNP operations (where required) for en route and terminal areas according to established timelines and intermediate milestones
  - implementation of approach procedures with vertical guidance (APV) (Baro-VNAV and/or augmented GNSS) for all instrument runway ends, either as the primary approach or as a back-up for precision approaches by 2016 with intermediate milestones as follows: 30 per cent by 2010, 70 per cent by 2014; and
- Urges that States include in their PBN implementation plan provisions for implementation of approach procedures with vertical guidance (APV) to all runway ends serving aircraft with a maximum certified take-off mass of 5700 kg or more, according to established timelines and intermediate milestones

Australia's PBN Implementation Plan uses a template developed by the ICAO PBN Programme for use by the ICAO Contracting States.

Australia has already completed conversion to the WGS-84 coordinate system and this will facilitate the timely introduction of PBN as all RNAV and RNP operations are conducted solely with reference to WGS-84 coordinates.

Why is a PBN Implementation Plan needed?

Current planning by the Planning and Implementation Regional Groups (PIRG's) is based on the Air Navigation Plans and the Regional Communication Navigation and Surveillance/Air Traffic Management (CNS/ATM) plans. These plans are mostly made up of tables that do not contain the necessary details for the implementation of each of the CNS and ATM elements. For this reason, the Regions will be developing Regional PBN implementation plans. The necessary concurrent and follow-on step is to develop national plans that implement the regional plans at the State level and address PBN implementation strategy at the national level.

In view of the need for detailed navigation planning, it was deemed advisable to call for preparation of a national PBN Implementation Plan by each State, to provide proper guidance and direction to the domestic air navigation service provider(s), airspace operators and users, regulating agencies and foreign operators who operate or plan to operate in the State. This guidance should address the planned evolution of navigation, as one of the key systems supporting air traffic management and describe the RNAV and RNP navigation applications that should be implemented, in at least the short and medium term, in the State.

What are the objectives of the Australian PBN Implementation Plan?

The Australian PBN implementation plan aims to meet the following strategic objectives:

- Provide a high-level strategy to transition Australian aviation from route based navigation using terrestrial radionavigation aids to area navigation using satellite navigation. This strategy is based on the ICAO PBN concepts of RNAV and RNP navigation specifications which will be applied to aircraft operations involving instrument approaches, Standard Instrument Departures (SID), Standard Terminal Arrival Route (STAR) as well as fixed and dynamic routes in oceanic and continental airspace in accordance with the implementation goals in Assembly Resolution 36-23
- Ensure that the implementation of the navigation portion of the CNS/ATM system is based on clearly established operational requirements
- Avoid unnecessarily imposing requirements for multiple equipment on board or multiple systems on the ground
- Avoid the need for multiple airworthiness and operational approvals for inter-regional and international operations
- Prevent commercial interests from superseding ATM operational requirements or generating unnecessary costs for Australian authorities, agencies and airspace users

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What is the intent of the Australian PBN Implementation Plan?

The intent of the Australian PBN Implementation Plan is to assist members of the Australian aviation community to plan and execute a swift transition to the RNAV and RNP concepts in order to maximise the safety, economic and environmental benefits of PBN and to guide synchronised investment in new technology and infrastructure. The main stakeholders of the aviation community that benefit from this plan and should therefore be included in the development process are:

- Aircraft owners and operators
- Airport owners and operators
- National and international aviation organisations
- Civil Aviation Safety Authority (CASA)
- Airservices Australia
- The Department of Infrastructure, Transport, Regional Development and Local Government

The Australian PBN Implementation Plan must also assist the Australian aviation community to plan future transition and investment strategies. Aircraft and airport owners and operators can use this plan to forecast future equipage and additional navigation capability investments; Airservices Australia can plan a gradual transition for evolving CNS/ATM infrastructure; CASA will be able to anticipate and plan future criteria as well as the future regulatory workload and associated training requirements for their work force.

What principles should be applied in development of the Australian PBN Implementation Plan?

The implementation of PBN in Australia should be based on the following principles:

- Continued application of conventional air navigation procedures during the transition period to assure availability to users that are not yet RNAV and/or RNP approved
- Selection of appropriate PBN navigation specifications using modelling tools as well as real-time and accelerated simulations, to support the navigation applications
- Conduct of cost-benefit analyses to justify the implementation of the RNAV and/or RNP navigation specification
- Conduct of pre and post implementation safety assessments to ensure the application and maintenance of the established target levels of safety
- Harmonisation with the regional PBN implementation plan

Benefits of PBN and Global Harmonisation

Introduction

The International Civil Aviation Organisation has identified six strategic objectives to enable the implementation of its vision of safe, secure and sustainable development of civil aviation. The six strategic objectives are as follows:

- Safety - enhance global civil aviation safety
- Security - enhance global civil aviation security
- Environmental Protection - minimise the adverse effect of global civil aviation on the environment
- Efficiency - enhance the efficiency of aviation operations
- Continuity - maintain the continuity of aviation operations
- Rule of Law - strengthen governance of international aviation

To enable these objectives, ICAO has developed a range of higher level plans and initiatives that embrace the concept of the global harmonisation of aviation infrastructure, equipment and procedures and the use of technology to enable CNS/ATM initiatives that collectively promote international aviation safety, efficiency and continuity. Two such initiatives are:

- The Global Air Navigation Plan
- The Global Aviation Safety Roadmap

The Global Air Navigation Plan

The Global Air Navigation Plan is an ICAO document that identifies a series of Global Plan Initiatives (GPI) which focus on specific performance objectives aimed at reducing global aviation's impact on the environment and increasing global ATM safety, efficiency and security through the use of available and foreseen aircraft and infrastructure technology. The GPI are therefore near to medium term in focus and leverage current and emerging technologies with the aim of air navigation system improvements that result in direct ATM system performance enhancements.

The GPIs are options for ATM improvements that, when implemented, would result in direct performance enhancement. States and regions should choose initiatives that meet performance objectives, identified through an analytical process, specific to the particular needs of a State, region, homogeneous ATM area, or major traffic flows.

Fundamental to the Global Air Navigation Plan are the air navigation system enhancements enabled through the GNSS. These include:

- GPI-5 RNAV and RNP (Performance Based Navigation) - aimed at improving safety, efficiency and capacity of the ATM system through the incorporation of advanced aircraft navigation capabilities to the air navigation system infrastructure
- GPI-9 Situational Awareness - aimed at improving safety, efficiency and capacity through the incorporation of air traffic information displays in aircraft cockpits (eg: ADS-B, ADS-C) and ground and obstacle proximity warning systems
- GPI-11 RNP and RNAV Standard Instrument Departures (SIDS) and Standard Terminal Arrivals (STARS) - aimed at improving safety and efficiency in the terminal area by providing greater flexibility between the end of the en-route phase of flight and the final approach phase of flight
- GPI-20 Implementation of WGS-84 by all States - aimed at providing a common geodetic reference system for all aerodromes, runways, obstacles and navigation aids in order to support RNAV systems, maximise the ATM enhancement opportunities of GNSS and avoid the creation of ATM seams
- GPI-21 Navigation Systems - aimed at providing an accurate, reliable and seamless global navigation infrastructure that facilitates the introduction and evolution of Performance Based Navigation through an appropriate mix of GNSS, INS and ground based navigation aids

The Australian Strategic Air Traffic Management Plan 2007 is aligned to the ICAO Global Air Navigation Plan and its associated GPIs. The Australian ATM strategic planning process is consistent with this philosophy and links ICAO GPIs to the strategies developed for Australia. This integration of strategies, system outcomes and performance outcomes is detailed in the Operational Evolution Document and ATM community member implementation roadmaps. Of particular relevance to PBN is GPI 21 - Navigation Systems.

Global Plan Initiative 21 - Navigation Systems

Global Plan Initiative 21 embraces GNSS-centred navigation due to the global nature of aviation operations and the ability to deliver a globally interoperable navigational infrastructure that delivers benefits in safety, efficiency and capacity. In order to achieve these benefits performance based navigation must be supported by an appropriate navigation infrastructure consisting of an appropriate combination of GNSS, self-contained navigation systems (eg: INS) and conventional terrestrial radionavigation aids. GNSS provides standardised positioning information to the aircraft systems to support precise navigation globally. One global navigation system will help support a standardisation of procedures and cockpit displays coupled with a minimum set of avionics, maintenance and training requirements.

GPI 21 also makes the following observations:

- The ultimate goal is a transition to GNSS that would eliminate the requirement for ground-based aids
- GNSS is vulnerable to interference and may require the retention of some ground aids in specific areas
- GNSS-centred performance based navigation enables a seamless, harmonised and cost effective navigational service from departure to final approach that will provide benefits in safety, efficiency and capacity
- GNSS implementation will be carried out in an evolutionary manner, allowing gradual system improvements to be introduced
- Near-term applications of GNSS are intended to enable the early introduction of satellite-based area navigation without any infrastructure investment, using the core satellite constellations and integrated multi-sensor airborne systems
- Medium / longer term applications will make use of existing and future satellite navigation systems with some type of augmentation, or a combination of augmentations required for operation in a particular phase of flight

Queenstown approach displays

Queenstown approach

The Global Aviation Safety Roadmap

The Global Aviation Safety Roadmap is an ICAO / industry cooperative strategic action plan, the primary objective of which is to provide a common framework for industry stakeholders including States, regulatory authorities, airline operators, airport operators, aircraft manufacturers, pilot associations, safety organisations and air traffic control service providers. The Roadmap lists 12 specific focus areas that are considered vital to the enhancement of global commercial aviation.

Of note is Focus Area 12 which concerns the use of technology in enhancing safety and in particular Annexes E, F and G to the Global Aviation Safety Roadmap. A brief description of each annex is as follows:

- Annex E – Use of Technology to Enhance Safety – Aircraft Operations, considers safety based upon the categorisation of safety incidents and technologies available to militate against them. Approach and landing accidents and CFIT are among these and technologies available to minimise the risk of such events include: flight path directors, vertical Flight Management Systems (FMS), RNAV and RNP approaches, Head Up Displays (HUD),auto land systems and Vertical Situation Displays (VSD)
- Annex F – Use of Technology to Enhance Safety – Air Traffic Management / Air Traffic Control, considers safety based upon the categorisation of safety incidents and technologies available to militate against them. CFIT, Midair and Ground Collisions are among these and technologies available to minimise the risk of such events include
  - Display of Mode S selected altitude, Automatic Dependant Surveillance - Contract (ADS-C), Automatic Dependant Surveillance -Broadcast (ADS-B) and Airborne Collision Avoidance System (ACAS)
  - Airport Surface Detection System (ASDS), Airport Movement Area Safety System (AMASS), Advanced Surface Movement Guidance and Control Systems (ASMGCS) and Multi-lateration (MLAT) based on ACAS, Mode S or ADS-B
- Annex G – Use of Technology to Enhance Safety – Airport Operations, considers safety based upon the categorisation of safety incidents and technologies available to militate against them. Ground Collisions are among these and technologies available to minimise the risk of such events are as for Annex F above

The common factor that enables the GPI and Focus Area 12 initiatives listed in the Global Air Navigation Plan and the Global Aviation Safety Roadmap is Precision Navigation and Timing (PNT). PNT is enabled through the GNSS and as such the GNSS is fundamental to the introduction of PBN and harmonisation of the global CNS/ATM system.

Performance Based Navigation (PBN)

Introduction

ICAO has set worldwide direction to rapidly transition to performance based navigation and approaches with vertical guidance. PBN RNAV and RNP navigation specifications define performance and other requirements for aircraft navigating along a route, on an instrument approach procedure or in defined airspace.

Performance requirements are defined in terms of accuracy, integrity, availability, continuity and functionality needed for a proposed operation in the context of a particular airspace concept. Navigation specifications also identify technology, systems and procedures which are recognised as suitable to meet the performance requirement.

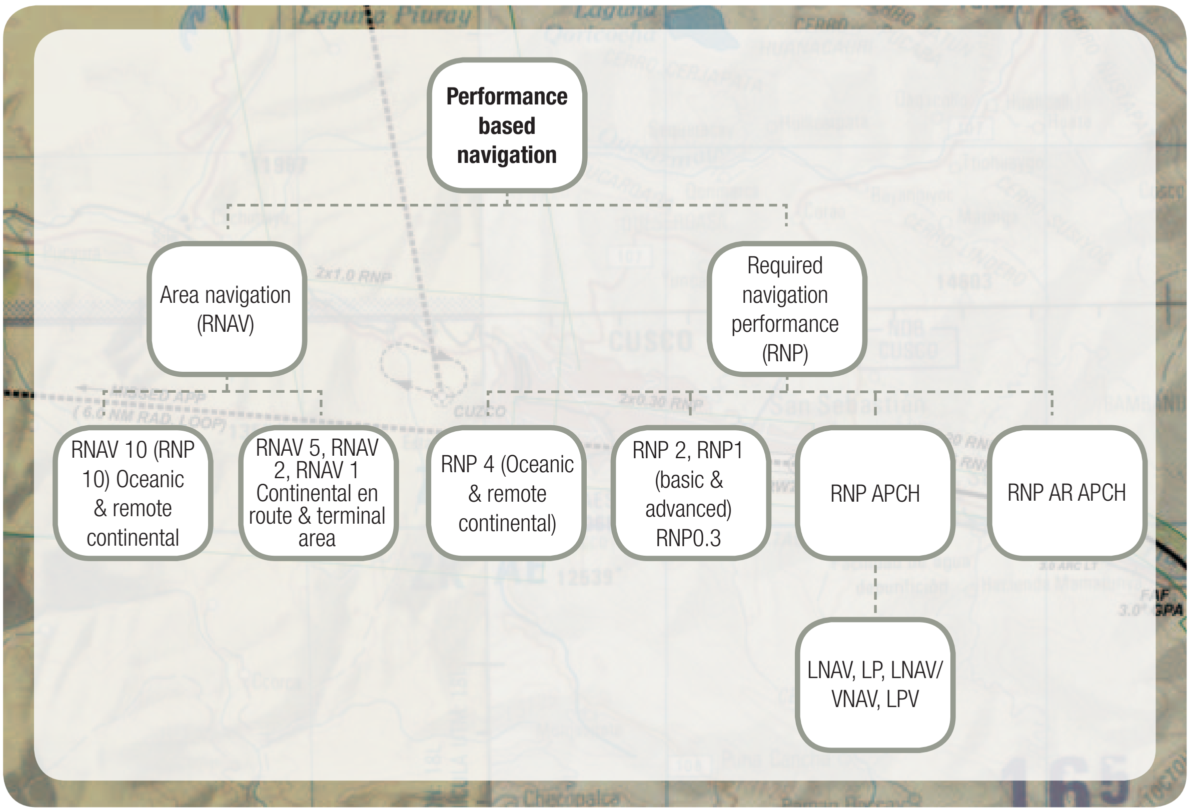
Area navigation is defined as a method of navigation which permits aircraft operation on any desired, pre-planned flight path. This allows more flexible and efficient aircraft operation compared to the traditional flying along fixed routes denoted by terrestrial radio navigation aids. Early area navigation systems required ATC navigation integrity monitoring - typically implemented by radar surveillance. The PBN/RNAV specifications are applicable to these systems.

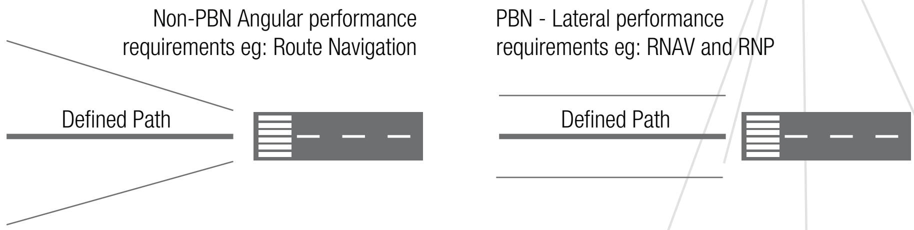
Modern area navigation avionics include navigation performance monitoring. This permits the transfer of navigation integrity monitoring to flight crew rather than ATC. This is necessary with very high accuracy navigation (0.3 to 0.1 NM); as it is impractical for ATC to detect errors of this size and there is insufficient time to successfully intervene. Aircraft with RNP capability are also RNAV capable.

In Australia, due to the paucity of terrestrial radionavigation aids and radar surveillance, the practical difference between RNAV and RNP operations is that RNAV operations require Inertial Navigation Systems (INS) and RNP operations require GNSS (either standalone or multi-sensor systems). The ATC procedural separation standard applied to aircraft using inertial navigation is significantly larger than that for aircraft using GNSS navigation and therefore greater efficiency will be gained in the ATM though the widespread use of GNSS enabled RNP rather than INS enabled RNAV.

RNP standards are the more capable of the two PBN specifications and is recognised worldwide as the navigation standard that should be adopted in the medium term to long term in order to support improvements in safety, efficiency and environment:

- Safely allow higher traffic density
- Enable higher accuracy, more efficient and sophisticated approach and departure operations including curved path, particularly useful in terrain and/or noise challenging areas
- Reduced emissions and noise





Adapted from ICAO PBN Manual

Background

Terrestrial radionavigation aids have been the basis of aircraft instrument navigation for many decades. Australia has some 430 ground radionavigation (NDBs, VORs and Distance Measuring Equipment - DMEs), which aircraft use to conduct point to point navigation along fixed routes (Route Navigation) and to conduct instrument approach to land procedures to aerodromes.

Route Navigation is the ability to navigate along predefined straight line route segments. Route navigation is navigation aid based and prescribes aircraft navigation equipment required for particular routes to be flown. NDB and VOR provide directional guidance as a bearing or radial from the aid and subsequently cross track accuracy decreases with range from the navigation aid. A positive position fix can only be determined when overflying a NDB or VOR or when a DME is co-located with the NDB or VOR. Position estimation along track is based upon time between positive fixes. Terrestrial radionavigation aids such as NDB, VOR and DME support route navigation. A fixed route can also be flown using area navigation.

The constraints of Route Navigation limit the safety and efficiency of aircraft operations. Approach and Departure Instrument Flight Procedures based on terrestrial radionavigation are constrained by the location, accuracy and other limitations of the supporting radionavigation.

To overcome the constraints of Route Navigation, Area Navigation systems were developed. Area navigation allows an aircraft to fly any pre-defined path with high accuracy between two points in space. Area Navigation is recognised as a necessary enabler to further optimise aircraft operation, increase terminal area safety and provide flexibility in placement of aircraft flight path to minimise aircraft noise intrusion on the community.

Early area navigation systems were based on inertial or radio direction finding and multi-lateration principles and included INS, LORAN (LOng RAnge Navigation), Omega, DME-DME or DME-VOR. LORAN and Omega are no longer in use. INS using DME/VOR update remains a commonly used combination.

Over the last 15 years, satellite based area navigation has matured. The GNSS meets the needs of Oceanic, Continental Remote, Continental En route, Terminal Area and Non-Precision Approach RNAV requirements for most aircraft. Modern jet and regional aircraft have sophisticated navigation capabilities integral to the Flight Management System and supported by GNSS and Inertial position sensors. GNSS avionics, suitable for all aircraft - largest jet to smallest General Aviation (GA), are available from a variety of manufacturers. These systems also support navigation performance monitoring. In Australia, GNSS is an approved primary means of navigation. GNSS navigation is currently widely used by all classes of aircraft and operations.

Area Navigation has been implemented in many parts of the world using local standards and practices. PBN is the international regulatory framework to standard the implementation of Area Navigation worldwide. PBN has two families of nav specs - RNAV intended to harmonise existing USA/Europe area navigation specifications and more capable RNP specifications required now and in the future.

PBN is identified as a key enabler in the USA's NextGen and Europe's SESAR ATM plans and ICAO has set direction for the worldwide adoption of PBN using appropriate selection of RNAV and RNP Navigation Specifications.

Key Concepts

Performance Based Navigation (PBN)

PBN is defined as area navigation based on performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in a designated airspace. PBN represents a fundamental shift from a sensor (equipment) based navigation concept to a performance (systems) based navigation concept. Navigation specifications need no longer be met through prescribed equipment components, such as INS or VOR/DME receiver, but rather through an aircraft's navigation systems ability to meet prescribed performance criteria.

Further, the development of the PBN concept recognised that advanced aircraft RNAV systems are achieving a predictable level of navigation performance accuracy which, together with an appropriate level of functionality, allows a more efficient use of available airspace to be realised. Identifying navigation requirements rather than the means of meeting the requirements will allow use of all RNAV systems meeting these requirements irrespective of the means by which these are met.

Under PBN, a navigation specification is either an RNP specification or an RNAV specification. Both RNAV and RNP must meet the same navigation performance requirements however an RNP specification includes a requirement for on-board self-contained performance monitoring and alerting while an RNAV specification does not.

PBN allows navigation system technology to evolve over time without requiring the operation itself to be reviewed, as long as the required levels of accuracy, integrity, availability, continuity and functionality needed for a proposed operation are met by the navigation system as a whole. As PBN identifies navigation requirements to be met irrespective of the means by which they are met; PBN offers a number of advantages over sensor-based navigation including:

- Increased airspace safety through the implementation of stabilised descent procedures using vertical guidance
- Reduced environmental impact through more efficient use of airspace (route placement, fuel efficiency and noise abatement)
- Reduced need to maintain avionics and terrestrial radionavigation aids for specific routes and procedures
- No need for development of sensor-specific operations for each new evolution of navigation systems
- Facilitation of the operational approval process by providing a limited set of global navigation specifications

Area Navigation (RNAV) Operations

RNAV permits aircraft to fly on any desired flight path within the coverage of terrestrial navigation aids, within the limits of the capability of its self-contained navigation aids, or a combination of these. RNAV has parallel lateral performance requirements and can be supported by a variety of technologies such as multiple DME, INS updated by DME/DME or DME/VOR and GNSS. An RNAV specification is a navigation specification which does not include requirements for on-board performance monitoring and alerting.

In Australia RNAV operations will require, as a minimum, INS although GNSS may be used to support RNAV specifications. Australia will not support RNAV operations using DME/DME or DME/VOR (only) area navigation systems.

RNAV Navigation System

Required Navigation Performance (RNP) Operations

RNP permits aircraft to fly on any desired flight path within the coverage of terrestrial navigation aids, within the limits of the capability of its self-contained navigation aids, or a combination of these. An RNP specification is a navigation specification which includes requirements for on-board performance monitoring and alerting. RNP has parallel lateral performance requirements and can be supported by a variety of technologies such as multiple DME, INS supported by DME/DME or DME/VOR and GNSS.

In Australia RNP operations will require, as a minimum, GNSS either a multi-sensor system or standalone navigator.

RNP Navigation System

Standard Instrument Departure (SID) and Standard Terminal Arrival Route (STAR)

SIDs are designated Instrument Flight Rule (IFR) departure route linking an aerodrome or a specified runway of an aerodrome with a specified significant point, normally on a designated ATS route, at which the en-route phase of flight commences. Major aerodromes typically have a ‘family’ of SIDs which link each runway end to the start of each major air routes.

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

SIDs and STARs can be conducted under either RNAV or RNP navigation specifications.

Approach Procedures

Conventional approach procedures include ILS, VOR, and NDB. These procedures exclusively use ground based navigation aids as the basis of the procedure design. Under PBN there is no requirement for ground based navigation aids to support the procedure although they may be incorporated into the missed approach procedure if desired. PBN does not include RNAV approach specifications as integrity monitoring is required for approach operations. Consequently RNAV (GNSS) approaches have been reclassified as RNP APCH - LNAV. This is reflected in the performance specifications where only RNP APCH specifications include a lateral accuracy value for all segments of an instrument approach (initial, intermediate, final and missed).

Precision Approach (PA) procedures such as ILS, Microwave Landing System (MLS) and GNSS Landing System (GLS) are not included in the PBN Standards and hence are not addressed here. It should be noted that PBN/RNP Arrival/Approach procedures can terminate in an ILS, MLS or GLS Procedure.

All PBN instrument approach to land procedures use the GNSS (either non-augmented or augmented signals) for lateral navigation (LNAV) guidance; where vertical navigation (VNAV) guidance is provided either Baro-VNAV or augmented GNSS is used. There are two classes of RNP approach operations RNP APCH and RNP AR APCH; the fundamental distinctions between them are:

- The RNP value of the final approach segment is fixed at 0.3nm for RNP APCH and may vary from 0.3nm to 0.1nm for RNP AR APCH
- RNP APCH may include vertical guidance; RNP AR APCH always includes vertical guidance
- RNP AR APCH operations requires specific crew training and operational approval

There are four types of RNP APCH procedures; they are:

- RNP APCH:
    - LNAV: where lateral guidance is provided by the GNSS Signal In Space (SIS)
    - LNAV/VNAV: where lateral guidance is provided by the GNSS SIS and vertical guidance is provided by barometric vertical navigation (Baro-VNAV);
    - LP (Localiser Performance): where lateral guidance equivalent to a localiser approach is provided by augmented GNSS SIS; and
    - LPV (Localiser Performance with Vertical guidance): where lateral and vertical guidance is provided by augmented GNSS SIS.

An RNP AR APCH is flown using non-augmented GNSS SIS and barometric vertical navigation and is applicable to aircraft equipped with GNSS multi-sensor navigation systems and suitably capable Flight Management Systems. RNP AR APCH utilise LNAV/VNAV minima based upon the RNP accuracy value which is between 0.3 and 0.1NM for current operations.

The advent of APV has introduced a third classification of instrument approach procedure into ICAO vernacular. The classifications of instrument approach to land procedures are therefore:

- Non-Precision Approaches (NPA)
- Approaches with Vertical guidance (APV)
- Precision Approaches (PA).

These are illustrated in the table below:

Approach Classification	Approach Type
Non Precision Approach (NPA)	NDB VOR DME (GPS) Arrival RNP APCH (0.3NM) LNAV (currently termed RNAV GNSS) LP (augmented GNSS required)
Approach with Vertical Guidance (APV)	RNP APCH (0.3NM) LPV (augmented GNSS required) LNAV/VNAV (Baro-VNAV) RNP AR APCH (0.3NM and below) LNAV/VNAV (Baro-VNAV)
Precision Approach (PA)	ILS MLS GLS

Approaches with Vertical Guidance (APV)

ICAO defines an APV as “An instrument approach procedure which utilises lateral and vertical guidance but does not meet the requirements established for precision approach and landing operations”. ICAO recognises Baro-VNAV and augmented GNSS SIS as suitable technologies to support vertical guidance applications and has enabled APV operations through the development of PansOps procedures for both Baro-VNAV and augmented GNSS. APV are:

- RNP APCH - LNAV/VNAV
  - Baro-VNAV approach procedures that include system performance monitoring and alerting for lateral navigation errors in the GNSS SIS and must meet demonstrated system accuracy requirements for the vertical navigation source (altimeter)
- RNP APCH - LPV
  - SBAS approach procedures that include system performance monitoring and alerting for lateral and vertical navigation errors in the GNSS SIS. LPV are a “landing system” design and can be considered as a GNSS enabled ILS
- RNP AR APCH
  - Baro-VNAV approach procedures that include system performance monitoring and alerting for lateral and vertical error budget requirements for the vertical navigation source (altimeter)

ICAO Direction

Tenth Air Navigation Conference (ANC-10)

ICAO, at the tenth Air Navigation Conference (ANC-10) in 1991 set direction that aviation worldwide should adopt satellite navigation as the means of navigation for all phases of flight. The initial deployment of GNSS had been slower than originally anticipated. However the combination of increasing State approvals and supply and development of new aircraft with integrated GNSS capability has resulted in increasing acceptance and use of satellite based navigation.`

Eleventh Air Navigation Conference (ANC-11)

At the eleventh Air Navigation Conference (ANC-11) in 2003, the recommendation to adopt satellite navigation was re-affirmed. ANC-11 encouraged more rapid deployment of satellite navigation and introduced Performance Based Navigation (PBN) as the implementation framework.

36th Annual Assembly

The ICAO 36th Assembly in 2007 re-affirmed the direction to adopt satellite navigation and PBN; it also set direction for the adoption of APV as the primary instrument approach procedure or as a backup to precision approach procedures.

Targets for implementation were set as follows:

Operational Use	2010	2014	2016
PBN Oceanic	70 %	100 %	
PBN En-Route	70 %	100 %	
PBN Terminal	30 %	60 %	100 %
RNP Approach	30 %	70 %	100 %

It is recognised that these targets are ambitious and it is unlikely that they will be widely met as many member States have legacy aircraft incapable of using Baro-VNAV and are not within SBAS service areas eg: Central and Southern Africa, the Middle East, South America, South East Asia and Australia.

Intention

The intention of the ICAO recommendation, to adopt PBN, is to standardise and harmonise the deployment of area navigation which is recognised as a necessary enabler for modern ATM applications, which will increase safety, operating efficiency and minimise environmental impact.

The intention of the ICAO direction to adopt APV as the primary instrument approach procedure or as a backup to precision approach procedures is to significantly reduce the risk of CFIT, runway undershoot and overrun through the provision of continuous lateral and vertical guidance during instrument approach to the runway. With the introduction of APV, NPA’s would be phased out of service resulting in the APV becoming the minimum world wide standard for an instrument approach to land procedure.

PBN RNAV

Capabilities

PBN RNAV is the less capable of the two families of PBN navigation specifications and in Australia is reliant upon an INS to support the specification. RNAV is suited to current and legacy aircraft operations however it is insufficient to support many of the new Air Traffic Management (ATM) applications envisaged in strategic plans (eg: 3 dimensional, or 4 dimensional ATM concepts).

The PBN RNAV Navigation Specifications are:

- RNAV 10: (known as RNP-10) intended for oceanic and remote continental operations
- RNAV 5: intended for continental en route operations
- RNAV 2: intended for terminal areas
- RNAV 1: intended for terminal areas

The PBN RNAV Navigation Applications include:

- RNAV SID: applied to terminal areas
- RNAV STAR: applied to terminal areas

It should be noted that Australia currently has unique area navigation specifications notably:

- Global Positioning System (GPS) Oceanic
- Australian RNAV (which permits a separation standard based on INS and is known as AUSEP)
- GPS RNAV

The Australian unique area navigation specifications will transition to ICAO PBN specifications. The likely transition path is:

- GPS Oceanic to RNP 4
- Australian RNAV (AUSEP) to RNAV 5
- GPS RNAV to RNP 2.

Note: In historical documentation RNAV 10 is referred to as RNP 10. RNP 10 is a member of the RNAV specification family. It is acknowledged that the cost of correcting documentation worldwide, to correct this anomaly, is excessive and not worth the effort.

Current status of Area Navigation in the Australian FIR

Australia has a very well developed area navigation capability and has operated to Australian unique specifications for many years. Area navigation, particularly GNSS enabled area navigation, is extremely well suited to the Australian operational environment which has characteristics including:

- Significant airspace volume largely comprising oceanic and continental en route specifications
- Limited conventional (radar) surveillance capability
- Low radionavigation aid density

PBN RNAV Oceanic operations in the Australian FIR include:

- RNAV 10

Note:

- Australia permits RNAV 10 in all en route airspace
- Australia does not conduct Remote Continental RNAV operations

Area navigation in Continental En Route operations in the Australian FIR include:

- AUSEP
- GPS RNAV

Area navigation Terminal operations in Australian FIR (no PBN navigation specification currently used) include:

- SIDs
- STARs

Area navigation Approach operations in Australian FIR include:

- RNAV (GNSS) to be renamed RNP APCH - LNAV

PBN RNP

Capabilities

PBN RNP is the more capable of the two families of PBN navigation specifications. The on board navigation performance monitoring and alerting is a necessary enabler for many new ATM applications envisaged in strategic plans. Full RNP capability is available to the latest generation of aircraft such as A320, B737-NG and B787 and may be available to other late generation aircraft via modification processes.

The PBN RNP Navigation Specifications are:

- RNP 4: intended for oceanic operations
- RNP 2: intended for continental en route operations
- Basic RNP 1: intended for terminal area operations

The PBN RNP Navigation Applications are:

- RNP APCH:
  - LNAV
  - LNAV/VNAV
  - LP
  - LPV
- RNP AR APCH:
  - LNAV/VNAV

Current status of RNP operations in Australia

RNP Oceanic operations in Australian FIR include:

- RNP 4

Note: Australia does not conduct Remote Continental RNP operations

RNP Continental En Route operations in Australian FIR include:

- RNP 4 (limited use with Flex Tracks)

RNP Terminal operations in Australian FIR include:

- SID - there are RNP SID's at nine precision aerodromes and one non-precision aerodrome in Australia (as at March 2010).

RNP Approach operations in Australian FIR include:

- RNP AR procedures
  - Currently conducted by two domestic airlines with a third scheduled to start in the near future
  - Aircraft types that are conducting, or intending to conduct, these approaches are B737-NG and A320
  - As at March 2010 Australia has 17 aerodromes with RNP approach or departure procedures and these are indicated in the table below:

Aerodromes with a Precision Approach	Aerodromes with a Non-Precision Approach
Adelaide*	Ayers Rock
Alice Springs*	Broome
Brisbane*	Gold Coast*
Cairns*	Kalgoorlie-Boulder
Canberra*	Karratha
Darwin*	Mount Isa
Hobart*	Port Headland
Melbourne*	
Townsville*	* indicates RNP SID
Sydney	

Approaches with Vertical guidance (APV)

Capabilities

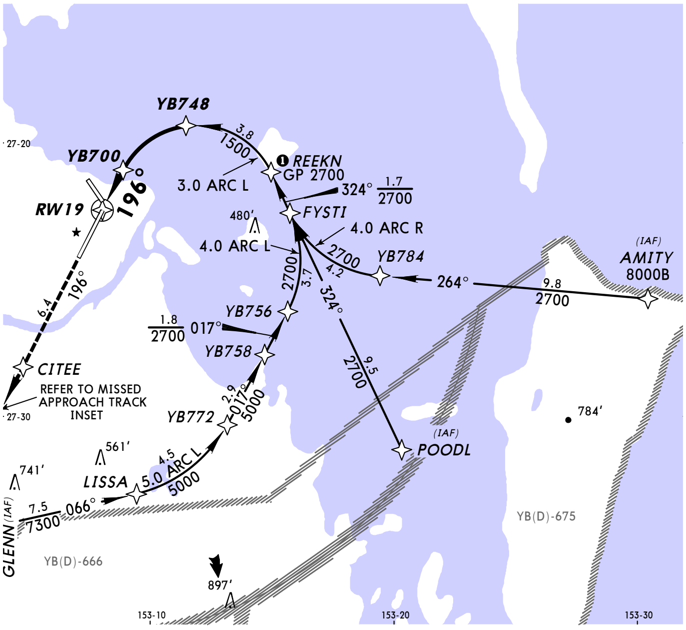
Controlled Flight into Terrain (CFIT) during approach, runway undershoots and runway overruns are the cause of many fatal aircraft accidents. Continuous vertical guidance combined with continuous lateral guidance is recognised as greatly reducing the risk of CFIT during approach and landing. ICAO considers the risk is reduced by a factor of 25 times compared to a classical circling approach or 8 times reduced for a straight in approach utilising lateral navigation guidance only.

APV types are reproduced in the table below:

Approach Category	Approach Type
APV	RNP APCH - LNAV/VNAV (Baro-VNAV) - LPV (augmented GNSS SIS) RNP AR APCH - LNAV/VNAV (Baro-VNAV)

Current status of APV operations in Australia

There are currently 16 Australian aerodromes served by RNP AR procedures as at February 2010. These are currently being conducted by individual operators on a case by case basis but are undergoing a transition to be made publically available to approved operators. There are currently no APV operations being conducted in Australia under APV Baro-VNAV or LPV design criteria.



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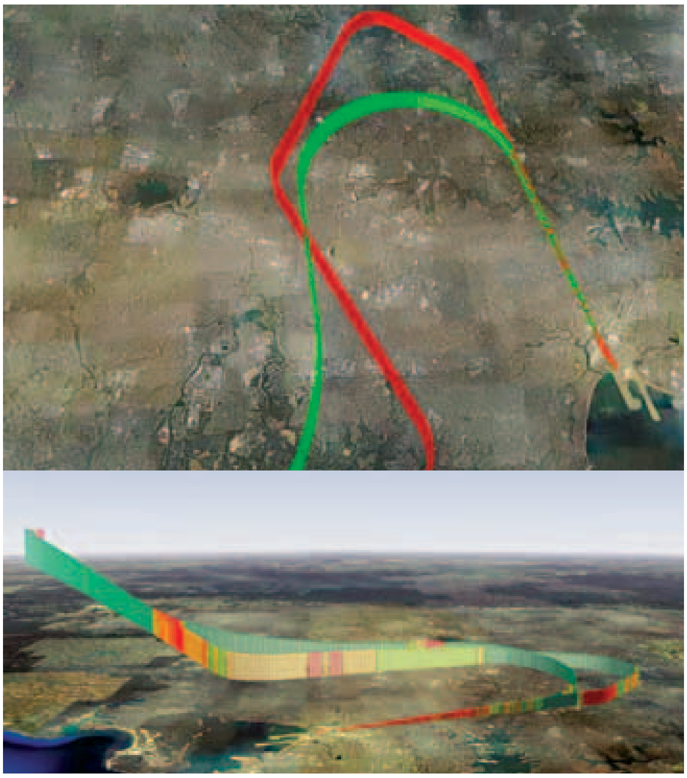
Challenges

Safety Challenges

Safety challenges revolve largely around the safe operation of the ATM system during the transition to PBN operations. Gaps will necessarily occur within the CNS/ATM system noting that PBN addresses only the navigation tenet of the system and advances in navigation may out pace advances in communication and/or surveillance. Safety challenges therefore include:

- Integration into the ATM system including software enhance to support PBN
- Safety monitoring of ATM system
- Mixed fleet/system operations
- Maintenance of the Target Level of Safety (TLS)
- Continued evolution of PBN navigation specifications and their deployment in the ATM system
- Development of supporting rule set
- Education and training of stakeholders
- Approach naming and charting conventions
- Vertical Advisory versus Vertical Guidance
- Data base integrity and control (Australia working towards Part 175 certificate for certification of AIS providers)
- GNSS system performance and prediction of availability service



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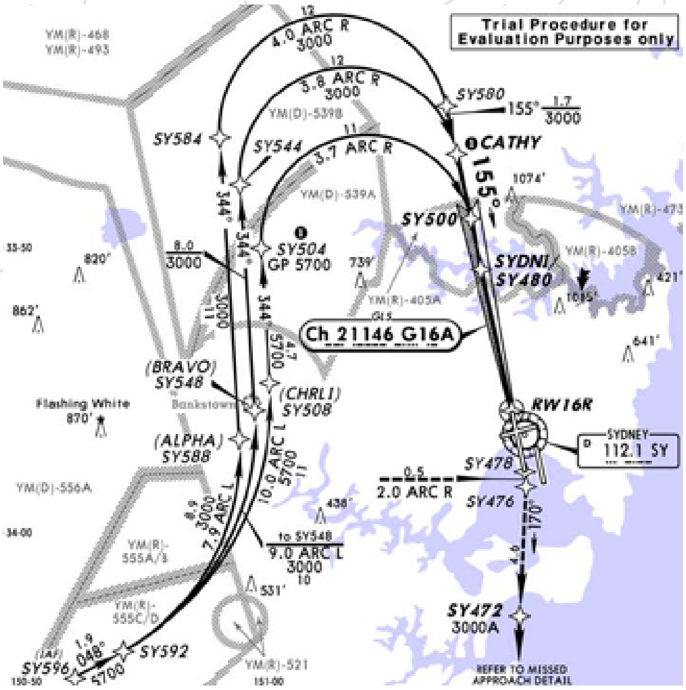

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Environment

Environmental challenges are significant, not least through the political sphere of influence for aircraft noise at major aerodromes and aircraft emissions (carbon footprint). PBN will provide significant efficiencies in the ATM system which will simultaneously increase system efficiency and reduce total carbon emission and aircraft noise levels. The introduction of a global Emission Trading Scheme (ETS) could provide aircraft operators with significant commercial advantage, particularly those operating to RNP specifications. Environmental challenges therefore include:

- Political developments/considerations
  - Increased capacity due PBN efficiency gains
  - Emission control/management
  - Noise control/management
- ETS
  - Timing of implementation will influence the rate of PBN implementation
  - Methodology for implementation eg: carbon credits/carbon trading
  - Demonstrated efficiencies associated with PBN operations

Infrastructure Support

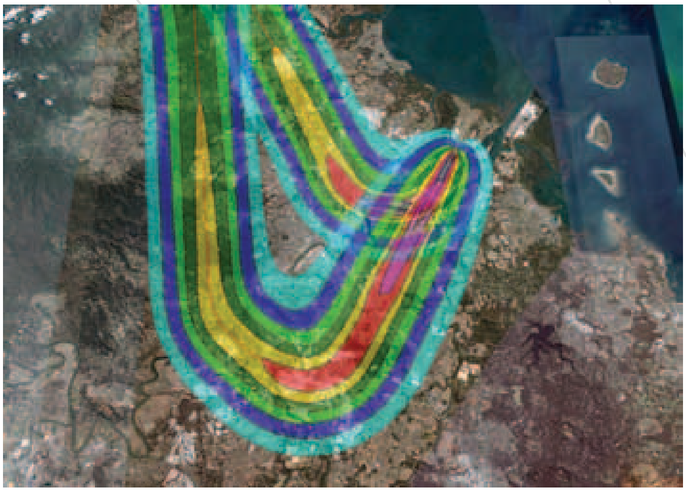
ICAO has designed PBN such that it can be supported by terrestrial radio navigation aids or self contained aircraft navigation systems (inertial and/or GNSS), however Australia's existing network of terrestrial navigation aids is of insufficient density to support PBN navigation specifications. PBN implementation in Australia will be supported by self contained aircraft navigations systems (inertial and/or GNSS based).

Australia will maintain a reduced network ("the backup network") of terrestrial radio navigation aids to provide an alternative means of navigation for terminal operations and Non-Precision Approach (NPA) using conventional navigation procedures.

The existing GNSS prediction service will be retained to support PBN.

The existing Automatic Weather Information Service (AWIS) will be expanded to support APV Baro-VNAV operations.

Approximately 400 APV Baro-VNAV procedures will need to be designed and validated.



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Efficient Operations

Efficiency gains enabled through PBN include:

- Reduced separation standards for air traffic routes in Oceanic, Remote Continental and Continental En Route airspace
- Greater flexibility of airspace design in terminal area airspace
- Reduced track miles, noise and fuel consumption through PBN enable RNP APCH procedures.

Australia has demonstrated these benefits:

- In oceanic airspace by the Aspire trans-Pacific demonstration flights of User Preferred Routes.
- in the terminal area by the Brisbane Green operational trial of RNP Approach and Departure procedures; this trial also demonstrated successful mixed fleet operation of PBN and conventionally navigated aircraft

Oceanic, Remote Continental and Continental En Route

Oceanic, remote continental and continental en route operations will have a disproportionately high level of navigation capability compared to that of communication and surveillance systems. Commensurate improvement to existing communication and surveillance systems and investment in future communication and surveillance technology will be critical in gaining the maximum safety, environmental and economic benefits of PBN in these airspace constructs. Adverse outcomes such as increased collision risk probability may occur through increased navigation accuracy without corresponding increases in communications and surveillance.

Approach Operations

A CASA sponsored study into GNSS augmentation for the introduction of APV into Australian airspace included an analysis of the Australian IFR aircraft fleet including the numbers of passengers carried, the types of aircraft that carried them and the capabilities of those aircraft to conduct various types of APV. The Augmentation technologies studied included ABAS, GBAS, GRAS and SBAS. The GRAS project has been terminated and passenger demographics combined with existing IFR fleet APV capabilities eliminated GBAS as a feasible option. ABAS and SBAS remained as feasible augmentation technologies to enable APV operations in Australia and the results have been reproduced in the tables below:

Table 1. Percentage of Passengers Carried by Class of Operation

Class of Operation	Typical Aircraft Types	IFR Passengers Carried	% of IFR Pax carried
Domestic RPT	A320, B737, B717, EMB 170, FK-100	85 816 802	88.4%
Regional RPT	DHC8, FK-50, Saab 340	11 039 292	11.4%
GA IFR	PA31, PC12, B412 S92	214 779	0.2%
Total		97 070 873	100%

Table 2. APV Capability of Australian IFR Fleet

APV Capability	Domestic RPT (291 aircraft)	Regional RPT (252 aircraft)	GA IFR (3057 aircraft)	IFR Fleet APV Capability (3600 aircraft)
RNP AR APCH LNAV/VNAV	26 (8.9%)	0	0	26 (0.72%)
RNP APCH LNAV/VNAV	269 (92%)	136 (54%)	125 (4.1%)	530 (14.7%)
LPV	26 (8.9%)	252 (100%)	3057 (100%)	3335 (92.6%)
LPV only	0	116 (46%)	2932 (95.9%)	3048 (84.6%)

Table 3. Passengers with APV Protection based on Augmentation Technology

Class of Operation	Passengers with APV Protection via ABAS	Passengers with APV Protection via ABAS and SBAS
Domestic RPT	88.4%	88.4%
Regional RPT	8.6%	11.4%
GA IFR	0.0%	0.2%
Total	97%	100%

Table 4. Aircraft with APV Protection based on Augmentation Technology

Class of Operation	Aircraft with APV Protection via ABAS	Aircraft with APV Protection via ABAS and SBAS
Domestic RPT	92%	92%
Regional RPT	54%	100%
GA IFR	4.1%	100%
IFR Fleet	14.7%	100%

The results of the analysis demonstrate that:

- By implementing barometric vertical navigation through both RNP APCH - LNAV/VNAV and RNP AR APCH design criteria, Australia will be able to provide APV protection to 97% of fare paying passengers but only 15% of the IFR fleet.

- By implementing barometric vertical navigation and augmented GNSS through RNP APCH - LNAV/VNAV and LPV and RNP AR APCH design criteria, Australia will be able to provide APV protection to 100% of fare paying passengers and 100% of the IFR fleet.

Subsequently the study recommended implementation of RNP APCH - LNAV/VNAV as soon as practicable with potential investment in a SBAS to support LPV to be determined. The potential investment in SBAS acknowledges the added safety benefit for individual aircraft (largely GA IFR aircraft) irrespective of the number of passengers onboard.

RNP AR APCH operations will provide significant increased safety benefit at non-precision aerodromes and significant environmental and economic benefits at precision aerodromes. Subsequently their introduction is being encouraged and supported by CASA and Airservices Australia through the provision of normal regulatory and air navigation services.

Australia, through the Aviation Policy Group, agrees with the study recommendations and is taking steps to implement barometric vertical navigation through RNP APCH - LNAV/VNAV and RNP AR APCH design criteria consistent with the PBN concept.

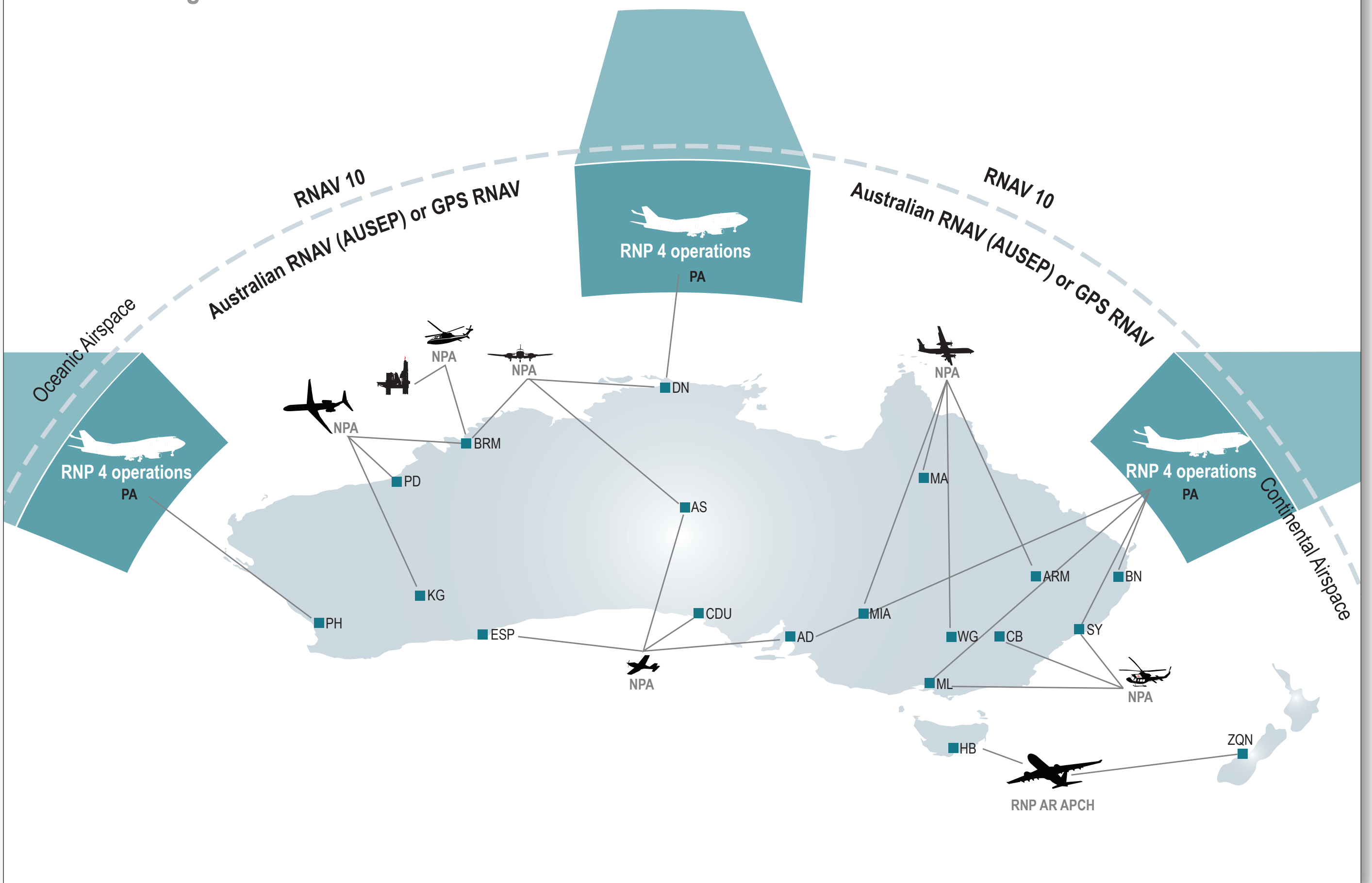
RNP AR approach to Lin Zhi, Tibet, a 95–mile serpentine missed approach between 17-20,000 ft mountains.

Implementation

Current Navigation Construct

Australia's current navigation construct is illustrated in the graphic below. Australia approved Primary Means GNSS navigation in 1995 and has widespread use of RNAV (GNSS) through the design and implementation of around 500 GNSS NPA approach procedures. RNAV 10 and RNP 4 are operational in oceanic airspace and APV have been introduced in some terminal areas through RNP AR procedures; however Australia remains highly dependant on conventional terrestrial navigation aids for approach to land procedures.

PBN IMPLEMENTATION PLAN—AUSTRALIA
Current navigation construct



Future Navigation Construct - Short Term (2008-2012)

Concept

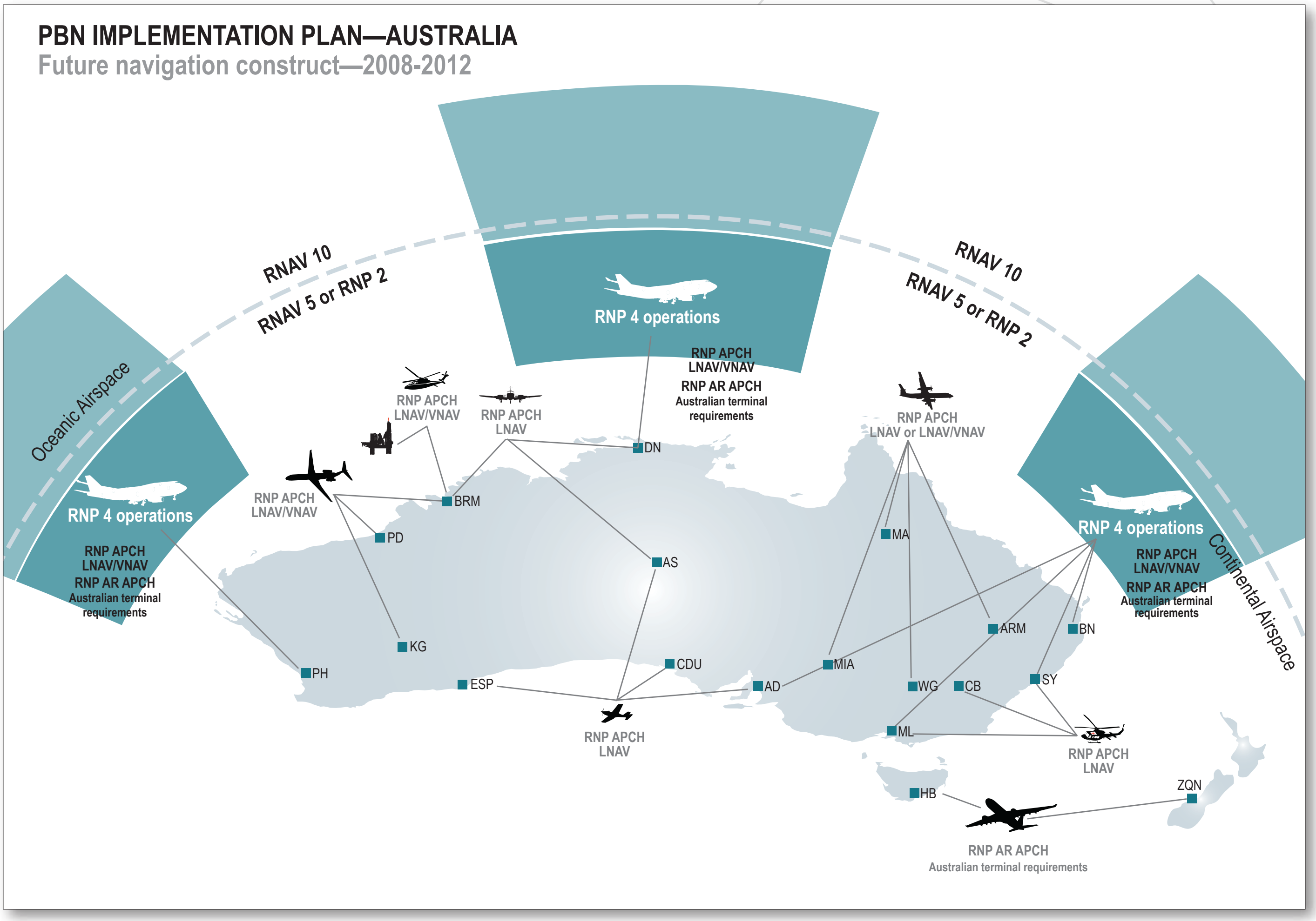
Australia's concept for the implementation of PBN in the short term is:

- RNAV available in all classes of airspace
- RNP to become available in all classes of airspace
- APV implemented through barometric vertical navigation

Methodology

Australia's methodology for the implementation of PBN in the short term is:

- RNAV
  - RNAV 5 over continental en route airspace
  - RNAV 1 for terminal navigation applications
- RNP
  - RNP 4 operations through oceanic and continental en route airspace
  - RNP APCH - LNAV (already implemented as RNAV(GNSS); name change required)
- APV to be implemented through barometric vertical navigation
  - RNP APCH - LNAV/VNAV



- PANS-OPS APV Baro-VNAV design criteria
- ILS backup at all ILS equipped aerodromes
- Primary approach at selected non-ILS equipped aerodromes
    - RNP AR APCH
- ICAO Doc 9905 design criteria
- Alternative approach at all ILS equipped aerodromes
- Primary approach at 19 non ILS equipped aerodromes
- Non-normal operations available to approved operators

Implementation Priorities

The order of PBN implementation in the short term has been chosen to maximise early safety environmental and economic benefits and meets the objectives of the ICAO directions on PBN and APV; it also takes advantage of existing RNP deployment. Much of the deployment can be conducted in parallel however where required, the following priorities for PBN implementation will be followed:

- Oceanic
    - RNAV 10
    - RNP 4
- Approach
    - RNP APCH - LNAV/VNAV
    - RNP AR APCH
- Terminal Area - RNP SIDs and STARs to complement APV Baro-VNAV procedures particularly at ILS equipped aerodromes
- Continental En Route

Oceanic and Remote Continental

In oceanic environments, PBN is implemented as a mixed environment RNAV 10 and RNP 4. RNAV 10 is available to all suitably equipped and approved aircraft. RNP 4 is especially required for aircraft participating in Flex Tracks, Dynamic Aircraft Route Planning System (DARPS) and User Preferred Route/Trajectory (UPR/T) operations. Australia has already implemented RNP 4 across the Pacific Ocean and in certain other oceanic airspace.

Continental En Route

Within the Australian FIR RNAV 5 and GPS RNAV will become the preferred en route navigation specifications.

Terminal Areas (Departures and Arrivals)

RNP based SIDs and STARs to be implemented at all ILS equipped and selected non ILS equipped aerodromes.

Approach Operations

Baro-VNAV is the preferred means of implementing APV in Australia due to fleet and infrastructure capabilities and passenger demographics. Australia has approximately:

- 300 aerodromes with IAL procedures
    - 30 aerodromes with precision approach (PA) procedures
    - 270 aerodromes with non-precision approach (NPA) procedures

Australia cannot meet the intent of ICAO Resolution 36/23 milestone 2. a) 2) - implementation of APV through Baro-VNAV or augmented GNSS for all instrument runway ends - without SBAS; the acquisition of which is not currently planned. Australia will therefore implement APV through barometric vertical navigation using:

- RNP APCH - LNAV/VNAV
- RNP AR APCH

Australia has some 500 RNAV (GNSS) Approach Procedures published in AIP; none include vertical guidance. Australia will rename existing RNAV (GNSS) procedures to RNP APCH-LNAV and adapt them to the APV Baro-VNAV design criteria where possible or redesign the procedure in its entirety as required.

The introduction of Baro-VNAV will require a capability to measure and transmit local QNH from an approved source at each aerodrome identified for APV Baro-VNAV approach procedures. The integrity of the barometric systems in Bureau of Meteorology (BoM) accepted Automatic Weather Stations (AWS) is such that they are an approved source of QNH. When combined with a transmission capability (typically a discrete VHF frequency) the AWS information is known as Aerodrome Weather Information Service (AWIS) and is delivered in an ATIS style format.

CASA has completed an assessment of the AWS and AWIS capabilities for the 198 APV applicable aerodromes and has determined:

- 56 aerodromes currently have an AWIS capability via a discreet VHF frequency
- 88 have an AWS but no associated AWIS capability (includes 6 AWIS aerodromes that require a VHF transmission upgrade)
- 54 have no AWS capability at all

The 56 AWIS aerodromes will form the first tranche of APV Baro-VNAV implementation with the following priorities:

- Precision approach aerodromes where a runway end serviced by an ILS does not have a runway aligned RNAV (GNSS) as a backup
- Certified NPA aerodromes
- Other precision approach aerodromes
- Registered NPA aerodromes

Consultation between CASA, AsA, BoM and aircraft and aerodrome operators will further refine overall and tranche by tranche priorities for the remaining aerodromes giving consideration to:

- obstacle data validity
- service frequency
- aircraft capacity
- prevailing weather conditions (cloud base and visibility)
- current and future aircraft avionics fit of aircraft operated to the aerodrome (RNP, APV Baro-VNAV or SBAS only capable)
- aerodrome RFF capabilities (specialist aviation RFF, general RFF, on or off field)
- alternate aerodrome proximity (with APV capability)

Helicopter Operations

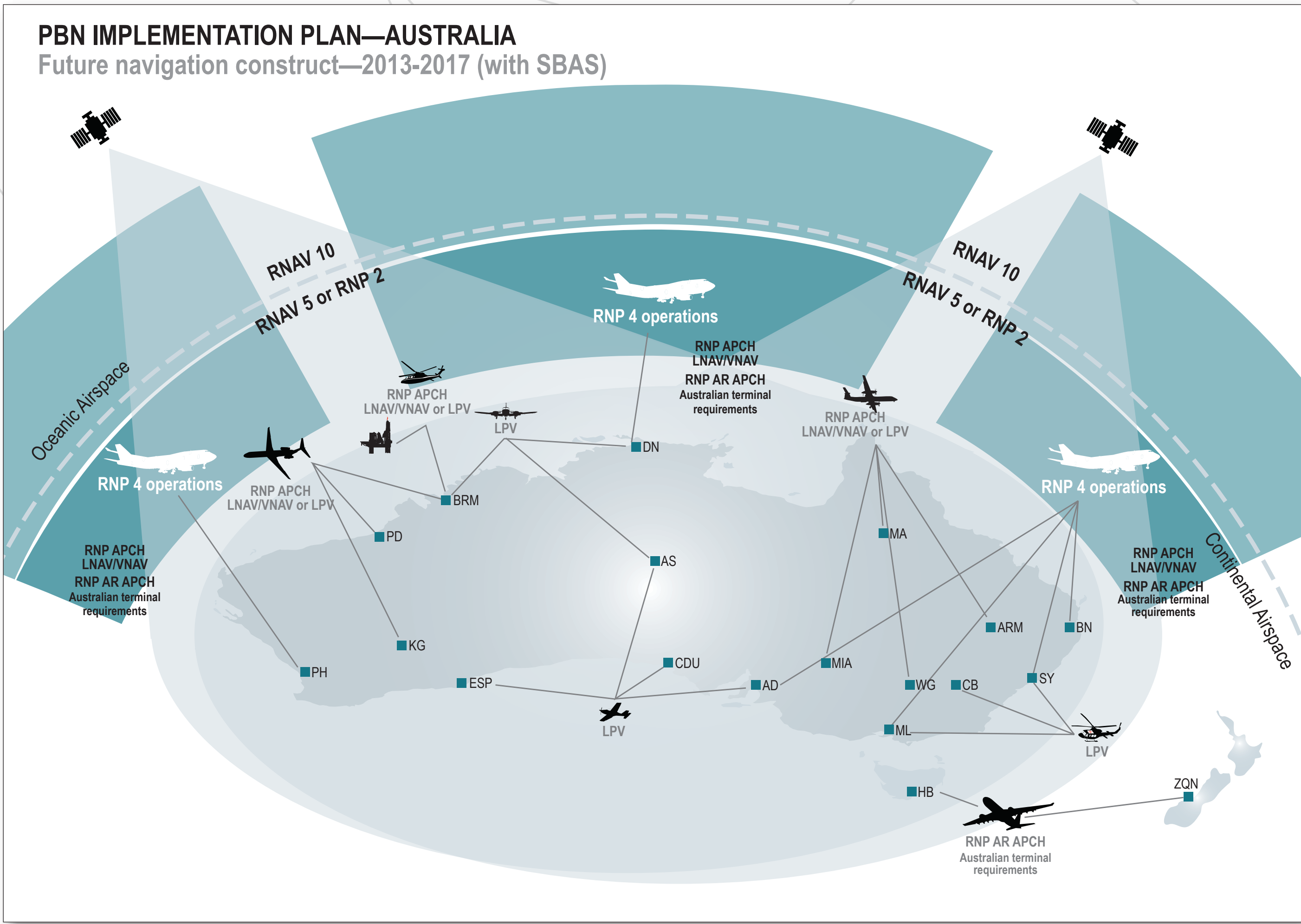
The Australian IFR helicopter fleet comprises approximately:

- 128 aircraft all with an LPV capability - 100%
- 120 aircraft with an LPV capability only - 94%
- 8 aircraft with an APV Baro-VNAV capability - 6%

IFR helicopters are typically engaged in offshore, SAR/EMS and/or private operations. The 8 APV Baro-VNAV capable aircraft (S92 and AW139) were assessed as being predominately engaged in offshore operations; the remaining 120 helicopters utilise RNP APCH - LNAV approaches (either to airfields or to helipads).

The introduction of APV-Baro VNAV:

- Will provide an APV capability for the 6% of the IFR helicopter fleet
- Will not provide an APV capability for 94% of the IFR helicopter fleet



Future Navigation Construct - Medium term (2013-2017) - with SBAS[1]

Concept

Australia's concept for the implementation of PBN in the medium term with an SBAS capability is:

- Parallel availability of RNAV and RNP specifications
- APV implemented through barometric vertical navigation and SBAS

Methodology

Australia's methodology for the implementation of PBN in the medium term with an SBAS capability is:

- RNAV
  - RNAV 5 over continental en route airspace
  - RNAV 1 for terminal navigation applications
- RNP
  - RNP 4 operations through oceanic and continental en route airspace
  - RNP 2 over continental en route airspace
  - Basic RNP 1 for terminal navigation applications

[1] Australia is considering acquiring SBAS capability. If this proceeds PBN deployment will be as described below.

- Acquisition of SBAS to support LPV operations from 2013 with an operational capability from 2015 and operational life of at least 10 years
- APV to be implemented through Baro-VNAV and SBAS
  - RNP APCH - LNAV/VNAV
    - PANS-OPS APV Baro-VNAV design criteria
    - ILS backup at all ILS equipped aerodromes
    - Primary approach at selected non-ILS equipped aerodromes
  - RNP AR APCH
    - ICAO Doc 9905 design criteria
    - Alternative approach at all ILS equipped aerodromes
    - Primary approach at 19 non-ILS equipped aerodromes
    - Non-normal operations available to approved operators
  - RNP APCH - LPV
    - PANS-OPS LPV design criteria
    - all non-ILS equipped aerodromes
    - selected ILS equipped aerodromes

Implementation Priorities

The order of PBN implementation in the medium term with an SBAS capability has been chosen to maximise early safety benefit, economic benefit and meet the objectives of the ICAO directions on PBN and APV; it also takes advantage of existing RNP deployment. Much of the deployment can be conducted in parallel however where required the following priorities for PBN implementation will be followed:

- Oceanic RNAV 10 and RNP 4
- Approach
  - RNP APCH - LNAV/VNAV
  - RNP AR APCH
  - RNP APCH - LPV
- Terminal Area - RNP SIDs and STARs to complement RNP APCH (particularly at ILS equipped aerodromes)
- Continental En Route

Oceanic and Remote Continental

In oceanic environments, PBN is implemented as a mixed environment of RNAV 10 and RNP 4.

Continental En Route

Within the Australian FIR RNAV 5 and RNP 2 will become the preferred en route navigation specifications. The navigation specification for RNP 2 has yet to be defined by ICAO however, it is expected that aircraft with a GPS RNAV capability will transition directly to RNP 2.

Terminal Areas (Departures and Arrivals)

RNP based SIDs and STARs to be implemented at all ILS equipped and selected non ILS equipped aerodromes.

Approach Operations

Baro-VNAV and SBAS in combination is the preferred means of implementing APV in Australia due to fleet and infrastructure capabilities and passenger demographics. Australia has approximately:

- 300 aerodromes with IAL procedures
- 30 aerodromes with precision approach procedures
- 270 aerodromes with non-precision approach procedures

Australia can meet the intent of ICAO Resolution 36/23 milestone 2. a) 2) - implementation of APV through Baro-VNAV or augmented GNSS SIS for all instrument runway ends - through a combination of Baro-VNAV and the provision of an SBAS capability. Australia will therefore implement APV through barometric vertical navigation and augmented GNSS SIS utilising:

- RNP APCH - LNAV/VNAV
- RNP AR APCH
- RNP APCH - LPV

Australia has some 500 RNAV (GNSS) Approach Procedures published in AIP; none include vertical guidance. Australia will adapt the current RNAV (GNSS) procedures to:

- APV Baro-VNAV design criteria where possible or redesign the procedure in its entirety as required
- LPV design criteria where possible or redesign the procedure in its entirety as required

The introduction of APV using barometric vertical navigation will be as described in the previous section. The introduction of APV using augmented GNSS SIS will require an SBAS capability consisting:

- A space segment of at least two geostationary satellites
- A ground segment of at least
  - 18 Ground Reference Stations (GRS)
  - 2 Master Control Stations (MCS)

The aerodrome priority for design and introduction of APV using the LPV design criteria and augmented GNSS SIS will require consideration of:

- Existing aerodrome procedures (noting that RNP APCH - LNAV/VNAV and RNP AR APCH will have been progressively implemented in the period 2008-2012)
- Non-runway aligned NPA
- Certified NPA aerodromes
- Precision approach aerodromes
- Registered NPA aerodromes

Consultation between CASA, AsA and aircraft and aerodrome operators will further refine overall and tranche by tranche priorities for all aerodromes giving consideration to:

- service frequency
- aircraft capacity
- prevailing weather conditions (cloud base and visibility)
- current and future aircraft avionics fit of aircraft operated to the aerodrome (RNP APCH, RNP AR APCH or SBAS only capable)
- aerodrome RFF capabilities (specialist aviation RFF, general RFF, on or off field)
- alternate aerodrome proximity (with APV capability)

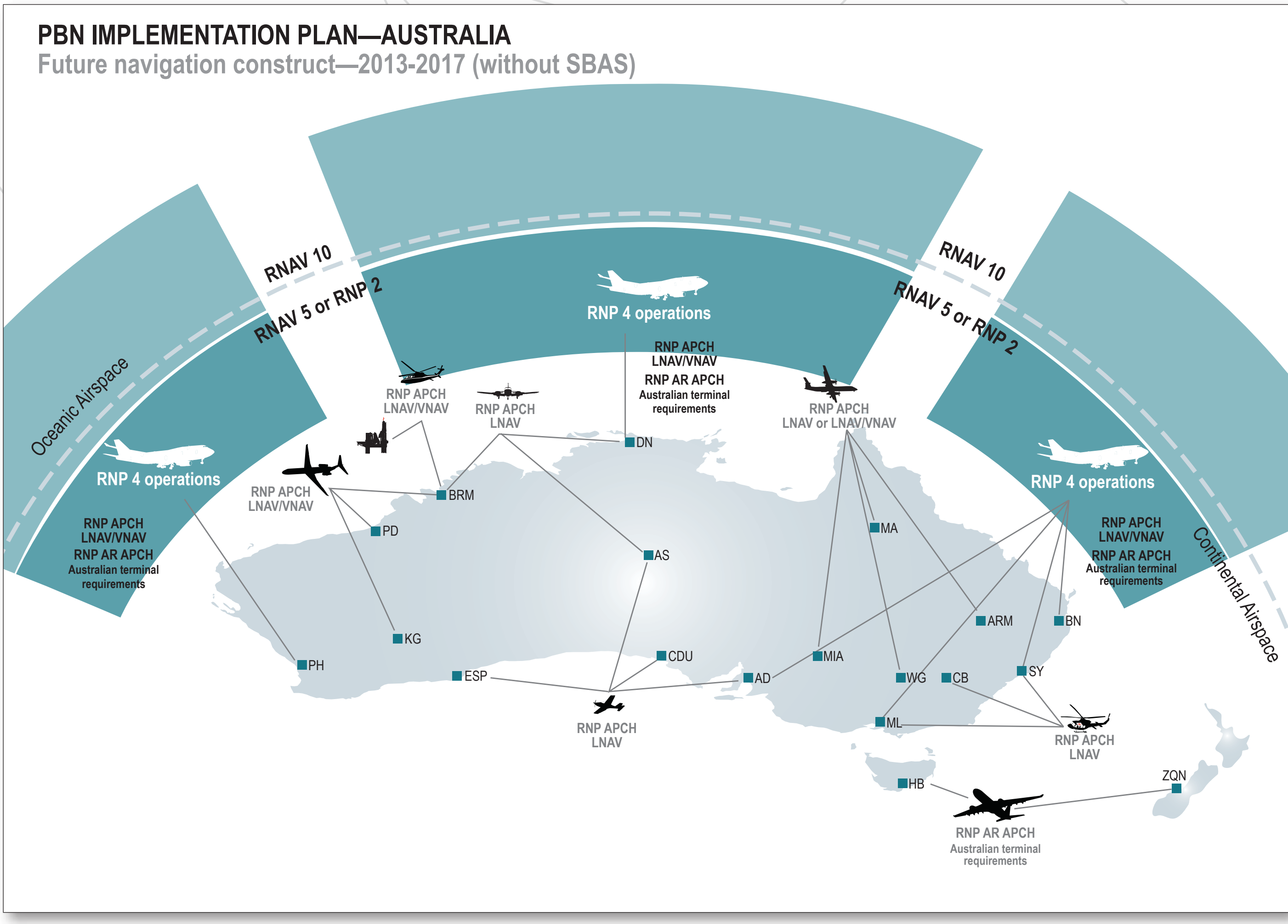
Helicopter Operations

The Australian IFR helicopter fleet comprises approximately:

- 128 aircraft all with an LPV capability - 100%
- 120 aircraft with an LPV capability only - 96%
- 8 aircraft with an APV Baro-VNAV capability only -6%

IFR helicopters are typically engaged in offshore, SAR/EMS and/or private operations. The 8 APV Baro-VNAV capable aircraft (S92 and AW139) were assessed as being predominately engaged in offshore operations; the remaining 120 helicopters utilise RNP APCH - LNAV approaches (either to airfields or to helipads).

All helicopter operators will have an APV capability through the introduction of RNP APCH - LNAV/VNAV and LPV procedures.



Future Navigation Construct - Medium term (2013-2017) - without SBAS

Concept

Australia's concept for the implementation of PBN in the medium term without an SBAS capability is:

- Parallel availability of RNAV and RNP specifications
- APV implemented through barometric vertical navigation

Methodology

Australia's methodology for the implementation of PBN in the medium term without an SBAS capability is:

- RNAV
  - RNAV 5 over continental en route airspace
  - RNAV 1 for terminal navigation applications
- RNP
  - RNP 4 operations through oceanic and continental en route airspace
  - RNP 2 over continental en route airspace
  - RNP 1 (basic and advanced) for terminal navigation applications
- RNP APCH - LNAV/VNAV
  - APV Baro-VNAV design criteria
  - ILS backup at all ILS equipped aerodromes
  - Primary approach at selected non-ILS equipped aerodromes
- RNP AR APCH
  - ICAO Doc 9905 design criteria
  - Alternative approach at all ILS equipped aerodromes
  - Primary approach at 19 non-ILS equipped aerodromes
  - Non-normal operations available to approved operators

Implementation Priorities

The order of PBN implementation in the medium term without an SBAS capability has been chosen to maximise early safety benefit, economic benefit and meets the objectives of the ICAO directions on PBN and APV; it also takes advantage of existing RNP deployment. Much of the deployment can be conducted in parallel however where required the following priorities for PBN implementation will be followed:

- Oceanic RNAV 10 and RNP 4
- Approach
  - RNP APCH - LNAV/VNAV
  - RNP AR APCH

- Terminal Area - RNP SIDs and STARs to complement RNP APCH (particularly at ILS equipped aerodromes)
- Continental En Route

Oceanic and Remote Continental

In oceanic environments, PBN is implemented as a mixed environment of RNAV 10 and RNP 4.

Continental En Route

Within the Australian FIR RNAV 5 and RNP 2 will become the preferred en route navigation specifications. The navigation specification for RNP 2 has yet to be defined by ICAO however, it is expected that aircraft with a GPS RNAV capability will transition directly to RNP 2.

Terminal Areas (Departures and Arrivals)

RNP based SIDs and STARs to be implemented at all ILS equipped and selected non ILS equipped aerodromes.

Approach Operations

Baro-VNAV remains the preferred means of implementing APV in Australia due to fleet and infrastructure capabilities and passenger demographics. Australia has:

- 197 aerodromes selected for APV Baro-VNAV operations
    - 30 precision aerodromes (all AWIS capable)
    - 67 non-precision aerodromes (24 AWIS capable)

Australia will not meet the intent of ICAO Resolution 36/23 milestone 2. a) 2) - implementation of APV through Baro-VNAV or augmented GNSS for all instrument runway ends - as it has not acquired an SBAS capability. Australia will therefore implement APV through Baro VNAV by:

- RNP APCH - LNAV/VNAV
- RNP AR APCH

Australia will adapt approximately 80% of the current RNAV (GNSS) procedures to APV Baro-VNAV design criteria and will redesign 20% of the procedures in their entirety.

Australia will fit an AWS and/or AWIS capability to 143 selected non-precision aerodromes to enable APV Baro-VNAV operations.

APV Baro-VNAV implementation priorities remain unchanged:

- Precision approach aerodromes where a runway end serviced by an ILS does not have a runway aligned RNP APCH - LNAV as a backup
- Certified NPA aerodromes
- Other precision approach aerodromes
- Registered NPA aerodromes

Factors affecting tranche by tranche priorities remain unchanged:

- service frequency
- aircraft capacity
- prevailing weather conditions (cloud base and visibility)
- current and future aircraft avionics fit of aircraft operated to the aerodrome (RNP, APV Baro-VNAV or SBAS only capable)
- aerodrome RFF capabilities (specialist aviation RFF, general RFF, on or off field)
- alternate aerodrome proximity (with APV capability)

Helicopter Operations

The Australian IFR helicopter fleet comprises approximately:

- 128 aircraft all with an APV I and II capability - 100%
- 120 aircraft with an APV I and II capability only - 94%
- 8 aircraft with an APV Baro-VNAV capability only - 6%

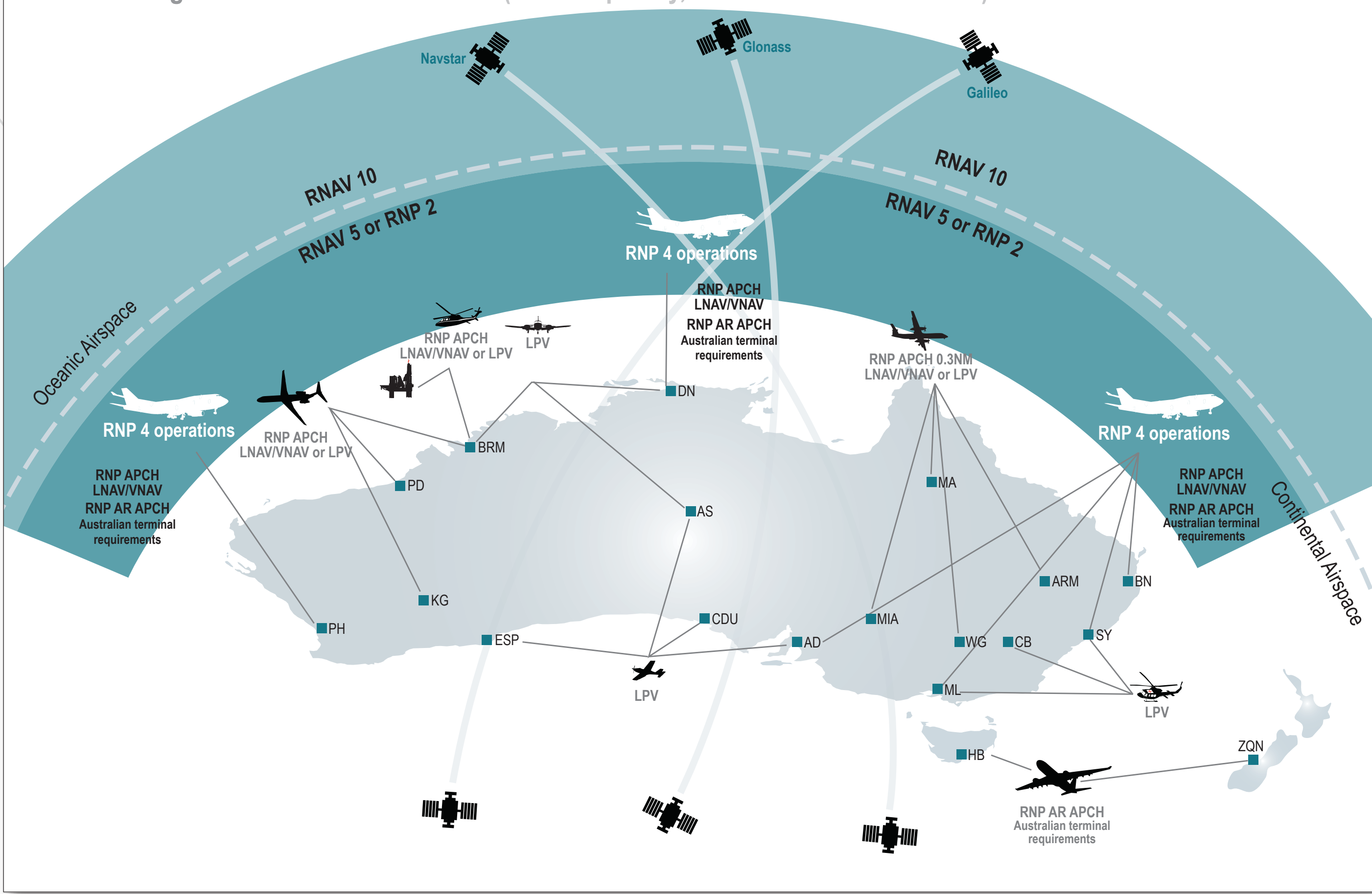
IFR helicopters are typically engaged in offshore, SAR/EMS and/or private operations. The 8 APV Baro-VNAV capable aircraft (S92 and AW139) were assessed as being predominately engaged in offshore operations; the remaining 120 helicopters utilise RNP APCH - LNAV approaches (either to airfields or to helipads).

The introduction of APV-Baro VNAV:

- Will provide an APV capability for the 6% of the IFR helicopter fleet
- Will not provide an APV capability for 94% of the IFR helicopter fleet

PBN IMPLEMENTATION PLAN—AUSTRALIA

Future navigation construct—2018-2022 (dual frequency, multi-constellation GNSS)



Far term (2018-2022)

Concept

Australia's concept for the implementation of PBN in the far term is:

- Parallel availability of RNAV and RNP specifications
- APV enabled through barometric vertical navigation and enhanced GNSS

Methodology

Australia's methodology for the implementation of PBN in the far term is:

- RNAV
  - RNAV 5 over continental en route airspace
  - RNAV 1 for terminal navigation applications
- RNP
  - RNP 4 operations through oceanic and continental en route airspace
  - RNP 2 over continental en route airspace
  - RNP 1 (basic and advanced) for terminal navigation applications
- APV to be implemented through Baro-VNAV and enhanced GNSS[2]
  - RNP APCH - LNAV/VNAV
    - PANS-OPS APV Baro-VNAV design criteria
    - ILS backup at all ILS equipped aerodromes
    - Primary approach at selected non-ILS equipped aerodromes
  - RNP AR APCH
    - ICAO Doc 9905 design criteria
    - Alternative approach at all ILS equipped aerodromes
    - Primary approach at 19 non-ILS equipped aerodromes
    - Non-normal operations available to approved operators
  - RNP APCH - LPV
    - PANS-OPS LPV design criteria
    - all non-ILS equipped aerodromes
    - selected ILS equipped aerodromes

[2] APV implementation through GNSS assumes LPV operations using the multi-constellation, dual frequency GNSS which becomes operational earlier than the 2025 estimate

Appendix

Appendix A - PBN Implementation Progress Report 2010

PBN IMPLEMENTATION PROGRESS REPORT

State: Australia
Date: 15 August 2009

Designation of PBN Focal Point

Reference: APANPIRG Conclusion 18/55 –Designation of Contact Person for PBN Implementation

"That, by 31 December 2007, States designate a focal contact person responsible for performance based navigation implementation and provide details of the contact person to ICAO Asia/Pacific Regional Office accordingly."

Status: Nominated

Focal Point: Dirk Noordewier, Air Transport Inspector, CASA, Level 4, 16 Furzer St, Phillip, ACT, 2606, Australia

Dirk.Noordewier@casa.gov.au

State PBN Implementation Plan

Reference: APANPIRG Conclusion 18/53 – Development of State PBN Implementation Plans

"That, the Regional Office encourages States to begin development of their State PBN implementation plans in harmony with the development of the Asia/Pacific Regional PBN implementation plan being coordinated by the Asia/Pacific PBN Task Force for submission to APANPIRG/19."

Status: Adopted by CASA and to be reviewed by ICAO APAC PBN TF

Approach Operations

Reference: ICAO Assembly Resolution A36-23

"States and planning and implementation regional groups (PIRGs) complete a PBN implementation plan by 2009 to achieve: implementation of approach procedures with vertical guidance (APV) (Baro-VNAV and/or augmented GNSS) for all instrument runway ends, either as the primary approach or as back up for precision approaches by 2016 with intermediate milestones as follows: 30 percent by 2010, 70 percent by 2014."

Status:

Implementation Targets (# of RWY Ends)			Completed (# of RWY Ends)		On Progress (# of RWY Ends)	
Y2010	Y2014	Y2016	LNAV	LNAV/VNAV	LNAV	LNAV/VNAV
60	78	60				

Note(s): (States may include information on recent publications of new PBN approach procedures.)

Arrival and Departure Operations

Reference: 1) ICAO Assembly Resolution A36-23

"States and planning and implementation regional groups (PIRGs) complete a PBN implementation plan by 2009 to achieve: implementation of RNAV and RNP operations (where required) for en route and terminal areas according to established timelines and intermediate milestones."

2) Interim Asia/Pacific PBN Regional Implementation Plan

"Short-term Implementation Targets: RNAV 1 SID/STAR for 50% of international airports by 2010 and 75% by 2012 and priority should be given to airports with RNP Approach."

"Medium-term Implementation Targets: RNAV 1 or RNP 1 SID/STAR for 100% of international airports by 2016. RNAV 1 or RNP 1 SID/STAR for 70% of busy domestic airports where there are operational benefits."

Implementation Targets (# of Int'l Airports)			Completed (# of Int'l Airports)		On Progress (# of Int'l Airports)	
Y2010	Y2014	Y2016	Arrival	Departure	Arrival	Departure

Note(s): (States may include information on recent publications with new PBN arrival/departure procedures.)

Appendix B - Australia's National RNP AR Network

Aerodrome	Runway Ends			
SYDNEY	34L	34R	25	
MELBOURNE	16	34	09	27
BRISBANE	01	19		
ADELAIDE	05	23	30	
PERTH	03	21	06	24
GOLD COAST	14	32		
CAIRNS	15	33		
CANBERRA	17	35		
The aerodromes below have RNP-AR procedures under trial and are not available to all operators				
HOBART	12	30		
TOWNSVILLE	01	19		
DARWIN	11	29		
ALICE SPRINGS	12	30		
KARRATHA	08	26		
BROOME	10	28		
KALGOORLIE/BOULDER	11	29		
AYERS ROCK	13	31		
MOUNT ISA	16	34		

PBN Plan Acronym List

ACAS	Airborne Collision Avoidance System
ADS-B	Automatic Dependant Surveillance - Broadcast
ADS-C	Automatic Dependant Surveillance - Contract
AMASS	Airport Movement Area Safety System
ANC	Air navigation Conference
APV	Approach with Vertical Guidance
ASDS	Airport Surface Detection System
ASMGCS	Advanced Surface Movement Guidance and Control Systems
ATC	Air Traffic Control
ATS	Air Traffic Services
Baro-VNAV	Barometric Vertical Navigation
BITRE	Bureau of Infrastructure Transport and Regional Economics
CDO	Continuous Descent Operations
CFIT	Controlled Flight into Terrain
CNS/ATM	Communication Navigation and Surveillance/Air Traffic Management
DARPS	Dynamic Aircraft Route Planning System
DME	Distance Measuring Equipment
EGNOS	European Geostationary Overlay Navigation Service
FMS	Flight Management System
GA	General Aviation
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HUD	Head Up Display
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
ILS	Instrument Landing System
INS	Inertial Navigation System
LORAN	LOng RAnge Navigation
LNAV	Lateral Navigation
LP	Localiser Performance
LPV	Localiser Performance with Vertical Guidance
NDB	Non Directional Beacon
NPA	Non Precision Approach
PA	Precision Approach
PANS-OPS	Procedures for Air Navigation Services - Aircraft Operations
PBN	Performance Based Navigation
PIRG's	Planning and Implementation regional Groups
PNT	Precision Navigation and Timing
RNAV	Area Navigation
RNP	Required Navigation Performance
RNP APCH	RNP Approach
RNP AR APCH	RNP Authorisation Required Approach
SBAS	Space Based Augmentation System
SID	Standard Instrument Departure
SIS	Signal in Space
STAR	Standard Terminal Arrival route
UPR/T	User Preferred Route/Trajectory
VHF	Very High Frequency
VOR	VHF Omni Range
VNAV	Vertical Navigation
VSD	Vertical Situation Display
WAAS	Wide Area Augmentation System


DN
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LIBLA
POMOT
QN684
HAWEA
QN680
QN698
QN676
KALDI
ADKOS
QN432
QN494
QN493
QN672
QN692
CRNET
NOT TO SCALE
SLOPE HILL
SH
QN668
QN654
RW23
QN658
TOLGT
6600'A
QN662
Do not exceed
180 KIAS
until TOLGT