INTERNATIONAL CIVIL AVIATION ORGANIZATION
ASIA AND PACIFIC OFFICE

ASIA/PACIFIC REGIONAL PERFORMANCE-BASED NAVIGATION IMPLEMENTATION PLAN

VERSION 4.0

ADOPTED BY APANPIRG/24

June 2013

(Effective until 12 November 2015)

RECORD OF AMENDMENT

Version	Activity	Date
0	Adopted by APANPIRG/19 as Interim Edition	September 2008
0.1	RASMAG Proposal	December 2008
0.2	Amended/Finalized by PBN/TF/4	March 2009
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1.0	Adopted by APANPIRG/20	September 2009
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3.0	Adopted by APANPIRG/22	September 2011
4.0	Adopted by APANPIRG/24	June 2013

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ASIA/PACIFIC REGIONAL PERFORMANCE-BASED NAVIGATION IMPLEMENTATION PLAN

1. Executive Summary

1.1 This Asia/Pacific Regional PBN Implementation Plan has been produced in line with Resolution A 36/23 adopted by ICAO Assembly in its 36th Session held in September 2007, Conclusion 18/52 adopted by APANPIRG/18 and other relevant resolutions adopted by ICAO Assembly in its 37th Session held in September 2010. The Regional PBN Plan addresses the strategic objectives for PBN implementation based on clearly established operational requirements, avoiding equipage of multiple on-board or ground based equipment, avoidance of multiple airworthiness and operational approvals and explains in detail contents relating to potential navigation applications. The Plan envisages the conduct of pre- and post-implementation safety assessments and continued availability of conventional air navigation procedures during transition. The Plan also discusses issues related to implementation which include traffic forecasts, aircraft fleet readiness, adequacy of ground-based CNS infrastructure etc. Implementation targets the period 2008-2016 were initially developed for Versions 1-3 of this Plan. However, these PBN implementation expectations have now been placed in the Asia/Pacific Seamless ATM Plan, which has a planning horizon until 2028. For the period 2016 and beyond it was envisaged that GNSS would be the primary navigation infrastructure. It was also expected that precision approach capability using GNSS and its augmentation systems would become available in the long term.

2. Explanation of Terms

2.1 The drafting and explanation of this document is based on the understanding of some particular terms and expressions that are described below:

2.1.1 **Asia/Pacific Regional PBN Implementation Plan.** A document adopted by APANPIRG, often referred to as the "Regional PBN Plan", offering appropriate guidance for air navigation service providers, airspace operators and users, regulating agencies, and international organizations–on the evolution of navigation capabilities as one of the key systems supporting air traffic management, and which describes the RNAV and RNP navigation applications that should be implemented in the short, medium and long term in the APAC Region.

2.1.2 **Performance Based Navigation** Performance based navigation specifies RNAV and RNP system performance requirements for aircraft operating along an ATS route, on an instrument approach procedure or in an airspace.

2.1.3 **Performance requirements.** Performance requirements are defined in terms of accuracy, integrity, continuity, availability and functionality needed for the proposed operation in the context of a particular airspace concept. Performance requirements are identified in navigation specifications which also identify which navigation sensors and equipment may be used to meet the performance requirement.

3. Acronyms

3.1 The acronyms used in this document along with their expansions are given in the following list:

ABAS	Aircraft-Based Augmentation System
AIS	Aeronautical Information Services
APAC	Asia and Pacific
APANPIRG	Asia/Pacific Air Navigation Planning and Implementation Regional Group
APCH	Approach
APV	Approach Procedures with Vertical Guidance
ATC	Air Traffic Control
Baro VNAV	Barometric Vertical Navigation
CNS/ATM	Communication Navigation Surveillance/Air Traffic Management
CPDLC	Controller Pilot Data Link Communications
DME	Distance Measuring Equipment
EMA	En-route Monitoring Agency
FASID	Facilities and Services Implementation Document
FIR	Flight Information Region
FMS	Flight Management System
GBAS	Ground-Based Augmentation System
GNSS	Global Navigation Satellite System
GRAS	Ground-based Regional Augmentation System
IATA	International Air Transport Association
IFALPA	International Federation of Air Line Pilots' Associations
INS	Inertial Navigation System
IRU	Inertial Reference Unit
PANS	Procedures for Air Navigation Services
PBN	Performance Based Navigation
PIRG	Planning and Implementation Regional Group
RASMAG	Regional Airspace Safety Monitoring Advisory Group
RCP	Required Communication Performance
RNAV	Area Navigation
RNP	Required Navigation Performance
SARP	Standards and Recommended Practices
SBAS	Satellite-Based Augmentation System
SID	Standard Instrument Departure
STAR	Standard Instrument Arrival
TMA	Terminal Control Area
VOR	VHF Omni-directional Radio-range
WGS	World Geodetic System

4. Introduction

Need for the regional PBN Implementation Plan

4.1 The Thirty-sixth Session of the ICAO Assembly held in Montreal in September 2007 adopted a Resolution to resolve that States and PIRGs complete a regional PBN implementation plan by 2009.

4.2 Recognizing that the PBN concept is now established, States should ensure that all RNAV and RNP operations and procedures are in accordance with the PBN concept as detailed in State letter AN 11/45-07/22 and the ICAO Doc 9613: PBN Manual for ensuring a globally harmonized and coordinated transition of PBN.

4.3 In view of the need for detailed navigation planning, it is advisable to develop a Regional PBN Plan to provide proper guidance to air navigation service providers, airspace operators and users, regulating agencies, and international organizations, on the evolution of navigation capabilities as one of the key systems supporting air traffic management, and which describes the RNAV and RNP navigation applications that should be implemented in the short and medium term in the APAC Region.

4.4 Furthermore, the Asia/Pacific Regional PBN Implementation Plan will contain the basic material serving as guidance for regional projects for the implementation of air navigation infrastructure, such as ABAS, SBAS, GBAS, GRAS, etc., as well as for the development of national implementation plans.

Roles of Navigation in supporting ATM operations

4.5 An “airspace concept” may be viewed as a general vision or master plan for a particular airspace. Based on particular principles, an airspace concept is geared towards specific objectives. Strategic objectives drive the general vision of the airspace concept. These objectives are usually identified by airspace users, air traffic management (ATM), airports as well as environmental and government policy. It is the function of the airspace concept and the concept of operations to respond to these requirements. The strategic objectives which most commonly drive airspace concept are safety, capacity, efficiency, access, and the environment.

4.6 Navigation is one of several enablers of an airspace concept. Communications, ATS Surveillance and ATM are also essential elements of an airspace concept.

4.7 The PBN concept specifies RNAV and RNP system performance requirements in terms of accuracy, integrity, availability, continuity and functionality needed for the proposed operations in the context of a particular Airspace Concept, when supported by the appropriate navigation infrastructure. In that context, the PBN concept represents a shift from sensor-based to performance-based navigation. Performance requirements are identified in navigation specifications which also identify the choice of navigation sensors and equipment that may be used to meet the performance requirements. These navigation specifications are defined at a sufficient level of detail to facilitate global harmonization by providing specific implementation guidance for States and operators.

4.8 Under the PBN concept, the generic navigation requirements are defined based on operational requirements. Thus, users may evaluate the available options. To ensure synchronization of investment and interoperability of the airborne and ground systems, the selection of the solution should be in consultation with aviation stakeholders, including international and domestic airline operators, air navigation service providers, and regulators. The solution selected should also be the most cost-effective one.

4.9 The development of the PBN concept recognized that advanced aircraft RNAV systems are achieving an enhanced and predictable level of navigation performance accuracy which, together with an appropriate level of functionality, allows a more efficient use of available airspace to be realized. It also takes account of the fact that RNAV systems have developed over a 40-year period and as a result there were a large variety of differing implementations globally. Identifying navigation requirements rather than on 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.

Benefits of Performance-Based Navigation

4.10 The main benefits derived from the implementation of PBN are:

a) Increased airspace safety through the implementation of continuous and stabilized descent procedures using vertical guidance;

b) Reduced aircraft flight time due to the implementation of optimal flight paths, with the resulting savings in fuel, noise reduction, and enhanced environmental protection;

c) Use of the RNAV and/or RNP capabilities that already exist in a significant percentage of the aircraft fleet flying in APAC airspace;

d) Improved airport and airspace arrival paths in all weather conditions, and the possibility of meeting critical obstacle clearance and environmental requirements through the application of optimized RNAV or RNP paths;

e) Implementation of more precise approach, departure, and arrival paths that will reduce dispersion and will foster smoother traffic flows;

f) Reduced delays in high-density airspaces and airports through the implementation of additional parallel routes and additional arrival and departure points in terminal areas;

g) Reduction of lateral and longitudinal separation between aircraft to accommodate more traffic;

h) Decrease ATC and pilot workload by utilizing RNAV/RNP procedures and airborne capability and reduce the needs for ATC-Pilot communications and radar vectoring;

i) Increase of predictability of the flight path.

Goals & Objectives of PBN Implementation

4.11 APANPIRG, in its Eighteenth meeting (September 2007), discussed various issues related to an early implementation of PBN in the region. To facilitate coordination between States, a PBN Task Force was formed under Conclusion 18/52 and tasked to develop a harmonized regional PBN implementation plan.

4.12 The Asia/Pacific Regional PBN Implementation Plan has the following strategic objectives:

a) To ensure that the implementation of the navigation item of the CNS/ATM system is based on clearly established operational requirements.

b) To avoid undue equipage of multiple on board equipment and/or ground-based systems.

c) To avoid the need for multiple airworthiness and operational approvals for intra- and inter-regional operations.

d) To explain in detail the contents of the Regional Air Navigation Plan, relating to potential navigation applications.

4.13 Furthermore, the Asia/Pacific Regional PBN Implementation Plan will provide a high-level strategy for the evolution of the navigation applications to be implemented in the APAC Region in the short term (2008-2012) and medium term (2013-2016). This strategy is based on the concepts of Area Navigation (RNAV) and Required Navigation Performance (RNP) in accordance with ICAO Doc. 9613: *Performance Based Navigation Manual*, and will be applied to aircraft operations involving instrument approaches, standard departure (SID) routes, standard arrival (STAR) routes, and ATS routes in oceanic and continental areas.

4.14 The Regional PBN Plan was developed by the APAC States together with the international organizations concerned (including IATA and IFALPA)~~,~~ and is intended to assist the main stakeholders of the aviation community plan a gradual transition to the RNAV and RNP concepts. The main stakeholders of the aviation community that benefit from this Regional Plan are:

- Airspace operators and users.
- Air navigation service providers.
- Regulating agencies.
- International organizations.

4.15 The Regional PBN Plan is intended to assist the main stakeholders of the aviation community plan the future transition and their investment strategies. For example, airlines and operators can use this Plan to derive future equipage and additional navigation capability investments; air navigation service providers can plan a gradual transition for the evolving ground infrastructure. Regulating agencies will be able to anticipate and plan for the criteria that will be needed in the future.

4.16 Recognizing the safety benefits of PBN, the thirty-sixth session of the ICAO Assembly held in Montreal, September 2007 adopted a Resolution to resolve that States and PIRGs prepare ~~a~~ PBN implementation plans by 2009 to achieve:

a) Implementation of RNAV and RNP operations (where required) for en route and terminal areas according to established timelines and intermediate milestones; and

b) Implementation of 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.

The ICAO Assembly also urges that States include in their PBN implementation plan provisions for implementation of APV to all runway ends serving aircraft with a maximum certificated take-off mass of 5700 kg or more, according to established timelines and intermediate milestones.

Planning Principles

4.17 Planning for the implementation of PBN in the APAC Region shall be based on the following principles:

a) Pre- and post-implementation safety assessments will be conducted in accordance with ICAO provisions to ensure the application and maintenance of the established target levels of safety.

b) Continued application of conventional air navigation procedures during the transition period, to guarantee the operations by users that are not RNAV and/or RNP equipped.

c) The first regional PBN implementation plan should address the short term (2008-2012) and medium term (2013-2016) and take into account long term global planning issues.

d) Target date for preparation of the first regional PBN implementation plan is APANPIRG/19 (September 2007).

5. PBN Operational Requirements & Implementation Strategy

5.1 Introduction of PBN should be consistent with the Global Air Navigation Plan. Moreover, PBN implementation shall be in full compliance with ICAO SARPs and PANS and support relevant ICAO Global Plan Initiatives.

5.2 The ICAO Council accepted the second amendment to the Global Air Navigation Plan for the CNS/ATM System in November 2006. The approved plan has been renamed as Global Air Navigation Plan (Doc 9750). The relevant Global Plan Initiatives including implementation of performance based navigation (PBN) and navigation system have been included in the Global Plan. The introduction of PBN must be supported by an appropriate navigation infrastructure consisting of an appropriate combination of Global Navigation Satellite System (GNSS), self-contained navigation system (inertial navigation system) and conventional ground-based navigation aids.

5.3 The consolidated *Navigation Strategy for the Asia/Pacific Region was* reviewed and updated by the Thirteenth meeting of CNS/MET Sub Group of APANPIRG in July 2009. The Strategy was subsequently adopted by APANPIRG in its Twentieth meeting held in September 2009 under Conclusion 20/46 and further updated in its Twenty Second Meeting held in September 2011 through Conclusion 22/29 based on a recommendation by CNS/MET SG/15.

Route Operations

5.4 As the routes structure and en-route operation are extensive and complicated in APAC - region, it is difficult to restructure and include the whole airspace in a single implementation plan for en-route operations.

5.5 Considering the traffic characteristics and CNS/ATM capability, en-route operations can be classified as Oceanic, Remote continental, and Continental en-route.

5.6 In principle, each classification of en-route operation (paragraph 5.5 above) should adopt, but not be limited to, a single RNAV or RNP navigation specification. This implementation strategy should be applied by implementing States in coordination with airspace users.

5.7 APANPIRG established the PBN Task Force to develop a PBN implementation plan for the Asia/Pacific Region and to address related regional PBN implementation issues. Accordingly, States are encouraged to work cooperatively bilaterally, multilaterally and with the PBN Task Force to ensure regional and sub-regional harmonization of en-route PBN implementation.

5.8 In areas where operational benefits can be achieved and appropriate CNS/ATM capability exists or can be provided for a more accurate navigation specification than that specified in this plan, States are encouraged to introduce the more accurate navigation specification on the basis of coordination with stakeholders and affected States.

5.9 Similarly, in circumstances where affected States are agreeable to completing an implementation in advance of the timelines specified in this plan, early implementation is encouraged on the basis of coordination between affected States and airspace users.

TMA Operations

5.10 TMA operations have their own characteristics, taking into account the applicable separation minima between aircraft and between aircraft and obstacles. TMA operations also involve–the diversity of aircraft, including low-performance aircraft flying in the lower airspace and conducting arrival and departure procedures on the same path or close to the paths of high-performance aircraft.

5.11 In this sense and as called for under APANPIRG Conclusion 18/53, States shall develop their own national plans for the implementation of PBN in sovereign TMAs. Such national plans should be based on the Asia/Pacific Regional PBN Implementation Plan, seek the harmonization of the application of PBN and avoid the need for multiple operational approvals for intra- and inter-regional operations. Applicable aircraft separation criteria should also be considered.

Instrument Approaches

5.12 States are encouraged to introduce PBN approaches that provide Vertical Guidance to enhance safety. Conventional approach procedures and conventional navigation aids should be maintained to support non-equipped aircraft during the transitional period.

5.13 During early implementation of PBN, IFR Approaches based on PBN should be designed to accommodate a mixed-equipage (PBN and non-PBN) environment. ATC workload should be taken into account while developing approach procedures. One possible way to accomplish this is to co-locate the Initial Approach Waypoint for both PBN and conventional approaches

6. Current Status & Forecast

APAC traffic forecast

6.1 Traffic forecasts have a special role to play in the planning and implementation processes; they represent the demand for future ATM. Global Air Navigation Plan (Doc 9750) requires that the Planning and Implementation Regional Groups (PIRGs) base their work on well developed traffic density forecasts. Guidance on the preparation of traffic forecasts is provided in *Manual on Air Traffic Forecasting* (Doc 8991). At the Asia/Pacific regional level, the traffic forecasting activities were started with the formation of ICAO Pacific Area Traffic Forecasting Group formed in 1991. The scope of the group was subsequently broadened to include Intra-Asia/Pacific traffic also and the group was renamed as Asia/Pacific Area Traffic Forecasting Group (APA TFG).

6.2 Report of the Fourteenth meeting of Asia/Pacific Area Traffic Forecasting Group (APA TFG/14) has been published as Doc 9915. Report includes medium term forecasts of air traffic in the Transpacific area and for selected Transpacific and Asia/Pacific city pair markets through 2012. Report also contains a long term forecast with a horizon to the year 2025 and the short term forecast for the period 2008 – 2010 and intermediate forecasts for each of the years 2015 and 2020. Forecasts are provided for total passenger traffic and aircraft movements and in the case of the aggregate transpacific market also for peak hour movements on selected groups for the year 2012.

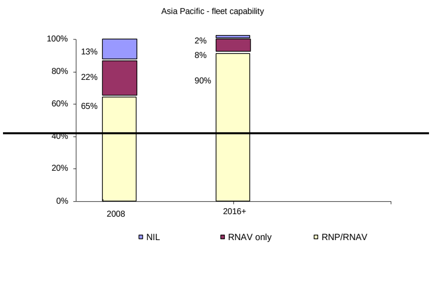
6.3 The February 2008 forecast prepared by IATA–for APAC traffic in respect of passenger, cargo, aircraft movements and new aircraft deliveries in the Regions is also provided in the Appendix B to this plan as reference.

Aircraft fleet readiness status

6.4 2007 was a record year for Asia/Pacific airlines with 418 new aircraft deliveries and more than 1,000 new orders. The overall number of deliveries to Asia/Pacific based airlines in 2008 is expected to total 430 aircraft.

6.5 All major commercial aircraft manufacturers since the 1980's have included RNAV capabilities. The commercial aircraft currently produced incorporate an RNP capability.

6.6 One significant issue for PBN implementation today is directly related to the multitude of FMS installations and varying degrees of capabilities associated with the current fleet of RNAV aircraft. Specifically, there are numerous FMS systems installed in today's fleets, all with varying capabilities.



CNS Infrastructure

Navigation infrastructure

Global Navigation Satellite System (GNSS)

6.7 Global Navigation Satellite System (GNSS) is a satellite-based navigation system utilizing satellite signals, such as Global Positioning System (GPS), for providing accurate and reliable position, navigation, and time services to airspace users. In 1996, the International Civil Aviation Organization (ICAO) endorsed the development and use of GNSS as a primary source of future navigation for civil aviation. ICAO noted the increased flight safety, route flexibility and operational efficiencies that could be realized from the move to space-based navigation. APANPIRG/23 agreed to GNSS being a requirement for all PBN approvals, and the Seamless ATM Plan was expected to include reference to airspace mandates for the carriage and use of GNSS.

6.8 GNSS supports both RNAV and RNP operations. Through the use of appropriate GNSS augmentations, GNSS navigation provides sufficient accuracy, integrity, availability and continuity to support en-route, terminal area, and approach operations. Approval of RNP operations with appropriate certified avionics provides on-board performance monitoring and alerting capability enhancing the integrity of aircraft navigation.

6. 9 GNSS augmentations include Aircraft-Based Augmentation System (ABAS), Satellite-Based Augmentation System (SBAS), Ground-Based Augmentation System (GBAS), and Ground-based Regional Augmentation System (GRAS).

Other PBN navigation infrastructure

6. 10 Other navigation infrastructure includes INS, VOR/DME, DME/DME, and DME/DME/IRU. These navigation infrastructures may satisfy the requirements of RNAV navigation specifications, but not those of RNP.

6. 11 INS may be used to support PBN en-route operations with RNAV 10 and RNAV 5 navigation specifications.

6. 12 VOR/DME may be used to support PBN en-route and STAR operations based on the RNAV 5 navigation specification.

6. 13 Uses of DME/DME and DME/DME/IRU may support PBN en-route and terminal area operations based on RNAV 5, RNAV 2 or RNAV 1 navigation specifications. Validation of DME/DME coverage area and appropriate DME/DME geometry should be conducted to identify possible DME/DME gaps, including identification of critical DMEs, and to ensure proper DME/DME service coverage. The use of ground based radio navigation aids for PBN is a transitional measure while GNSS based infrastructure is implemented. Inertial systems will be integrated with GNSS for improved performance.

Surveillance infrastructure

6. 14 For RNAV operations, States should ensure that sufficient surveillance coverage is provided to assure the safety of the operations. For RNP operations, surveillance coverage may not be required. Details on the surveillance requirements for PBN implementation can be found in the ICAO PBN Manual and ICAO PANS-ATM (Doc 4444), and information on the current existing surveillance infrastructure in APAC can be found in ICAO FASID tables.

Communication infrastructure

6. 15 Implementation of RNAV/RNP routes includes communication requirements. Details on the communication requirements for PBN implementation can be found in ICAO PANS-ATM (Doc 4444), ICAO RCP Manual (Doc 9869), and ICAO Annex 10. Information on the current existing communication infrastructure in APAC can also be found in ICAO FASID tables.

7. Implementation Plan for Performance Based Navigation

ATM Operational Requirements

7.1 The Global ATM Operational Concept (Doc 9854) makes it necessary to adopt an airspace concept able to provide an operational scenario that includes route networks, minimum separation standards, assessment of obstacle clearance, and a CNS infrastructure that satisfies specific strategic objectives, including safety, access, capacity, efficiency, and environment.

7.2 In this regard, the following programmes will be developed:

a) traffic and cost benefit analyses

b) necessary updates on automation

c) operational simulations in different scenarios

d) ATC personnel training

e) Flight plan processing

f) Flight procedure design training to include PBN concepts and ARINC-424 coding standard

g) Enhanced electronic data and processes to ensure appropriate level of AIS data accuracy, integrity and timeliness

h) WGS-84 implementation in accordance with ICAO Annex 15

i) iuniform classification of adjacent and regional airspaces, where practicable

j) RNAV/RNP applications for SIDs and STARs

k) Coordinated RNAV/RNP routes implementation

l) RNP approach with vertical guidance

Implementation Plan

Route Operations

7.3 During the planning phase of any implementation of PBN routes, States should gather inputs from all aviation stakeholders to obtain operational needs and requirements. These needs and requirements should then be used to derive airspace concepts and to select appropriate PBN navigation specification. For specific details of expected PBN applications, reference should be made to the Asia/Pacific Seamless ATM Plan.

Terminal Airspace

7.4 For specific details of expected PBN terminal airspace applications, reference should be made to the Asia/Pacific Seamless ATM Plan.

7.5 The application of RNP APCH with Baro-VNAV procedures is expected to be implemented in the maximum possible number of airports, commencing primarily with international airports. To facilitate transitional period, conventional approach procedures and conventional navigation aids should be maintained for non-equipped aircraft.

7. 6 States should promote the use of APV operations (Baro-VNAV or augmented GNSS) to enhance safety and accessibility of RNP approaches.

7. 7 The application of RNP AR APCH procedures should be considered in selected airports, where obvious safety and operational benefits can be obtained.

7.8 The introduction of application of landing capability using GNSS and its augmentations is expected to guarantee a smooth transition toward high-performance approach and landing capability.

Contingency

7.9 The establishment of a backup system in case of GNSS failure or the development of contingency procedures should be considered as part of the Safety Assessment.

GNSS Implementation Strategies

7.10 GNSS is expected to be a primary navigation infrastructure for PBN implementation. States should work co-operatively on a multinational basis to implement GNSS in order to facilitate seamless and inter-operable systems and undertake coordinated research and development programmes on GNSS implementation and operation.

7.11 States are encouraged to consider segregating traffic according to navigation capability and granting preferred routes to aircraft with better navigation performance.

7.12 With the expectation that precision approach capability using GNSS and its augmentation systems will become available, States are encouraged to explore the use of such capability where there are operational and financial benefits.

8. Transitional Strategies

8.1 During transition to PBN, sufficient ground infrastructure for conventional navigation systems must remain available to serve non-equipped flights. Before existing ground infrastructure is considered for removal, users should be given reasonable transition time to allow them to equip appropriately to attain equivalent PBN-based navigation performance. States should approach removal of existing ground infrastructure with caution to ensure that safety is not compromised. Performance of safety assessments and consultation with users through regional air navigation planning processes will be necessary.

8.2 States should coordinate to ensure that harmonized separation standards and procedures are developed and introduced concurrently in all flight information regions along major traffic flows to allow for a seamless transition towards PBN.

8.3 States should cooperate on a multinational basis to implement PBN in order to facilitate seamless and inter-operable systems and undertake coordinated research and development programmes on PBN implementation and operation.

8.4 States are encouraged to consider segregating traffic according to navigation capability and granting preferred routes to aircraft with better navigation performance**,** taking due consideration of the needs of State aircraft.

8.5 States should encourage operators and other airspace users to equip with PBN-capable avionics. This can be achieved through early introductions of RNP approaches, preferably those with vertical guidance.

8.6 ICAO Asia-Pacific Regional Office should provide leadership supporting implementation and transition towards PBN.

9. Safety Assessment & Monitoring Requirements

Need for a safety assessment

9.1 To ensure that the introduction of PBN applications within the Asia/Pacific Region is undertaken in a safe manner, in accordance with relevant ICAO provisions implementation shall only take place following conduct of a safety assessment by the implementing State or group of States that demonstrates that an acceptable level of safety will be met. This assessment may also need to demonstrate that residual levels of risk associated with specific PBN implementations are acceptable. Additionally, after implementation ongoing periodic safety reviews shall be undertaken by the implementing State or group of States, where required, in order to establish that operations continue to meet acceptable levels of safety.

En-route safety assessment and monitoring

9.2 When considering en-route PBN implementations, the ICAO *Procedures for Air Navigation Services – Air Traffic Management* (PANS-ATM, Doc 4444, Chapter 5, Section 5.4) contains procedures and RNAV procedural separation minima for use in the separation of aircraft in the en-route phase. In some cases, these separation minima require specific RNP capabilities and are based on collision risk modelling which determines communications and surveillance requirements. However, this modelling does not include all operational and technical aspects and is dependent upon parameter values that may vary depending on the particular airspace where the separation minimum will be applied. Therefore, prior to implementation, a system verification of sufficient duration and integrity must be performed to assess such parameters and conditions including weather deviations or other contingency events for the airspace concerned and to demonstrate that operational and technical requirements will be met.

9.3 APANPIRG has established the Regional Airspace Safety Monitoring Advisory Group (RASMAG) to facilitate the airspace safety monitoring aspects for implementations of reduced separation minima and CNS/ATM applications within the Asia and Pacific Regions. RASMAG has adopted the term En-route Monitoring Agency (EMA) to describe an organization providing airspace safety assessment, monitoring and implementation services for international airspace in the Asia/Pacific region to assist the implementation and operation of reduced horizontal (lateral and longitudinal) separation minima. To ensure regional harmonization of en-route safety assessment requirements and methodologies, implementing States are encouraged to work cooperatively with RASMAG who will provide guidance and technical assistance to States to support their en-route PBN implementations.

Undertaking a safety assessment

9.4 The implementing State or group of States shall ensure that a safety assessment and, where required, ongoing monitoring of PBN implementations are conducted. The implementing State or group of States may have the capability to undertake such activities or, in the case of en-route implementations, may seek assistance from an En-route Monitoring Agency. The latter course of action is preferred as an EMA can establish the necessary monitoring and data collection activity in an effective manner for the international airspaces in which the EMA holds responsibility.

9.5 In undertaking a safety assessment to enable en-route implementation of PBN, a State authority or EMA shall:

1) Establish and maintain a database of PBN approvals;
2) Pre-implementation - conduct safety and readiness assessments and, for international implementations, report results to RASMAG;
3) Post-implementation - maintain awareness of data link performance and monitor aircraft horizontal-plane navigation performance and the occurrence of large navigation errors (lateral and longitudinal), implement remedial actions as necessary and, for international implementations, report results to RASMAG;
4) Monitor operator compliance with State approval requirements after PBN implementation;
5) Initiate necessary remedial actions in any instances where PBN requirements are not met.

9.6 Detailed information relating to the international airspace jurisdiction, roles and responsibilities of regional EMAs is contained in the *Asia/Pacific En-route Monitoring Agency Handbook*, which is available from the ICAO Asia/Pacific Regional Office.

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Appendix A – CHANGES TO THE ASIA/PACIFIC REGIONAL PBN IMPLEMENTATION PLAN

Whenever a need is identified for a change to this document, the Request for Change (RFC) Form (see below) should be completed and submitted to the ICAO Asia and Pacific Regional Office. The Regional Office will collate RFCs for consideration by the Performance Based Navigation Task Force (CNS/MET Sub-group of APANPIRG).

When an amendment has been agreed by a meeting of the Performance Based Navigation Task Force then a new version of the PBN Regional Plan will be prepared, with the changes marked by an "|" in the margin, and an endnote indicating the relevant RFC, so a reader can see the origin of the change. If the change is in a table cell, the outside edges of the table will be highlighted; e.g.:

Final approval for publication of an amendment to the PBN Regional Plan will be the responsibility of APANPIRG.

PBN Regional Plan REQUEST FOR CHANGE FORM

RFC Nr:	

Please use this form when requesting a change to any part of this PBN Regional Plan. This form may be photocopied as required, emailed, faxed or e-mailed to ICAO Asia and Pacific Regional Office +66 (2) 537-8199 or icao_apac@bangkok.icao.int

1. SUBJECT:			
2. REASON FOR CHANGE:			
3. DESCRIPTION OF PROPOSAL: [expand / attach additional pages if necessary]			
4. REFERENCE(S):			
5. PERSON INITIATING:		**DATE:**	
ORGANISATION:			
TEL/FA/X/E-MAIL:			

6. CONSULTATION		**RESPONSE DUE BY DATE:**		
	Organization	**Name**	**Agree/Disagree**	**Date**
7. ACTION REQUIRE :				
8. PBN REGIONAL PLAN EDITOR			**DATE REC'D :**	
9. FEEDBACK PASSED			**DATE :**	

AMENDMENT RECORD

Amendment Number	Date	Amended by	Comments

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Appendix B – IATA Traffic Forecast

"By 2010 Asia will be the largest single market for aviation" - IATA 27th Feb 2008. Globally predicted passenger traffic will rise by 4.9 per cent per year between 2007 and 2026, almost trebling in two decades as jet planes got bigger and more people flew on them. Meanwhile airfreight will rise by 5.8 per cent annually in the same period.The greatest demand will come from the Asia-Pacific region, where airlines will take delivery of 31 per cent of new planes in the next 20 years, compared with 24 per cent for Europe and 27 per cent for North America.

Passenger
Asia Pacific airlines saw a marginal drop in demand growth from 6.2 per cent in December 2007 to 5.7 per cent in January 2008. Currently, airlines in the region benefited from increased competitiveness due to the strong Euro and the booming economies of both India and China.

Cargo
Steady year-on-year airfreight growth of 4.5 per cent was recorded in January 2008. In the larger freight markets there is continued strength. Asia Pacific airlines saw demand increase 6.5 per cent, up from 6 per cent in December 2007, boosted by the booming economies in China and India.

For the period 2002-2020 aircraft movements are expected to increase at an annual growth rate of 5.4 per cent, to reach almost 294 thousand aircraft movements by the year 2020. Average annual growth rates of 6.5, 5.7 and 5.2 per cent are forecast for the periods 2005 - 2010, 2010-2015 and 2015 - 2020, respectively.

TRANSPACIFIC PASSENGER FORECAST			
Average Annual Percentage Growth Rates			
	Low	Medium	High
2005-2010	5.3	6.5	7.8
2010-2015	4.5	5.7	7.0
2015-2020	4.0	5.2	6.5
2002-2020	4.1	5.4	6.7

The Intra-Asia/Pacific passenger aircraft movements are expected to increase at an average annual growth rate of 4.6 per cent to the year 2020. The growth rates for the intermediate periods of 2005-2010, 2010- 2015 and 2015-2020 are 5.0, 4.3 and 4.2 per cent, respectively.

INTRA ASIA /PACIFIC AIRCRAFT MOVEMENT FORECAST			
Average Annual Percentage Growth Rates			
	Low	Medium	High
2005-2010	3.6	5.0	5.5
2010-2015	3.1	4.3	5.2
2015-2020	3.1	4.2	5.2
2002-2020	3.3	4.6	5.6

New Aircraft Deliveries by Region

Record new aircraft orders were placed by the airline industry in 2005 – 2007. The large numbers of new orders represent strong confidence in the future prospects of the global airline industry. In its latest forecast of aviation growth, European aircraft maker Airbus said the world's fleet of large passenger jets (of more than 100 seats) would double in the next 20 years to nearly 33,000. The greatest demand will come from the Asia-Pacific region, where airlines will take delivery of 31 per cent of new planes in the next 20 years, compared with 24 per cent for Europe and 27 per cent for North America.

New Aircraft Deliveries by Region	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012+**
	Existing						
Africa	**665**	**26**	**15**	**20**	**16**	**13**	**28**
Asia Pacific	**3,578**	**329**	**428**	**407**	**344**	**267**	**440**
Europe	**5,301**	**292**	**348**	**364**	**251**	**153**	**297**
Latin America/Caribbean	**1,031**	**93**	**91**	**45**	**66**	**43**	**65**
Middle East	**626**	**41**	**57**	**44**	**36**	**27**	**164**
North America	**6,987**	**240**	**293**	**309**	**222**	**163**	**412**
Total	**18,188**	**1,026**	**1,237**	**1,208**	**944**	**679**	**1,551**
Increase in Global aircraft fleet (%)	**4.2**	**4.9**	**4.6**	**4.9**	**3.4**	**2.4**	**2.4**

Appendix C - Reference documentation for developing operational and airworthiness approval

General Guidelines for Obtaining Airworthiness and Operational Approvals for PBN Navigation Specifications, Version 1.0, **International Air Transport Association**, August 2008. (URL - http://www2.icao.int/en/pbn/ICAO%20Documentation/State%20and%20International%20Organization%20Publications/IATA%20Guidelines%20for%20PBN%20Operational%20Approval.pdf**)**

States should consider using the COSCAP Operational Approval Handbook http://www.bangkok.icao.int/edocs/COSCAP_PBNOPS_HANDBOOK%20Version%202_4.pdf as a reference until ICAO Operational Approval guidance material is published.

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Appendix D – Practical Example of tangible benefits

Practical examples of tangible benefits derived from the implementation of PBN are:

- Increased airspace safety through the implementation of continuous and stabilized descent procedures using vertical guidance;
- Provision of runway-aligned final approach path which may not be possible from conventional navigation
- Reduced aircraft flight time due to the implementation of optimal flight paths, with the resulting savings in fuel, noise reduction, and enhanced environmental protection;
- Improved airport and airspace arrival paths in all weather conditions, and the possibility of meeting critical obstacle clearance and environmental requirements through the application of optimized RNAV or RNP paths;
- Implementation of more precise approach, departure, and arrival paths that will reduce dispersion and will foster smoother traffic flows;
- Reduced delays in high-density airspaces and airports through the implementation of additional parallel routes and additional arrival and departure points in terminal areas;
- Reduction of lateral and longitudinal separation between aircraft to accommodate more traffic;
- Decrease ATC and pilot workload by utilizing RNAV/RNP procedures and airborne capability and reduce the needs for ATC-Pilot communications and radar vectoring;
- Increase of predictability of the flight path.
- Reduction of maintenance and flight inspection costs associated with conventional navigation aids

Examples of measurable benefits resulting from PBN implementation in Australia are attached as **Attachment A** and **Attachment B**.

An example of measurable benefits resulting from PBN implementation in Thailand is attached as **Attachment C**.

Appendix E: Basic Planning Elements (BPEs) Table

Basic Plan Elements	Regional Plan References
1. Policy and Implementation Planning Formation of a key working group Standards & Requirements in accordance with ICAO Communication with stakeholders	4.0
2. Assessment of CNS infrastructure	6.11-6.16
3. Assessment for PBN fleet readiness Based on actual operator traffic	6.4-6.7
4. Selection of appropriate PBN navigation specification	7.3-7.18
5. Strategies for en-route implementation Key traffic flows and city pairs identified Domestic International Harmonization in en-route, across FIRs	5.4-5.9
6. Strategies for terminal area implementation, including timeline Specify terminal areas selected for implementation by 2010	5.10- 5.11
7. Strategies for Instrument approach implementation, including timeline Specify procedures selected for implementation by 2010 APV (Baron-VNAV and/or augmented GNSS) Designate RNP APRCH (LNAV or LNAV/VNAV) Designate RNP AR APCH (with operational justification)	4.16(b) / 5.12-5.13 / 7.8-7.10 / 7.16- 7.18
8. Transition strategy Include decommissioning plan	4.17(b) / 8.0
9. Safety Assessment Pre- and post- implementation safety assessments conducted in accordance with ICAO provisions Seek guidance and technical assistance from RASMAG Periodic safety reviews undertaken by the State or group of States where required	4.17(a) / 9.0
10. Description of the tangible benefits Benefits to operations derived from PBN implementation	4.10 / Appendix D
11. Regulatory Framework and Process for Operational Approval	Appendix C

AIRSERVICES AUSTRALIA

RNP Project

BRISBANE GREEN

Stage One Report

March 2008

airspace | airside | **AIRSERVICES AUSTRALIA**

Contents

Executive Summary

The Brisbane Green Project is a world first integration of Required Navigation Performance (RNP) approaches and departures into a busy international airport. The successful introduction of Stage One of the project has laid the foundation for widespread adoption of this technology at all of Australia's major airports. This report represents a work in progress and we have taken a conservative approach to the benefits from this stage of the project. The results are, however very encouraging.

Airservices Australia has worked closely with Naverus inc., Qantas Airways and the Civil Aviation Safety Authority of Australia (CASA) to achieve this successful outcome. Airservices is committed to introducing leading edge ATM capability in close collaboration with our stakeholders. To date there have been RNP approaches deployed to 9 airports across Australia including Alice Springs, Ayers Rock, Brisbane, Cairns, Gold Coast, Hobart, Canberra, Townsville and Sydney. The broad range of environments where RNP is being deployed within Australia demonstrates its suitability as a global solution.

At present there are six RNP approach and twelve RNP departure procedures deployed at Brisbane. In the first twelve months of the project, over 15,500 RNP procedures have been conducted including more than 8,000 approaches.

Of the 8000 approaches, 1612 were conducted in night or instrument conditions that required an instrument approach.

Key findings for Stage One:

- Based on 1612 procedures flown in instrument conditions:
  a. Estimated cumulative savings in flight time are 4,200 minutes achieved through a 17,300NM reduction in distance flown;
  b. Estimated cumulative savings in jet fuel are more than 200,000 kg;
  c. Estimated carbon dioxide emission reductions of 650,000 kg;
- There was a reduction in aircraft noise impact;
- Non-RNP aircraft benefited through reduced delays resulting from shorter arrivals for RNP aircraft;
- There were no reported occurrences of an RNP capable aircraft being denied an RNP clearance upon request;
- Comparing the first quarter and the last quarter of Stage One of the project, there was a 29% increase in the number of flights cleared via an RNP approach;
- There was no reduction to airport acceptance rates and a slight reduction in average delay;
- There have been no weather related go-around events;
- There have been no cases of aircraft exceeding the RNP design parameters; and
- There were no occurrences of the approaches being unavailable due to navigation system outages.

The most important insight gained from the project was that collaboration between stakeholders is essential.

On behalf of Airservices Australia I would like to thank Naverus Inc., Qantas Airways and the Civil Aviation Safety Authority of Australia for their contributions and collaboration in Brisbane Green. I would also like to acknowledge the outstanding efforts of the Airservices project staff and the air traffic controllers who have made this project possible. I look forward to reporting the results of this ongoing work to you as future stages unfold.

Greg Russell
Chief Executive Officer
Airservices Australia
March 2008

Introduction

Airservices Australia has a long tradition of innovation and collaboration to achieve the needs of the aviation industry, particularly in the advancement of safety, efficiency and the environment. In 2006, Airservices Australia and Naverus Inc., in close collaboration with Qantas Airways and the Civil Aviation Safety Authority of Australia (CASA), began work to implement high precision, performance-based instrument approach and departure procedures within Australia.

These procedures, based upon Required Navigation Performance (RNP), are designed to take advantage of the sophisticated navigational capability of modern aircraft. Initially implemented at terrain challenged locations such as Juneau, Alaska, RNP approaches and departures are now demonstrating real safety, efficiency and environmental benefits at a wide range of airports where modern aircraft operate.

The rollout of RNP approach and departures is now in progress for 15 airports across Australia, including the milestone "Brisbane Green" project at Brisbane International Airport.

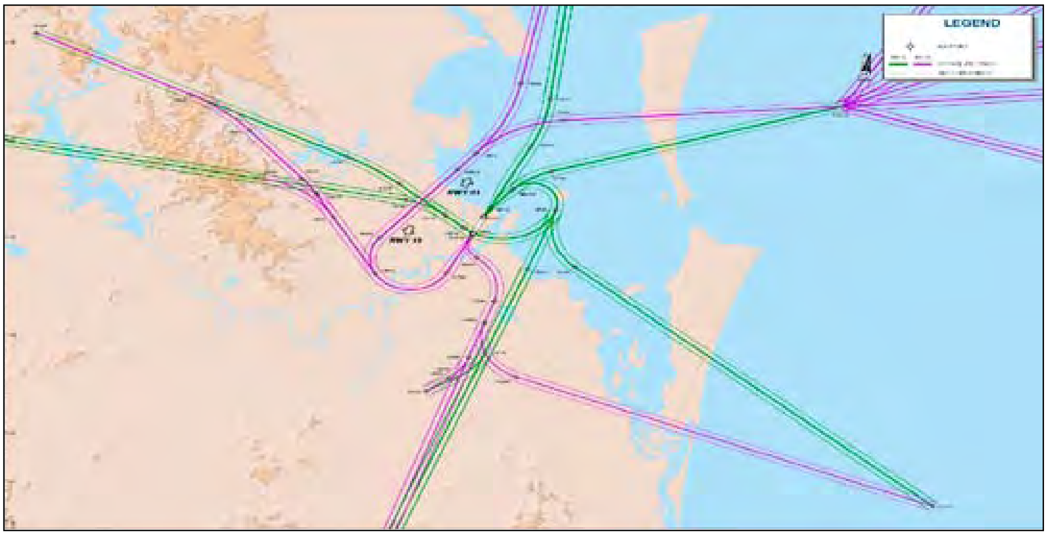
The purpose of Brisbane Green is to determine the most effective way to integrate RNP at a busy international airport supporting mixed (RNP and conventional) operations. The objectives of the project are to:

- identify, measure and report the benefits and costs of RNP to all stakeholders;
- develop ATC and flight crew operating procedures;
- identify, resolve and document issues and consequences; and
- gather a body of data to support the development by ICAO of terminal area RNP separation standards.

Under the project, RNP approaches have been deployed to Brisbane's main runways and connected to the Standard Arrival (FIGURE 1) and Departure (FIGURE 2) Route structure.

FIGURE 1.

FIGURE 2.



The procedures are approved for use by qualifying aircraft in revenue service for day and night operations and in all weather conditions. Track mile savings are significant compared to the track to the ILS for the same runway. Table 1 details the savings from arrival to runway threshold.

TABLE 1.

Track Mile Savings – RNP		
No.	**RNP TRACK**	**Miles Saved**
1.	DAYBO RWY 01	13.1
2.	DAYBO RWY 19	4.9
3.	AMITY RWY 01	12.8
4.	AMITY RWY 19	8.9
5.	AMBERLEY RWY 01	Nil
6.	AMBERLEY RWY 19	17.3

This report is based on the results from Stage One of the project, covering the first year of operation commencing January 2007 through to January 2008. As the project develops, new aircraft types participate, and complementary technologies are introduced, additional reports will be published. The intent is to foster collaboration and harmonisation with the international community in the interests of a safer, environmentally sustainable, more efficient and performance-based Air Traffic Management system.

Supporting this intent is Airservices' commitment to collaboration with other stakeholders to achieve an environmentally sustainable aviation industry. In February 2008, Airservices, the United States Federal Aviation Administration and Airways New Zealand created the Asia and South Pacific Initiative to Reduce Emissions (ASPIRE) Partnership.

Under ASPIRE, the three air navigation service providers undertook to work closely with airlines and other stakeholders in the region, to:

- accelerate the development and implementation of operational procedures to reduce the environmental footprint for all phases of flight on an operation by operation basis, from gate to gate;
- facilitate world-wide interoperability of environmentally friendly procedures and standards;
- capitalise on existing technology and best practices;
- develop shared performance metrics to measure improvements in the environmental performance of the air transport system; and
- provide a systematic approach to ensure appropriate mitigation actions with short, medium and long-term results.

Brisbane Green is an example of the work to be advanced under the ASPIRE initiative and demonstrates the benefits of a collaborative approach.

Background

Airservices Australia

Airservices Australia provides air traffic management (ATM) and related airside services to the aviation industry. Recognised internationally as a leader in the field, Airservices is committed to providing safe and environmentally sound services across Australia and in the surrounding region.

Each year, Airservices manages air traffic operations for more than three million domestic and international passenger flights carrying some 47 million passengers. The aviation industry also relies on Airservices for aeronautical data, telecommunications and navigation services.

The Future

The aviation industry is experiencing unprecedented growth, with air traffic in the Asia-Pacific region forecast to double in the next decade alone. To provide the necessary airspace capacity, while also raising system performance in terms of safety, efficiency, security and environment, the aviation community must turn to new techniques and technologies – an 'information technology revolution' for aviation.

No single technology provides all the solutions, and Airservices is working to integrate a variety of technologies to provide an internationally harmonised, performance-based ATM system that caters for a range of aircraft capabilities in diverse operating environments. However, one of the keystones of the future will be RNP.

RNP, and performance based navigation in general, is identified by the International Civil Aviation Organization (ICAO) as an enabler of the Global Air Navigation Plan (Doc 9750). The deployment of RNP is considered as an essential element in both the US NextGen and European SESAR plans, and the Australian ATM Strategic Plan also notes a major role for RNP in delivering the ATM target operational concept.

Airservices is working with Naverus Inc. to deploy RNP across Australia. This is a strategic relationship that brings together the strengths of both organisations to provide the leading edge in air traffic management capability.

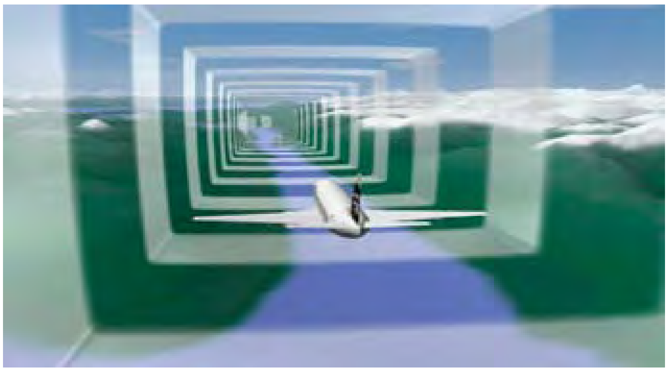
Naverus Inc.

Naverus is based in the United States and Australia, and specialises in the development of "next generation" navigation solutions designed for modern aircraft. Beginning with their involvement in the deployment of RNP in Alaska during the early 1990's, the principals of Naverus have pioneered the use of terminal area RNP procedures.

Naverus is the world's leading RNP procedure designer, having designed the majority of procedures currently operating in revenue service throughout the world.

RNP Technology and Operations

RNP is a way of defining the navigational capability of the aircraft, taking into account the performance of the avionics, on-board systems and flight characteristics. RNP is a level of navigational performance expressed in nautical miles. The RNP defines the width of the airspace corridor required for the procedure.



RNP utilises the aircraft's Flight Management System (FMS) to integrate numerous sources of position data (including inertial, satellite and air data) to provide highly accurate navigation with real-time integrity monitoring and alerting. RNP is able to provide flexible, accurate and safe instrument approaches without the infrastructure demands of conventional approach navigation systems. Today it is used at some of the most remote and challenging environments in the world, providing access and delivering unprecedented improvements to safety.

Significantly however, a number of recent deployments of RNP have been at airports where terrain does not constrain operations. The ability to curve the approach path has allowed the designer to manoeuvre the aircraft around obstacles, and restricted or built up areas. This often results in a shorter approach when compared to the conventional procedure.

Aircraft Capability

Modern Transport Category aircraft equipped with FMS and GNSS are able to meet the airworthiness requirements for RNP operations.

RNP capability is usually certified by the manufacturer of the aircraft at the time of production. In many cases however, older aircraft can be retro-fitted to RNP approach capability by undergoing system upgrades.

RNP approach capability is fast becoming a standard feature of modern aircraft. In Australia, over 60% of the domestic jet transport fleet are certified to RNP0.3 or better.

Australian RNP Implementation

The integration of RNP into day-to-day air traffic flow management is a tangible step toward delivering Airservices' Gate-to-Gate and User Preferred Trajectory objectives. Airservices has offered en-route services based on RNP4 to suitably equipped aircraft since 2005, and is now rolling out RNP approach and departure procedures for 'next generation' aircraft. These procedures, based on aircraft performance ranging from RNP0.3 down to RNP0.1, are some of the most advanced deployed anywhere in the world.

The implementation program for terminal area RNP operations in Australia currently includes 15 airports but will be extended as benefit and need is determined. It is planned that Australia will have an integrated enroute and terminal area RNP network by 2010, ranging from non-towered remote airfields (such as Ayers Rock in central Australia) to capital cities (such as Sydney and Brisbane). To date there have been in excess of 26,000 RNP approach and departure operations conducted nationally.

Completion of Stage One of the Brisbane Green project is a milestone within the RNP program as it marks the successful integration of RNP approach and departure procedures into the air traffic flow management of an international hub.

FINDINGS

1. The broad range of environments where RNP is being deployed within Australia demonstrates its suitability as a global solution.

2. Projected aviation growth demands evolution to satellite and data-link technology to replace legacy infrastructure and procedures.

3. RNP is considered a keystone technology for Australia and ensures harmonisation with ICAO and Regional strategic plans.

4. RNP maximises use of the onboard navigational capability of modern aircraft.

5. The integration of RNP into the ATM system provides greater flexibility to balance operational requirements with community expectations.

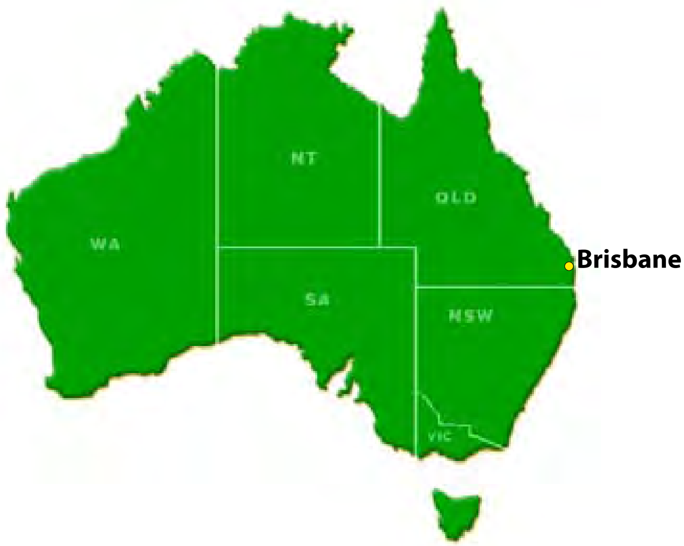
6. Industry collaboration has proven the foundation element to ensure benefit realisation from RNP deployment

The Brisbane Green Project

The Brisbane Green project has provided early delivery and demonstration of the safety, economic and environmental benefits of RNP. The project also provides the opportunity to capture data to support safety evidence for development of RNP separation standards and rules.

Brisbane International Airport

Based on passenger throughput Brisbane International Airport is Australia's third busiest. During 2007 the airport had approximately 173,000 aircraft movements with passenger numbers in excess of 17.5 million. This places Brisbane airport within the world's top 100 airports for passenger throughput and is comparable in these terms to San Diego USA, Vienna, Austria or Osaka, Japan. Twenty-one international airlines and five domestic carriers conduct operations at Brisbane Airport, using a variety of aircraft ranging from turbo-prop and helicopter through to heavy jet operations.



Traffic in the Brisbane area is managed by a Terminal Control Unit (TCU) and ATC Towers at Brisbane International and several nearby airports. Surveillance in the terminal area is provided by primary and secondary radar, with upgrade to Mode S SSR planned for 2009. Other Airservices projects will see Automatic Dependent Surveillance - Broadcast (ADS-B), and Advanced Surface Movement Guidance and Control Systems (A-SMGCS) deployed in the Brisbane area within the next few years.

Brisbane Airport is served by a main north south runway (01/19) and a shorter crossing east/west runway (14/32). The airport has ILS CAT-1 approaches to both ends of the main runway.

There are six RNP approach procedures in use to the two main runway ends, providing alternatives to the existing ILS procedures and visual approach paths. The RNP 0.3 procedures provide for a 250ft decision height and were designed by Naverus in close collaboration with Airservices' air traffic control specialists.

Project Schedule

The Project is divided into three stages of approximately 12 months each. Stage One commenced on 18th January 2007 and involved participation of the Qantas 737-800 fleet; 33 airframes. To date there have been in excess of 15,500 RNP operations conducted at Brisbane with more than 8000 approaches. This represents approximately 63% of all RNP operations nationally.

Stage 2 commenced in early 2008, and includes the Jetstar A320/A321 and Air Vanuatu 737NG fleets. To date, this has involved an approval process by CASA and the development and deployment of crew training for the two airlines.

Stage 3, to commence in 2009, is expected to include Virgin Blue Airlines and other international carriers, with additional aircraft types.

Procedures Implementation

All RNP procedures at Brisbane have been designed to RNP 0.3 criteria with their use approved by CASA. Initial design commenced some seven months prior to implementation at Brisbane. Initial designs were distributed to ATC for review and tested in the Qantas 737 flight simulators before being flight checked.

An Online Training (OLT) package was developed for air traffic controller training. The package targeted the specific elements of change within each operational unit. Completion of the OLT package was mandatory for all air traffic control personnel prior to their participation in the Brisbane Green project.

Qantas pilots undertake theoretical and simulator training to qualify for RNP instrument approaches generally. Importantly no additional training was required for these RNP qualified pilots to participate in the project.

New pilot/controller phraseologies were developed in conjunction with CASA and airline participants. These phrases were also applicable to other locations where RNP was being introduced and were therefore standardised throughout Australia. Future enhancements to the ATC automation system may eliminate the need for these measures.

FINDINGS

1. Full integration of RNP into the air traffic flow management of a busy international hub is achievable.
2. Integration of air traffic management considerations from commencement of the design stage is essential.
3. Stage 2 and 3 of the Project will see a four-fold increase of the airframes involved in RNP operations at Brisbane.

Safety Analysis

The approach to safety for the Brisbane Green Project has included both qualitative and quantitative analysis pre and post implementation. Airservices and Qantas both have robust Safety Management Systems (SMS) and these systems have been fully applied.

Reporting Requirements

CASA has put in place specific reporting requirements to ensure timely identification and resolution of issues. Additionally there has been significant information exchange between stakeholders.

Throughout the project, Airservices has recorded 1 instance reported as an "event" and 4 instances reported as an "incident" via its formal reporting process. All instances were fully assessed and where appropriate remedial processes put into effect. In all cases, instances were assessed to be of a minor nature. Given the number of procedures flown, this outcome is considered a very positive result.

Conformance

A study of lateral conformance of Brisbane Green RNP operations was also undertaken. Data was collected from 543 flights, from the period of August 2007 to end January 2008. Aircraft are required to navigate within 1 x RNP (in this case 0.3 nautical miles or 556 metres) of the prescribed path 95% of the time. It was demonstrated that RNP aircraft are exceeding this requirement.

Aircraft conformed to the path prescribed with a standard deviation of 0.0224 nautical miles or 41.5 metres and there were no instances of aircraft exceeding the approach design tolerance. This data will also be used to support a safety assessment by ICAO's Separation and Airspace Safety Panel (SASP) for development of new RNP based separation standards.

Non-normal Operations

RNP procedures deployed in Australia make provision for emergency operations including engine and other system failures at any point in the approach or departure. The safe extraction of a disabled aircraft is provided with an alternative flight path which automatically steers the aircraft over the lowest terrain and delivers it to an altitude where it can safely return to land.

In terrain challenged airports like Queenstown, New Zealand, Cairns and Canberra this capability has reduced the workload on pilots in an emergency and dramatically raised the safety of operations. RNP is valued as an effective weapon in the fight against the Controlled Flight into Terrain (CFIT).

FINDINGS

1. A transparent and collaborative approach to safety activities between the airline, ANSP and regulator are a foundation to project success.
2. A total of 1 event and 4 incidents were reported for more than 8000 approaches and 7000 departures.
3. 100% compliance within the RNP navigation requirement has been achieved.
4. Inherent characteristics of RNP support safety improvements.

Efficiency Analysis

For the 12 months of Stage One, more than 200,000 kg of fuel was saved during RNP approaches. For aircraft conducting an instrument approach, RNP can have a positive impact on delays and fuel consumption through track shortening and Continuous Descent Arrivals (CDA).

Reduced Flight Distance

A conventional instrument approach such as an ILS is constructed by extending a line from a navigation aid (on the ground) to a point in space where the approach commences. In the case of the ILS, this point is approximately 10NM from the runway. An RNP approach is not dependent upon the location of ground aids and is constructed as a series of straight and curved segments. The length of the straight segment immediately before the runway threshold may be as short as one mile. This feature allows the designer to curve the approach around obstacles, restricted and noise sensitive areas and to "abbreviate" the approach to achieve a reduction in the distance flown by the aircraft as it approaches to land.

During Stage One of the Brisbane Green Project the total number of track miles saved is estimated to exceed 17,300 nm (approximately 4,200 minutes of flight time). This result is based upon the instances where a participating B737-800 was able to conduct the RNP approach where otherwise an ILS approach would have been required. This has resulted in approach tracks being shortened by up to 17.3NM.

Track shortening at the end of the approach has far more impact than track shortening at the beginning of the approach because the rate of fuel consumption of a jet engine increases as the aircraft descends and configures for landing.

Reducing fuel consumption during arrival and descent is a key efficiency and environmental objective. The job of the air traffic controller is to safely separate aircraft. Aircraft can be separated both laterally and vertically and therefore it is common for arriving aircraft to level off at intermediate altitudes as air traffic controllers provide vertical separation from aircraft passing below. For the aircraft to interrupt its descent, thrust must be applied and that means more fuel is burned.

Continuous Descent Arrival

A CDA is one where the vertical path of the aircraft is uninterrupted and optimised for use of idle thrust. An RNP approach is designed to allow the FMS to manage the energy during descent, eliminating unnecessary level segments. The accuracy of navigation and speed control during the descent also allows the air traffic controller to predict the progress of the aircraft and aids in the sequencing of landing aircraft. For the controller, the need to intervene in the descent or the navigation of the aircraft is greatly reduced.

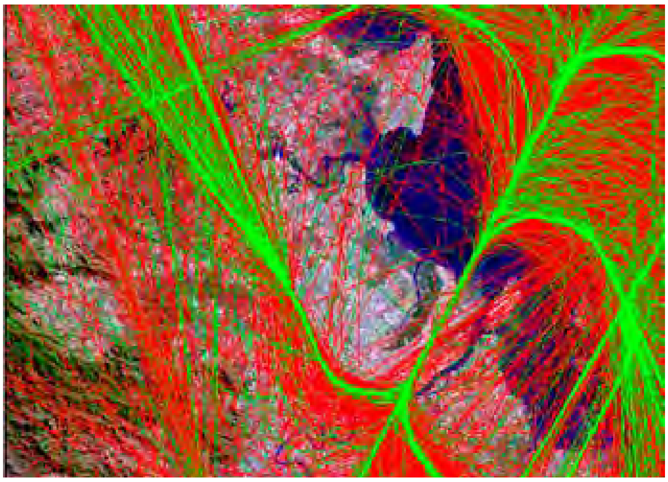
As a result, RNP aircraft arriving into Brisbane are able to conduct a CDA from the top of descent thereby allowing the aircraft to virtually glide at idle thrust for approximately the last 20 minutes of flight.

Airspace Capacity

It was found that the time saved through an RNP approach was consistent and predictable, and that the accumulation of time saved by an RNP approach flows on to following aircraft in the sequence. This generates savings for all flights into an airport where RNP approaches are deployed whether aircraft are RNP or Non-RNP and provides the potential for increased throughput of arriving aircraft to the airport.

FIGURE 3 shows the predictability of RNP approach paths (green) by contrast with the significant variation to flight path for conventional procedures and the associated controller workload.

FIGURE 3.



Use of RNP Procedures

The suitability of RNP approaches in normal airport operations was identified as a success measure for Stage One, specifically how often the controller was able to grant an RNP approach as opposed to an ILS or visual approach was assessed. To date there has been no reported instances of an RNP capable aircraft being denied an RNP approach.

Comparing the first and last quarter of Stage One of the project there was a 29% increase in the number of flights cleared via an RNP approach.

Airport Capacity

Another measurement of success for the project was the impact of RNP approaches on airport capacity. Analysis from the month immediately prior to commencement of Stage One (December 2006) compared to the final month of this stage (December 2007) indicates that no reduction to airport acceptance rates has occurred and indeed, there was a slight overall reduction in average delay of 28 seconds. This initial finding will be the subject of more detailed analysis throughout later stages.

This is a very encouraging outcome and indicates that in Brisbane, RNP has rapidly assimilated into the ATC environment. The presence of an RNAV STAR system and flow management protocol has resulted in a reduced need for tactical intervention through radar vectoring. This has facilitated a high and increasing level of RNP approach clearances.

The potential accumulated benefit to airport capacity is substantial and throughout later stages of the project empirical data will be collected to measure the impact of RNP on the overall capacity of the terminal airspace.

FINDINGS

1. The RNP approaches at Brisbane provided shorter approaches by up to 17.3 NM.
2. The total number of track miles saved during Stage One is estimated to exceed 17,300NM;
3. Identified fuel savings are in excess of 200,000 kg.
4. Flight time savings for arrivals exceeded 4,200 minutes.
5. The RNP approaches at Brisbane provided greater trajectory predictability allowing reduced controller intervention.
6. There has been no reduction to airport acceptance rates and a slight overall improvement to average delay by 28 seconds.
7. RNP facilitates a CDA which provides for significant fuel savings.
8. Non-RNP flights following an RNP aircraft gain benefit through less delay derived from the shorter RNP approach.

Environmental Analysis

The aviation industry has been managing its environmental impacts for many years, and aircraft noise is regularly raised in public debate about the operation and expansion of airports. Aviation's contribution to greenhouse gas emissions, although small when compared to others, is anticipated to grow. Environmentally sound decision-making is therefore critical to the long-term development of the industry.

More broadly, Australia has committed to working on climate change issues. In January 2006, Australia, China, India, Japan, Republic of Korea and the United States launched the Asia Pacific Partnership on Clean Development and Climate (AP6) and in December 2007 Australia became a signatory to the Kyoto Protocol to the United Nations Framework Convention on Climate Change. Airservices' partnership with the FAA and Airways New Zealand in ASPIRE is part of this commitment.

The aviation industry has responded to the issue of emissions with the International Air Transport Association (IATA) and ICAO specifically encouraging the implementation of new ATM practices and technologies in the management of aviation's environmental impacts.

Carbon Dioxide (CO_2)

Every kilogram of fuel saved saves just over three kilograms of CO_2 emissions. By comparing airline fuel consumption data with airport movement records, it has been possible to determine, with a high degree of confidence, that Stage One of Brisbane Green has saved more than 650,000 kg of CO_2 emissions.

This estimate has been based upon the ICAO recommended methodology for converting minutes of flight to CO_2 emissions. Further analysis is underway and based on actual fuel usage it indicates that for some approaches the emissions savings may be considerably higher.

But this is the beginning. This remarkable result has been achieved by just 33 aircraft in 12 months of operations. It is expected that Stage Two will significantly improve on this result with the phased inclusion of more participant aircraft over the coming 12 months.

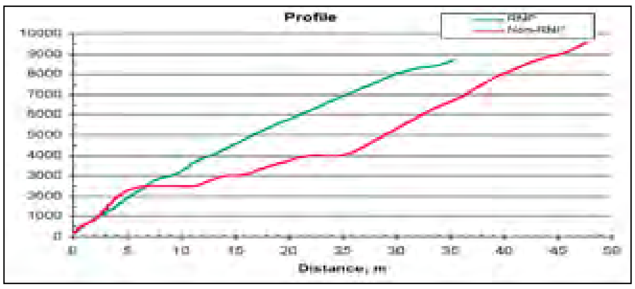
Nitrous Oxide (NOx)

Nitrous Oxide is the third largest greenhouse gas contributor to overall global warming, behind carbon dioxide and methane. Nitrous Oxide emissions by jet aircraft are correlated to the thrust produced by the engine. An approach without level flight segments, that does not require additional thrust to maintain an altitude during the approach, can minimise the production of NOx.

Level segments have traditionally been used to allow aircraft to lose speed, intercept the instrument approach, sequence flows to the runway or facilitate vertical segregation of routes. RNP procedures offer alternative means to achieve these goals, while providing a CDA from high-altitude cruise to the runway.

FIGURE 4 depicts actual data for an RNP and Non-RNP approach in Brisbane within 15mins Actual Time of Arrival (ATA).

FIGURE 4.



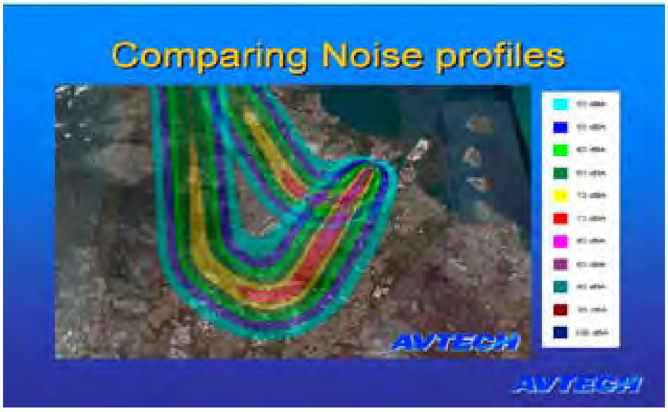
In general terms this data supports our expectation that NOx will be significantly reduced through the introduction of RNP. Stage Two of the project will see the capture and analysis of further detailed data.

Noise

Aircraft noise has been a major focus in Australia and elsewhere in the world, particularly since the development of commercial jet aircraft. Technological developments in the last 40 years have significantly reduced the noise impact from aircraft on communities in the vicinity of airports. In that time perceived noise from individual aircraft has been reduced by a factor of four.

The introduction of stricter Chapter 4 noise requirements in January 2006 have made little, if any, difference to the noise levels around Australian airports due to the modern domestic fleet, most of which were already meeting the Chapter 4 standards. As a result, noise impacts around major Australian airports have been found to increase largely proportional to air traffic increases. Improved ATM techniques will be pivotal in managing noise in the short to medium term.

FIGURE 5.



Noise footprints for the RNP procedures were estimated by AVTECH, Sweden AB (FIGURE 5). This indicated that the 70 dB and 75 dB footprints would be significantly reduced in size, and the accuracy of the RNP design allowed the procedure to be placed over non-residential areas, such as the Brisbane River.

FIGURE 6 shows the flight paths for RNP (green) and Non-RNP (red) aircraft approaching Brisbane runway 01 via the "River" noise abatement procedure. The RNP path ensures that the low level final approach is conducted over the river and industrial areas.

FIGURE 6.

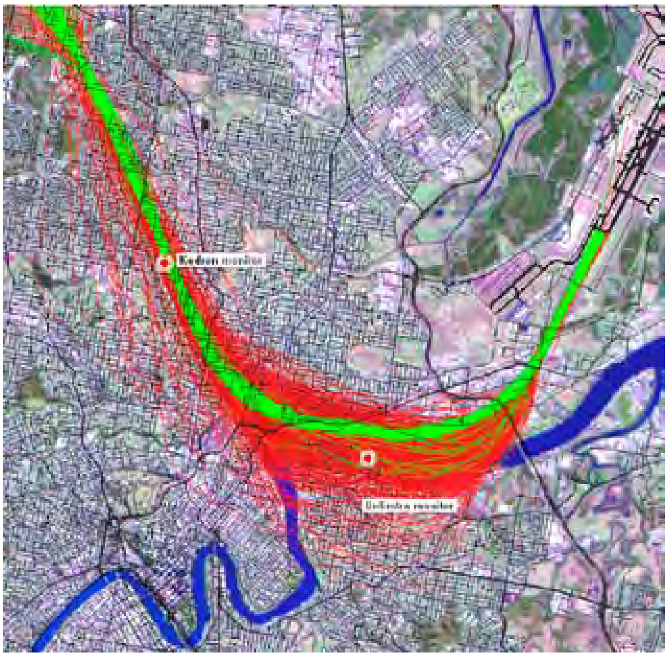
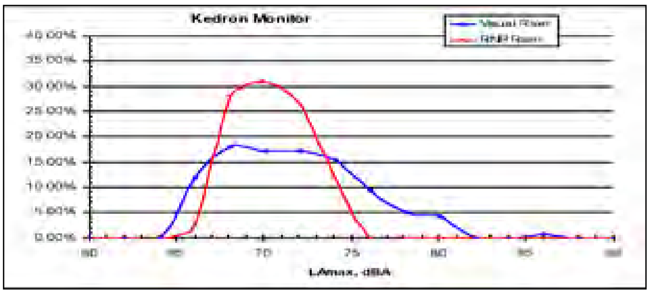


FIGURE 7 demonstrates lower noise levels for RNP flights at the Kedron noise monitor indicating that these aircraft are at higher altitude than typically flown during a visual approach. This shows that very few RNP flights generated noise above 75dB at Kedron.

FIGURE 7.



Noise forecasts for RNP and conventional approaches (FIGURE 5) have been validated using noise monitors at Kedron and Bulimba (FIGURE 6) and other locations.

FINDINGS

1. RNP approach and departure procedures provide practical means to reduce CO_2, NOx and noise emissions.
2. The Brisbane Green Project has saved 650,000 kg of CO_2 emissions in the first year alone.
3. Expectations of reduced NOx emission levels are supported by experience of uninterrupted CDA during RNP approaches.
4. The flexibility and accuracy of RNP operations allows for noise footprints to be placed over non-residential areas.

Future Steps

Stage One of the RNP Project – Brisbane Green has been successful and has exceeded the expectations of the stakeholders. Data gathered in Stage One has validated the benefits which can be realised by the implementation of performance based navigation technology.

The success of the Brisbane Green project and the qualifications of benefits have provided Airservices Australia with the confidence to commit to the deployment of RNP across Australia. Brisbane Green is a model for Airservices and other ANSPs to build on in the development of performance based navigation programs around the world.

A large body of high quality data has been collected from the project validating the benefits of RNP approach and departure operations. Stages Two and Three will continue to capture this data and more, while also focusing upon the introduction of additional aircraft types and complementary technologies. This will further establish the business case for the integration of RNP approach and departures within complex air traffic management environments.

By working with airspace users, regulators, other air navigation service providers and leading edge ATM capability providers such as Naverus, Airservices will continue to advance the Australian CNS/ATM system. Through our RNP implementation program, Airservices and stakeholders will deliver:

- Increased safety in all weather conditions;
- Lower fuel consumption and greenhouse gas emissions;
- Reduced noise for airport communities; and
- Reduced impost of weather and terrain upon operations.

Airservices Australia wishes to acknowledge the contributions of Naverus Inc., Qantas Airways and the Civil Aviation Safety Authority of Australia to the success of the Brisbane Green RNP project.

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Glossary

ABBREVIATION	DETAIL
ANSP	Air Navigation Service Provider
AP6	Asia Pacific Partnership on Clean Development and Climate
ATC	Air Traffic Control
ATM	Air Traffic Management
ASPIRE	Asia and South Pacific Initiative to Reduce Emissions
CASA	Civil Aviation Safety Authority (Australia)
CDA	Continuous Descent Arrival
CFIT	Controlled Flight Into Terrain
CNS	Communication, Navigation and Surveillance
CO_2	Carbon Dioxide
dB	Decibel
FMS	Flight Management System
GNSS	Global Navigation Satellite Systems
IATA	International Air Transport Association
ICAO	International Civil Aviation Organization
ILS	Instrument Landing System
Kg	Kilogram
NM	Nautical Mile
NOx	Nitrous Oxide
OLT	Online Training
RNAV	Area Navigation
RNP	Required Navigation Performance
RWY	Runway
SASP	Separation and Airspace Safety Panel (ICAO)
SMS	Safety Management System
STAR	Standard Arrival Route

Brisbane

Efficiency Analysis of simulated RNP Approaches versus ILS with fixed reference.

Version: 2.0

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Table of Contents

1. Background

Qantas is currently using RNP Approaches in Brisbane for Runway 01 and 19. Benefits have been identified such as reduced emissions, noise and fuel consumption. Noise has earlier been studied for both real flights using Qantas QAR Data and simulated flights[1].

The objective of this study is to illustrate efficiency using RNP approaches compared to ILS for runway 01 and 19.

We compare here each approach from a fix point in space to 200ft.

Simulation was done using the AVTECH AASES 737 Simulator with GE Avionics FMS version U10.7.

Assumptions used:

- 737-600 (-800 not available)
- Engine Rating 20,000 LB
- Weight leaving cruise approx. 138,000 LB.
- Cost Index 33
- Cruise at FL330
- Speed below 250kt below 10,000ft
- Wind 0
- No level segments except for ILS procedure prior to intercept Glide slope.
- ILS: Gear and flaps (30 degrees) extended and aircraft at Vapp before final descent from 2500ft for runway 19 and 3000ft for runway 01.
- RNP: Gear and flaps (30 degrees) extended and aircraft at Vapp before 1000 ft.

[1] Brisbane – Study of RNP Approaches versus ILS v 1.0 - 080226

2. The Approaches

2.1. Runway 01

For the ILS and the RNP flight into RWY01 we used the following STARs and approaches:

- **RNP**. DAYBO8 / DAYBO - RNAV (RNP) M RWY 01 - 26NM
- **ILS.** GLENN4 / DAYBO-FLYNN-RWY01 ILS - 41NM

As fixed point we chose a point at 321 degrees/100nm from DAYBO. A flight from Cairns would pass close or at such a point.

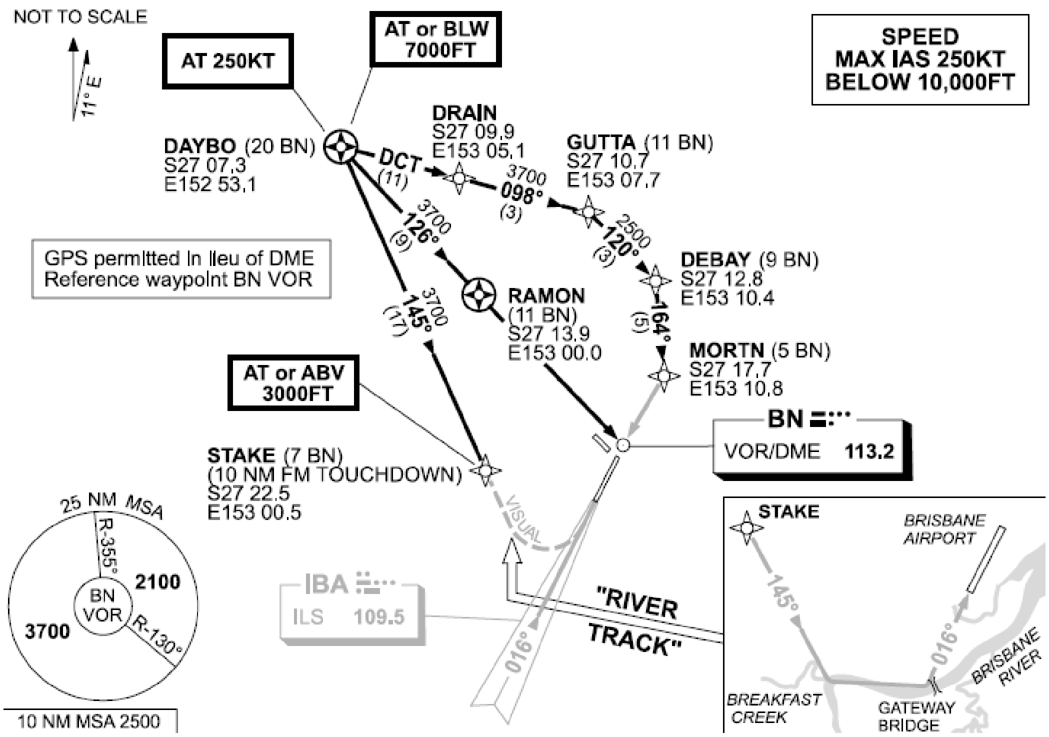


Figure 1 – DAYBO 8

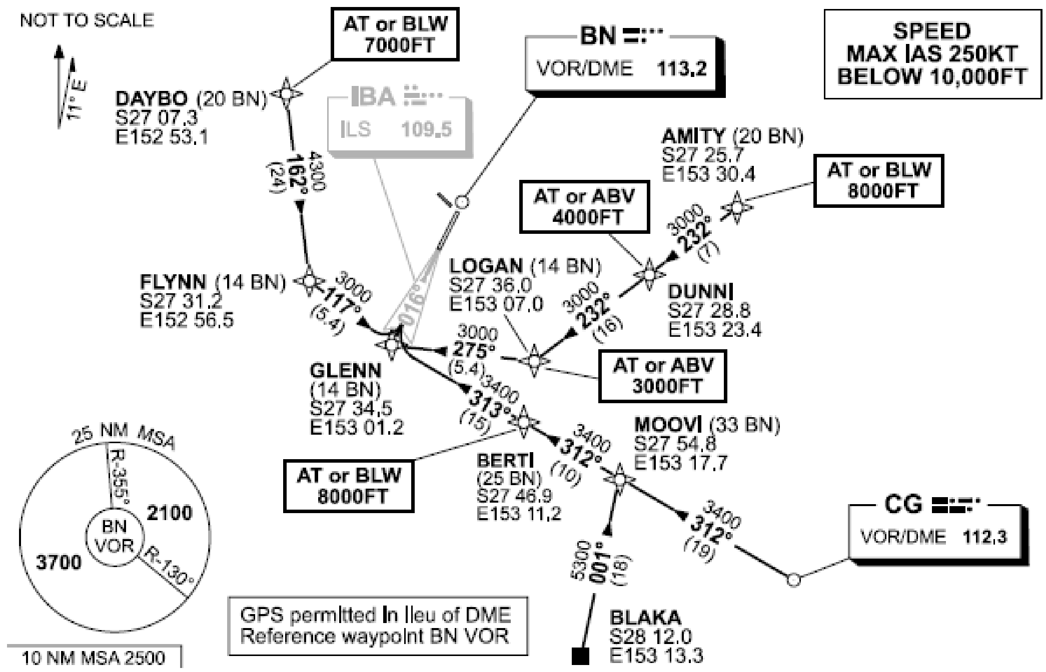


Figure 2 - GLENN4

DME DIST	11.7	11	10	9	8	7	6	5	4.1				
ALT (3° APCH PATH)	3000	2780	2460	2140	1825	1510	1190	865	560				

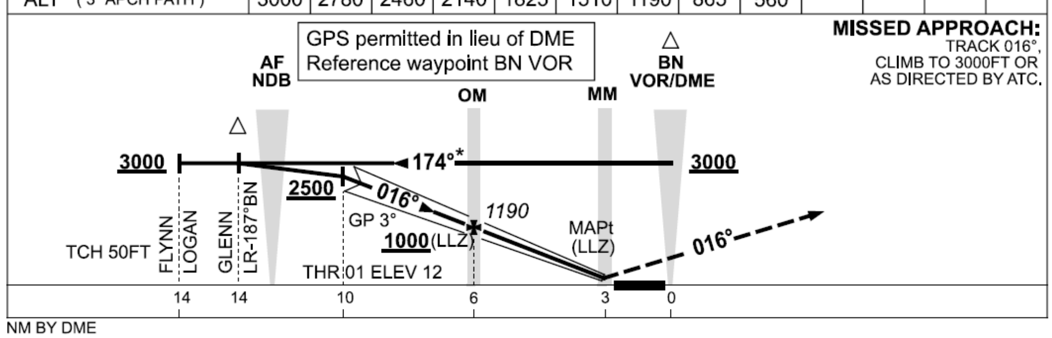


Figure 3 - ILS RWY 01

Runway 19

For the ILS and the RNP flight into RWY 01 we used the following STARs and approaches:

- **RNP**.GOLD COAST4: CG-CRAWS-POODL RNAV (RNP) P RWY 19 - 60NM
- **ILS.** SINNK3: CG-CRAWS-LEAKY-BOATS-SINNK-RWY19 ILS - 73NM

As fixed point we chose a point at 160 degrees/70nm from CG. A flight from Sydney would pass close or at such a point.

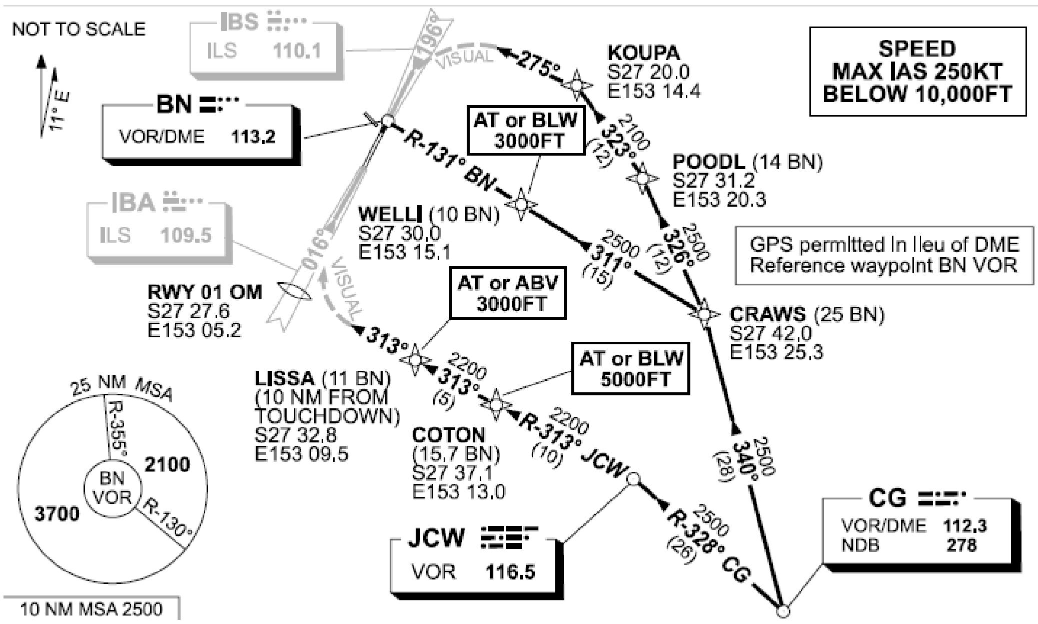


Figure 4 – GOLD COAST 4

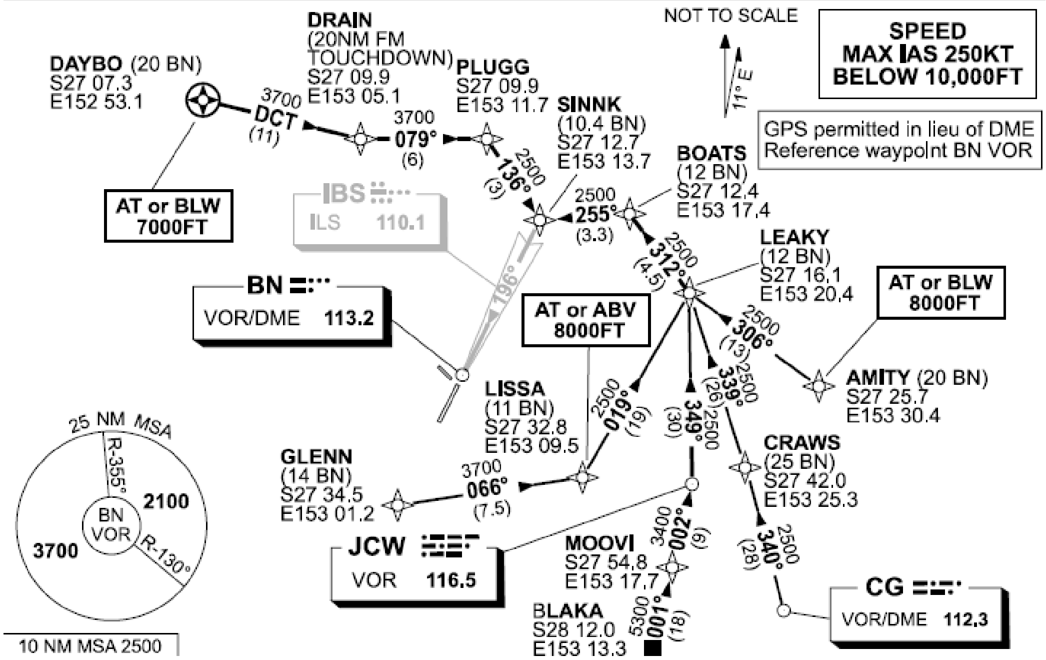


Figure 5 - SINNK 3

DME DIST	1.3	2	3	4	5	6	7	7.8					
ALT (3° APCH PATH)	410	640	960	1275	1595	1915	2230	2500					

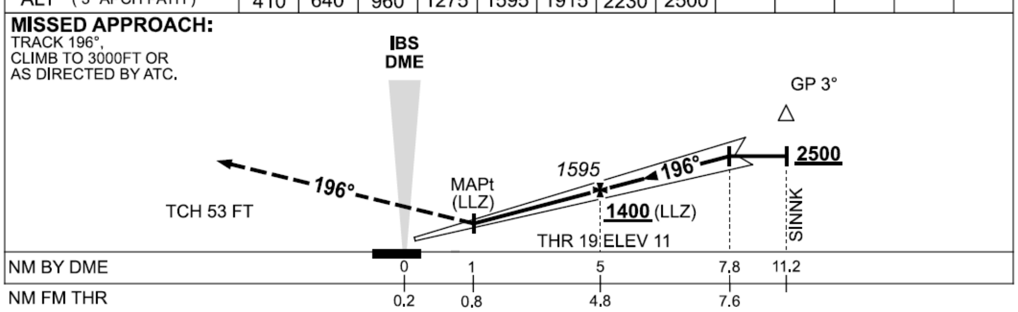


Figure 6 - ILS RWY 19

We note that the approach via SINNK has a long level segment before intercepting ILS Glide compared to a small level segment at GLENN for runway 01.

Figures are parts of Australian AIP by Airservices Australia. Images are for reference only.

3. Results

3.1. Lateral Profile

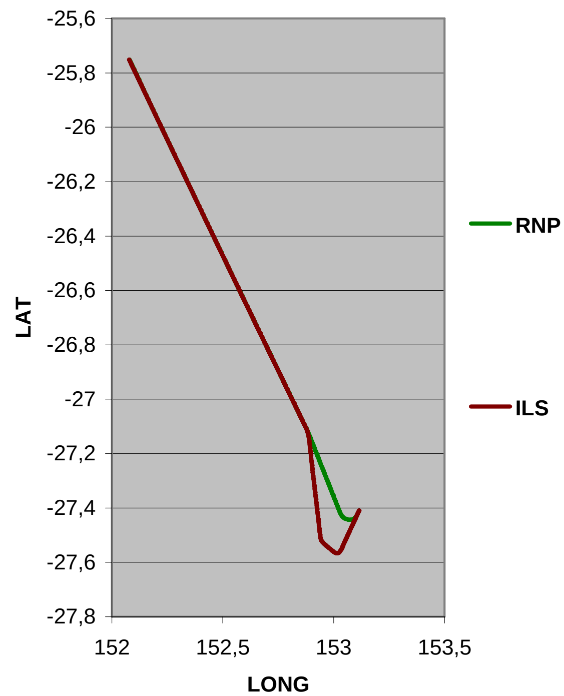


Figure 7 - Brisbane RWY 01 Approach 100nm from DAYBO

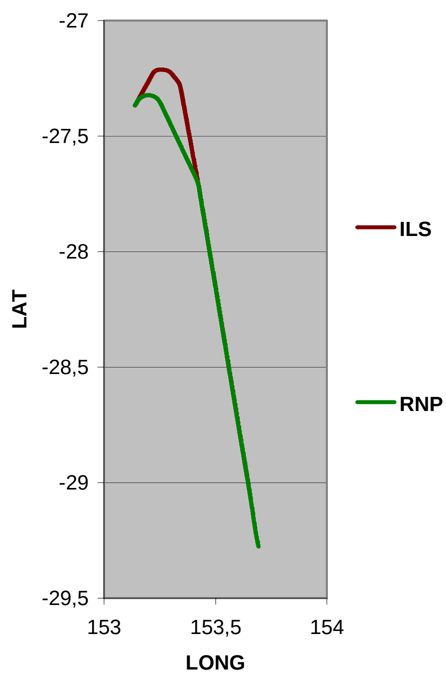


Figure 8 - Brisbane RWY 19 Approach 70nm from CG

3.2. Vertical Profile and fuel burn

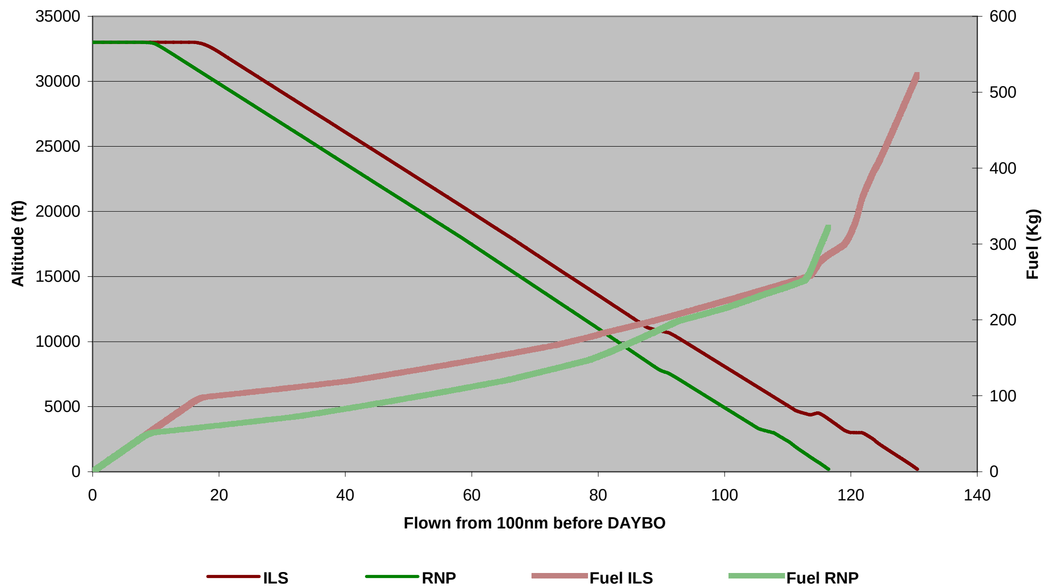


Figure 9 - Brisbane RWY 01 Approach starting 100nm from DAYBO

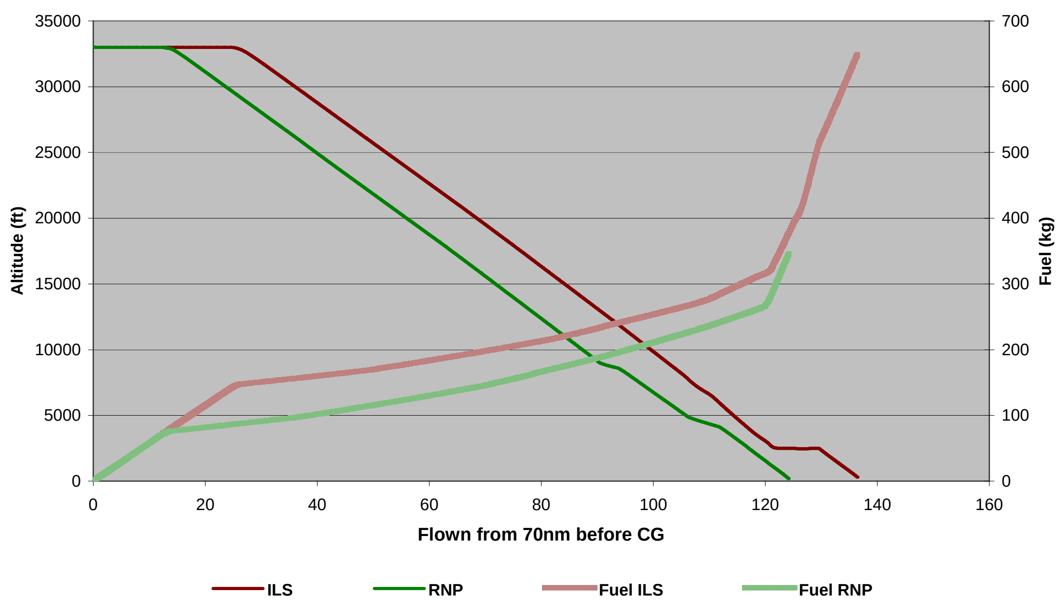


Figure 10 - Brisbane RWY 19 Approach 100nm starting 70 nm before CG

4. Conclusion

Fuel burn is reduced for both RNP procedures compared to ILS. The improvements are linked to differences in drag, track miles and level-offs in the descent.

Reduced track miles will reduce fuel consumption. The savings in track miles are:

- Runway 01: 41nm-26nm = 15nm
- Runway 19: 73nm-60nm = 13nm
-

The remaining difference in consumption is linked to increased thrust and/or increased drag. For the vertical profile on previous page we have identified:

- Runway 19. An increase in fuel consumption during the level segment between SINNK and the intercept point of the ILS descent.

- Runway 01. The level-off segment for the ILS from GLENN at 3000ft is shorter than the level off segment for runway 19 resulting in a lower consumption compared to ILS19.

From FL330 we see the following consumptions and corresponding emissions:

Runway and ILS/RNP	Fuel used (kg)	CO2 (kg)	NOX (kg)
01 ILS	522	1639	5.7
01 RNP	321	1008	3.5
19 ILS	655	2057	7.2
19 RNP	345	1083	3.8

The analysis has determined a reduction in fuel consumption and emissions as follows:

Estimated reduction RNP versus ILS.	Fuel saved (kg)	CO2 (kg)	NOX (kg)
01	201	631	2.2
19	310	973	3.4

These simulations are modeled on the vertical profile from Qantas Brisbane data which exclude radar vectors and associated level segments. Potential gains for RNP would be greater in a terminal area which uses radar vectors and a step down descents.

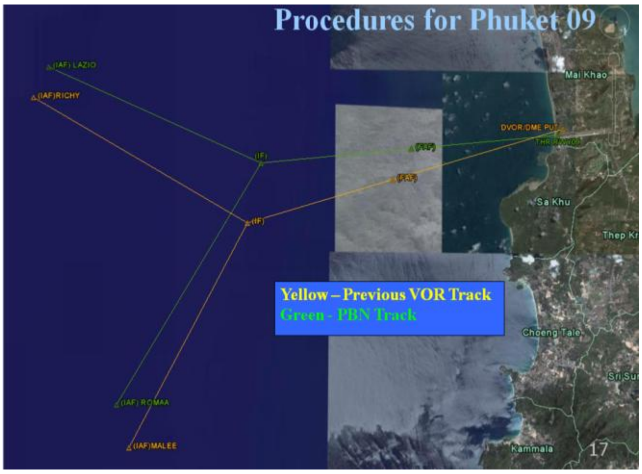
It is noted that an improved Continuous Descent Approach (CDA) is achieved with an RNP compared to an RNAV-ILS approach as the result of the precise trajectory and improved energy management characteristics of the RNP procedure.

1. **Tangible Benefits of PBN Implementation in Thai Terminal Airspace**

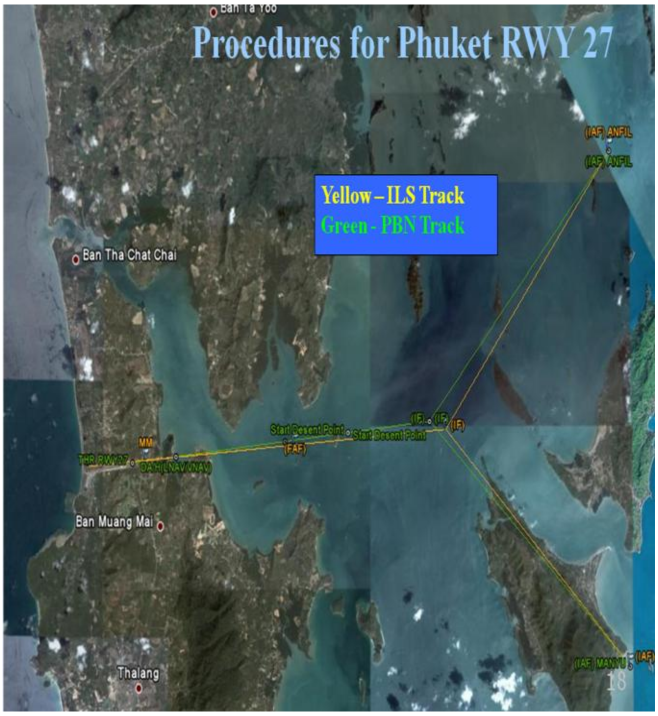
1.1 **Phuket:** Since February 2009, Thai DCA has approved full operation of RNP APCH procedures for Phuket International Airport. These procedures enhance safety and efficiency in the approach operation and also resolve the offset problems caused by the limitation of installation sites of conventional navigation aids.

1.2 The following safety benefits are the results of RNP Approach implementation for Phuket International Airport:

- Runway 27 - Providing a runway-aligned approach path as compared to the current ILS approach which has 1.4 degree offset.
- Runway 09 - Providing a runway-aligned approach path as compared to the current VOR approach which has 5 degree offset.

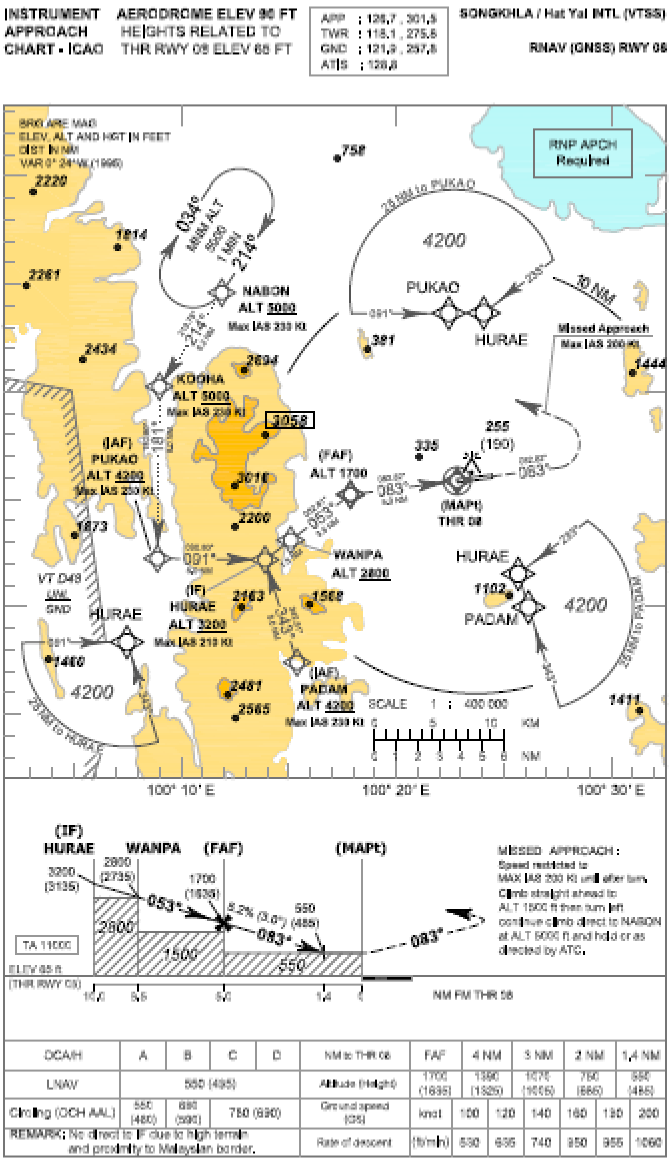


RNP APCH procedures for Phuket Runway 09



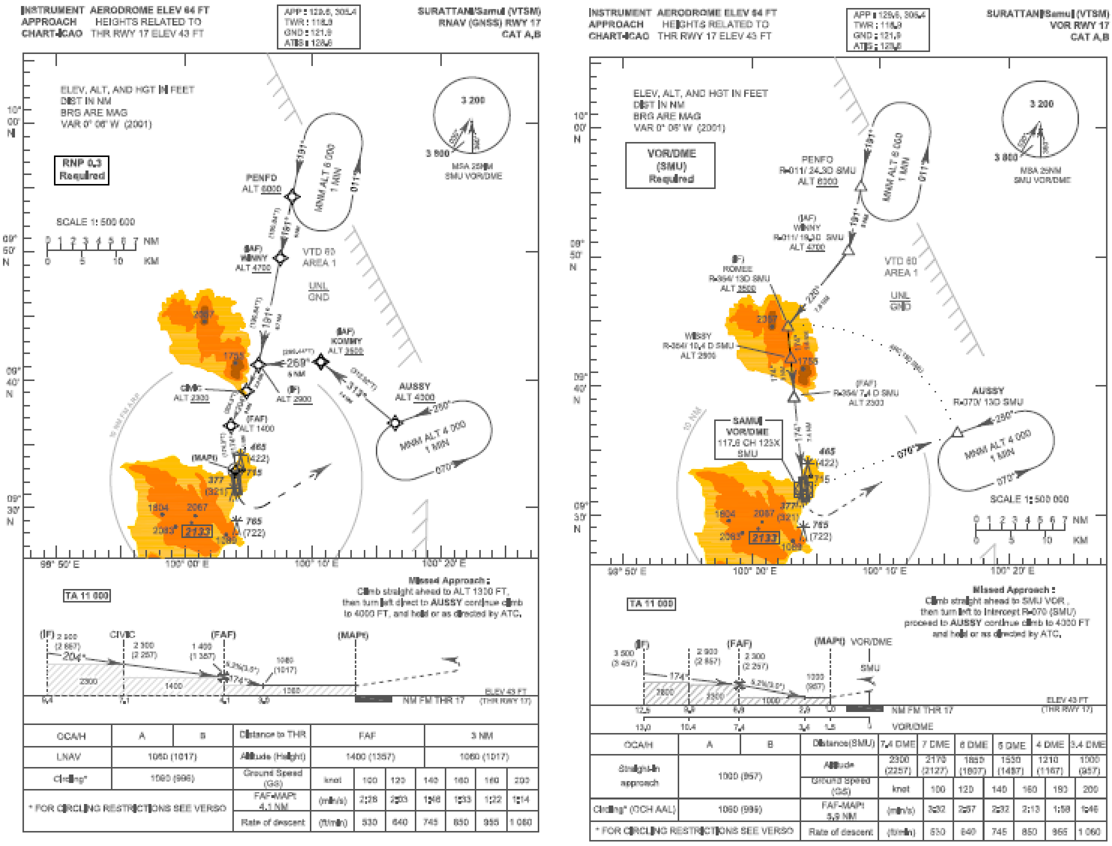
RNP APCH procedures for Phuket Runway 27

1.3 **Hat Yai:** RNP APCH procedures for Hat Yai International Airport have been designed and successfully flight validated by AEROTHAI. The procedures have been available for commercial operations since December 2009. These RNP APCH procedures help enhancing the level of safety and efficiency in approach and landing operations to Hat Yai International Airport, especially to Runway 08, of which no instrument approach procedure with conventional navigation aids was feasible. Moreover, RNP APCH procedures for Runway 26 also provide back-up approach procedures for the existing ILS procedures.



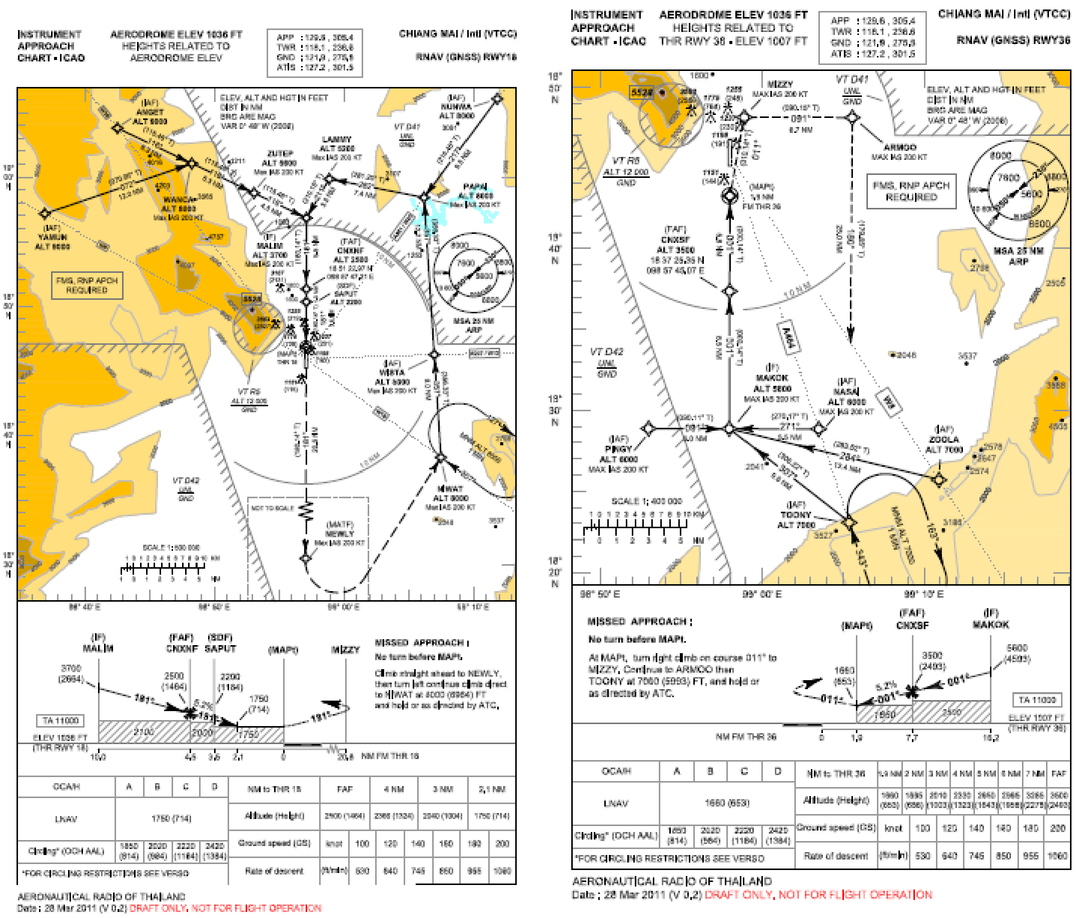
RNP APCH procedure for Hat Yai Runway 08

1.4 **Samui:** Two RNP APCH procedures for Samui Airport have designed and successfully flight validated by AEROTHAI. The procedures have been authorized to be used in commercial operations by the Thai DCA since May 2010. These RNP APCH procedures help enhancing the level of safety and efficiency in approach and landing operations to Samui Airport, especially to Runway 17, since their flexible flight path can navigate the aircraft around mountainous areas while still providing the runway-aligned final segment.



RNP APCH procedure for Samui Runway 17 as compared to VOR Runway 17

1.5 **Chiang Mai:** AEROTHAI in coordination with Thailand's National Working Group for PBN and GNSS implementation has completed the design for additional RNP APCH procedures for Chiang Mai International Airport. As of March 2011, AEROTHAI has successfully flight-validated the two RNP APCH procedures. Commercial operations for the procedures have been expected before the end of 2011. Once completed, these RNP APCH procedures will help enhancing the level of safety and efficiency in approach and landing operations to Chiang Mai International Airport, especially to Runway 18, of which no straight-in, runway-aligned approach procedure is feasible with the existing VOR.



RNP APCH procedures for Chiang Mai International Airport

1.6 The following tables summarize notable safety benefits derived from PBN implementation at Phuket, Hat Yai, Samui and Chiang Mai Airports:

Phuket	**Conventional**	**PBN**
Runway 27	1.4-degree ILS offset	Runway aligned approach
Runway 09	5-degree VOR offset	Runway aligned approach
	OCA at 850 feet	OCA at 750 feet

Samui	**Conventional**	**PBN**
Runway 17	Runway aligned, yet pass through unstable weather area	Runway aligned approach, side-step to avoid the unstable weather area

Hat Yai	**Conventional**	**PBN**
Runway 08	Unavailable due to mountainous terrain	Runway aligned approach

Chiang Mai	**Conventional**	**PBN**
Runway 18	VOR circling approach with high circling OCA/H	Runway aligned approach