



Performance based navigation: The ICAO PBN programme

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Overview

- Background
- PBN concept and goals
- PBN navigation specifications
- Status of ICAO PBN reference documents
- PBN flight inspection and validation
- ICAO PBN implementation activities



Background

- ICAO PBN concept = evolution of the ICAO RNP concept
- RNP concept: FANS Committee / RGCS panel (late '80s)
- Manual on Required Navigation Performance (Doc 9613)
 - RNAV: A method of navigation that permits aircraft operation on any desired flight path
 - RNP: A statement of the navigation performance accuracy necessary for operation within a defined airspace



What went wrong?

- The RNP Manual addressed only the en-route phase of flight for oceanic and remote applications
- No specific requirements for continental en-route and terminal applications
- High-level concept only
- Consequences:
 - proliferation of national standards / functional requirements
 - variety of required navigation sensors for the same RNP type
 - differing air crew requirements
 - emerging industry concepts of RNP not addressed
- In other words:
 - the same RNP type means different things in different airspaces

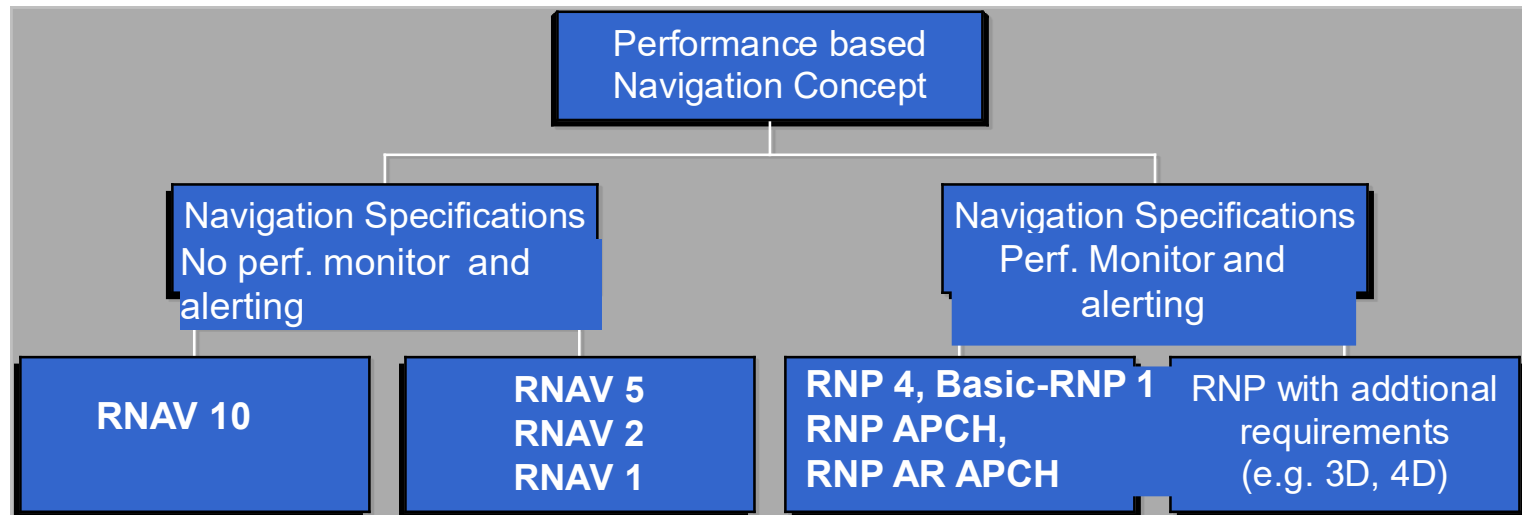


How do we fix it?

- GNSS Panel raises the issue in ICAO (May 2003)
- 11th ICAO Air Navigation Conference (September 2003) recognizes the "urgent need for global harmonization of PBN concepts and requirements"
- ICAO Study Group created (RNPSORSG)
 - to harmonize existing RNAV and RNP operations and to cater for future operational demands
 - by defining global detailed navigation specifications, addressing all system aspects including:
 - Performance required for accuracy, integrity, continuity and availability
 - Functionalities necessary to achieve required performance
 - Navigation sensors to achieve required performance
 - Flight crew procedures to achieve required performance
 - Clear operational approval requirements and implementation guidance



The PBN concept



PBN: Area navigation based on performance requirements described in navigation specifications



On-board performance monitoring and alerting

- **A monitoring function**

- Performed by the aircraft (or aircraft and pilot in combination)
- Monitors total system error (TSE)
- TSE = root square sum of (PDE, FTE, NSE)
 - PDE: Path definition error
 - FTE: Flight technical error
 - NSE: Navigation system error

- **An alerting function**

- Alerts when:
 - TSE requirement is not met; or if
 - probability that TSE exceeds 2x accuracy value is larger than 10^{-5}



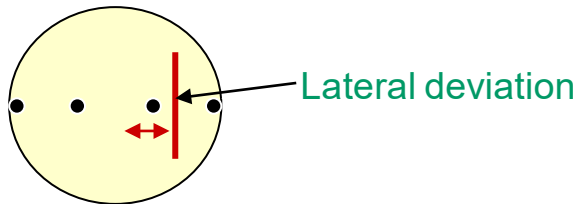
Example of O-B monitoring and alerting

NSE Monitoring and Alerting



Alerting Threshold: (1x accuracy) Nm
Pb missed alerting: 10-7/FI Hr

FTE Monitoring and Alerting



Crew procedure based on display scaling
Effective threshold: $\frac{1}{2}$ full scale deflection
Pb missed alerting: not quantified. Crew procedure.

PDE Monitoring and Alerting

Based on Data quality process

- LOA or equivalent
- Gross error check: Crew procedure

TSE monitoring and alerting

All error components monitored or controlled



PBN Manual

(Doc 9613, 3rd edition)

- Provides guidance to States on how to implement RNAV and RNP in their airspace
- **Volume I**
 - Part A – The PBN concept
 - Part B – Implementation guidance
- **Volume II**
 - Part A – General
 - Part B – Implementing RNAV (Navigation Specifications)
 - Part C – Implementing RNP (Navigation Specifications)
- Final draft available at <http://www.icao.int/pbn/>



Structure of a navigation specification chapter of the PBN Manual

- **X.1 Introduction**
- **X.2 ANSP Considerations**
- **X.3 Navigation Specification**
- **X.4 References**

(where “X” is the chapter number in Vol. II, Part B and C)



Section X.2 - ANSP considerations

- **Nav aids infrastructure**
- **Communication and ATS surveillance**
- **Obstacle clearance and route spacing**
- **Publication**
- **Controller training**
- **Status monitoring**
- **ATS system monitoring**



Section X.3 - Navigation specification

- **X.3.1** **Background**
- **X.3.2** **Approval process**
- **X.3.3** **Aircraft requirements**
- **X.3.4** **Operating procedures**
- **X.3.5** **Pilot knowledge and training**
- **X.3.6** **Navigation database**
- **X.3.7** **Oversight of operators**



Navigation specification vs Flight Phase

NAVIGATION SPECIFICATION	FLIGHT PHASE							
	En Route Oceanic / Remote	En Route Continental	ARR	APPROACH				DEP
				Initial	Intermed	Final	Missed	
RNAV 10 (RNP 10)	10							
RNAV 5		5	5					
RNAV 2		2	2					2
RNAV 1		1	1	1	1		1	1
RNP 4	4							
Basic-RNP 1			1	1	1		1	1
RNP APCH				1	1	0.3	1	
RNP AR APCH				1 - 0.1	1 - 0.1	0.3 - 0.1	1 - 0.1	



Relationship with existing specifications

- **Do not reinvent the wheel**
- **Use existing specifications e.g., Orders, ACs, AMC, TGL etc.**
- **A more logical structure**
- **Common format and content**
- **More complete to enable uniform implementation**



Status of ICAO PBN reference documents

- Final draft of PBN manual available
 - March 2007
- State Letter with Navigation Specifications sent
 - 27 April 2007
- Assembly Resolution 36-23 endorsed by the 36th ICAO Assembly
 - September 2007



Implementation goals in A36-23

- States and/or regions develop an **implementation plan** by 2009 to achieve the following goals:
 - *implementation of PBN operations (where required) for en-route and terminal areas according to established timelines/milestones;*
 - *Implementation of approach procedure with vertical guidance (APV), for all instrument runway ends, either as the primary approach or as a back-up for precision approaches by **2016**;*
 - *States are encouraged to include in the plan provisions for implementation of APV' to all runway ends serving aircraft in excess of 5700 kg.*
- **Shared responsibility of ICAO, Regions, States and stakeholders**



Status of ICAO PBN reference documents

- ICAO RNP AR Procedure Design Manual (Doc 9905)
 - Final draft: March 2008
- ICAO Quality Assurance Manual for Flight Procedure Design (Doc 9906) (three volumes)
 - Final draft: March 2008
- Also on the PBN Web Site www.icao.int/pbn:
 - State implementation plan template
 - Implementation checklist
 - PBN approach and terminal implementation status
 - Guidance and information from States and International organizations on a variety of PBN-related issues



Status of ICAO PBN reference documents

- **Flight plan provisions: PANS-ATM (Doc 4444)**
 - Nov 2008
- **Flight procedure design requirements: PANS-OPS (Doc 8168)**
 - November 2008
- **PBN terminology changes to Annexes**
 - Annex 2, 6, 10, 11: 2008
 - Annex 4 and 15: 2009
 - Annex 3: 2010



Status of ICAO PBN reference documents

Web Based Training

Available on
www.icao.int/pbn

A screenshot of a web browser displaying the ICAO Performance Based Navigation (PBN) training module. The browser window title is 'PERFORMANCE BASED NAVIGATION (PBN) - Microsoft Internet Explorer provided by ICAO ICT'. The address bar shows the URL 'http://www.ecacnav.com/test/pbn-training/pbn/frames/firstwin.htm'. The page content includes a navigation menu with tabs for 'General Introduction', 'Introduction to PBN', 'Concepts of PBN', 'Summary/Aims', and 'Area Navigation'. The main content area is titled 'ABOUT THIS TRAINING MODULE:' and contains text about the module's purpose and structure. A 'Module structure:' section lists four main topics. Below this is a 'Moving through the topics:' section. The page also features a 'TOPIC TABS' section with a diagram showing the navigation flow, a 'TEXT AREA' with instructions, a 'GRAPHICS & ACTIVITY AREA' with a progress indicator, and a 'GLOSSARY' section. The browser's status bar shows 'Page 1 of 3' and the time '16:34'.



ICAO guidance documents on PBN procedures inspection/validation

**Doc 8168 *PANS OPS*, Vol II
Part 1, Section 2, Chapter 4 “*Quality Assurance*”**

**Doc 8071 *Manual for the Testing of Radio Navigation Aids*
Volume 2, Chapter 5**

“*Navigation infrastructure assessment in support of PBN*”

www.icao.int/pbn (under “*Documentation*”)



PBN procedure flight inspection

PANS OPS, Vol II Part 1, Section 2, Chapter 4 “Quality Assurance”

4.6.3.2 “Flight validation should not be confused with flight inspection. Flight inspection of instrument flight procedures is required to assure that the appropriate radio navigation aids adequately support the procedure. This is carried out as part of a formal flight inspection programme and is performed by a qualified flight inspector using an appropriately equipped aircraft.”





PBN flight inspection

- Example: PBN DME/DME RNAV 1/2 flight inspection
 - Review existing FI records, note specific issues
 - If sufficient recent records available, all or part of FI can be omitted
 - Prepare list of DME to be inspected
 - Perform FI to confirm signal in space compliance with Annex 10
 - verify coverage availability and accuracy of individual DME facilities (e.g. check for reflections and shading at lower altitudes)
 - FI equipment recommended: capability to record multiple DME signals simultaneously
 - Assess FI report to confirm assumptions of initial assessment and identify DME facilities that degrade the navigation solution
- Example: GPS / ABAS flight inspection
 - Verify adequate signal reception for specific procedure
 - Test for unintentional interference



PBN procedure validation as an element of quality assurance

- Quality assurance is needed in each step of the procedure design process to ensure:
 - Necessary levels of accuracy and integrity in data quality
 - Compliance with design criteria
 - Adequate mitigations in place if portions of criteria are waived
- Procedure validation:
 - Ground validation
 - Flight validation
 - Database validation



Ground validation (1)

PANS OPS, Vol II Part 1, Section 2, Chapter 4 “Quality Assurance”

4.6.2. Ground validation is a review of the entire instrument flight procedure package by a **person(s) trained in procedure design and with appropriate knowledge of flight validation issues.**

- It is meant to catch errors in criteria and documentation, and evaluate on the ground, to the extent possible, those elements that will be evaluated in a flight validation.
- ...The ground validation will also determine if flight validation is needed for modifications and amendments to previously published procedures.



Ground validation (2)

- Obstacle verification
 - Independent review by procedure designer
- Data verification
 - Independent review of source data
- Charting
 - Independent review
- Coding
 - Software tool or
 - Expert review
- Flyability – software tools (from PC-based to full flight simulator)
 - Not necessarily an issue with standard procedures (e.g. 'T' approaches), but critical for some aircraft types
 - Range of aircraft and meteo conditions



Flight validation (1)

PANS OPS, Vol II Part 1, Section 2, Chapter 4 “Quality Assurance”

4.6.3.1 ... The objectives of the flight validation of instrument flight procedures

- a) provide assurance that adequate obstacle clearance has been provided;
- b) verify that the navigation data to be published, as well as that used in the design of the procedure, is correct;
- c) verify that all required infrastructure, such as runway markings, lighting, and communications and navigation sources, are in place and operative;
- d) conduct an assessment of flyability to determine that the procedure can be safely flown; and
- e) evaluate the charting, required infrastructure, visibility and other operational factors



Flight validation (2)

- Obstacle verification
 - Required where complete survey of all obstacles and terrain in all segments cannot be accomplished
- Data verification-verify that the navigation data to be published, as well as that used in the design of the procedure, is correct;
 - e.g. does procedure arrive at the intended aiming point?
- Flyability
 - Detailed workload and charting assessments, but
 - High level qualitative assessment of manoeuvring only (rely mainly on Ground Validation)
- Infrastructure assessment
 - Runway markings, lighting, communications, navigation, etc



Database validation

- RNAV procedures coded using ARINC 424 path terminators to define specific nominal tracks
- Coded procedures not available in operational databases until effective date
 - Recommend implementation date 3 to 10 days after effective date, especially for new procedures in high density traffic areas
- Test databases may be provided for ground (simulator) and flight validation
- Flight validation does not validate integrity of procedure subsequently coded in operational database
- Operator responsible for validating the operational database

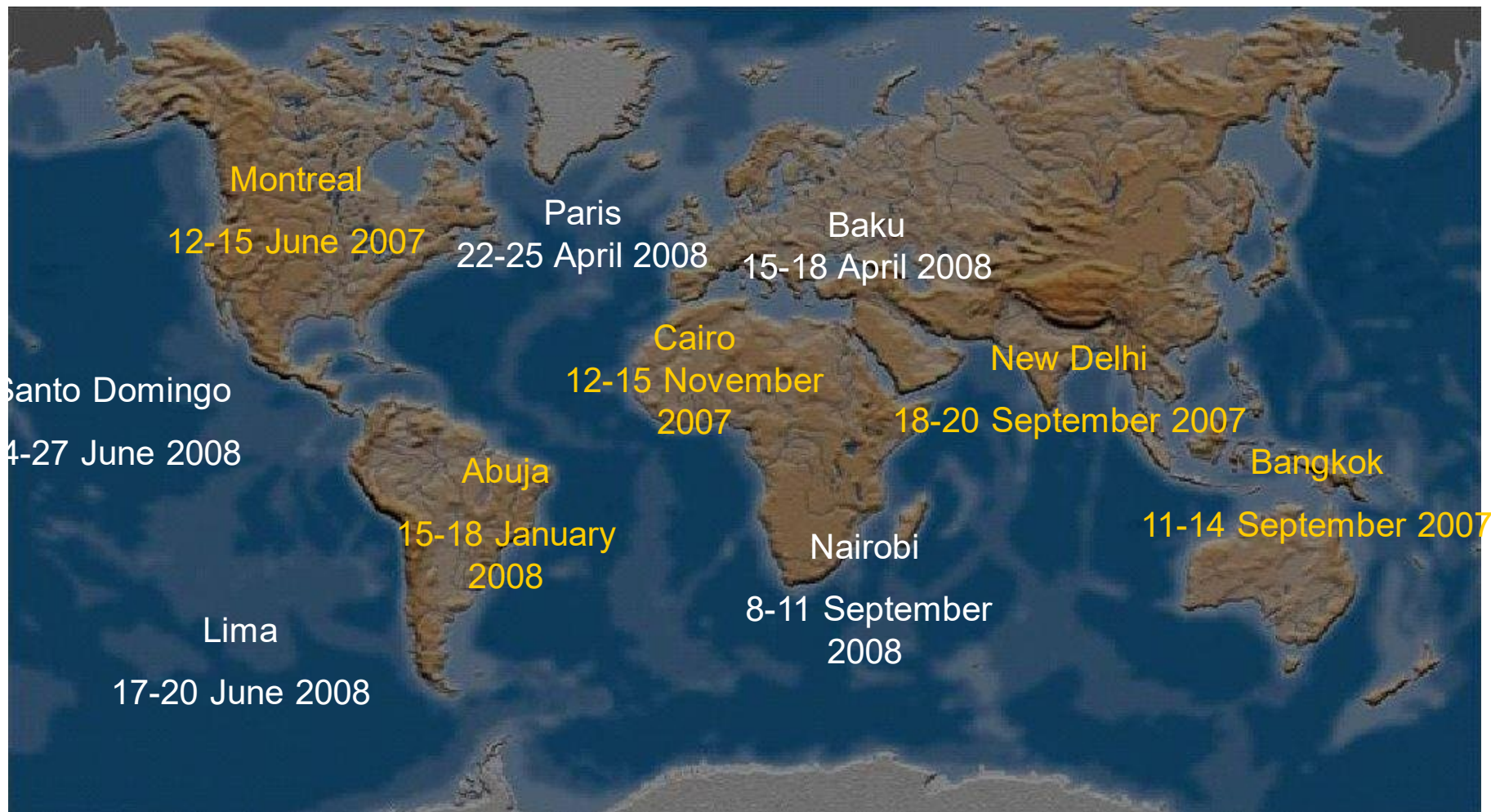


Implementation role: ICAO

- **Familiarization (PBN seminars)**
 - **States, Stakeholders, ICAO**
- **Implementation**
 - **Planning assistance** (Regional
 - **Execution assistance** PBN Task Forces)
 - **Verification**
- **Development and maintenance of ICAO provisions and coordination with industry**



Familiarization tools: “Introduction to PBN” Seminars





Implementation role: States

- Participate in development of Regional PBN implementation plan
- Develop National PBN implementation plan by the end of 2009
- Provide focal point for PBN implementation
- Lead and coordinate PBN implementation with other stakeholders, including ANSPs, operators, aerodromes, regulators, interest groups, in
- Identify issues or showstoppers (e.g. WGS 84) that could delay implementation, mitigate and relay to ICAO



State PBN Implementation Plan

- To describe the RNAV and RNP navigation applications that should be implemented in at least the short and medium term, in the State for specified routes, SID, STAR, approaches
- To address the planned transition to PBN, as one of the key systems supporting air traffic management to provide proper guidance and direction to the domestic air navigation service provider(s), airspace operators and users, regulating agency, as well as foreign operators who operate or plan to operate in the State
 - Assist the main stakeholders plan a gradual transition to the RNAV and RNP concepts
 - Assist the stakeholders in planning their investment strategies during the future transition



Implementation role: other stakeholders

- **Cooperate** with States in their planning and implementation
- **Commit** the resources necessary to carry out their part of the strategy for regional and State implementation



Conclusion

- PBN concept has been established as a step in the evolution of a performance-based global air traffic management (ATM) system
- ICAO is fully committed to PBN implementation
- Commitment and active involvement in implementation is required from States and other stakeholders



Thank you for your attention!