ICAO APAC Webinars – Fundamentals of ANS

Performance Based Navigation(PBN)

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Regional Officer, PBN

About Me

- Joint General Manager (Flight Procedure Design) in Airports Authority of India.
- Last 18 Years in Flight procedure Design.
- Designed and Implemented many Conventional as well as PBN SIDs/STARs and Approach Procedures.
- Senior PANS-OPS Instructor.
- Background as an Air traffic Controller and OJT Radar Instructor.
- Appointed as Regional Officer, PBN, ICAO APAC RSO w.e.f. 1st June 2020. Yet to join due to COVID-19 situation.

Objectives

- To improve understanding:
  - Fundamental knowledge of PBN
  - ICAO requirements
  - Regional planning
  - Implementation activities

Agenda

- Basics of PBN
- Regional requirements
- What ICAO can offer
- Q&A session

BASICS OF PBN

What is PBN?

❖ **PBN stands for "Performance Based Navigation".**

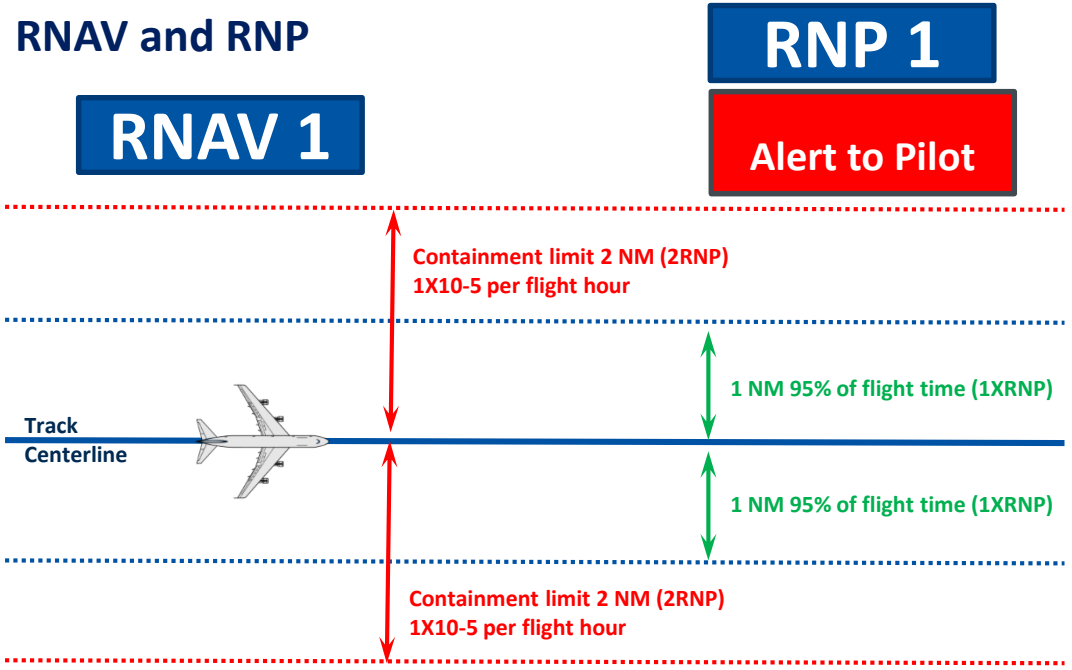
PBN is Navigation based on specified system performance requirements for aircraft operating on an air traffic route, instrument approach procedure, or in a designated airspace.

➢ **Comprises of RNAV and RNP**

- **RNAV –** Area Navigation
- **RNP -** Area Navigation with on-board performance monitoring and Alerting(**OPMA**) requirement.

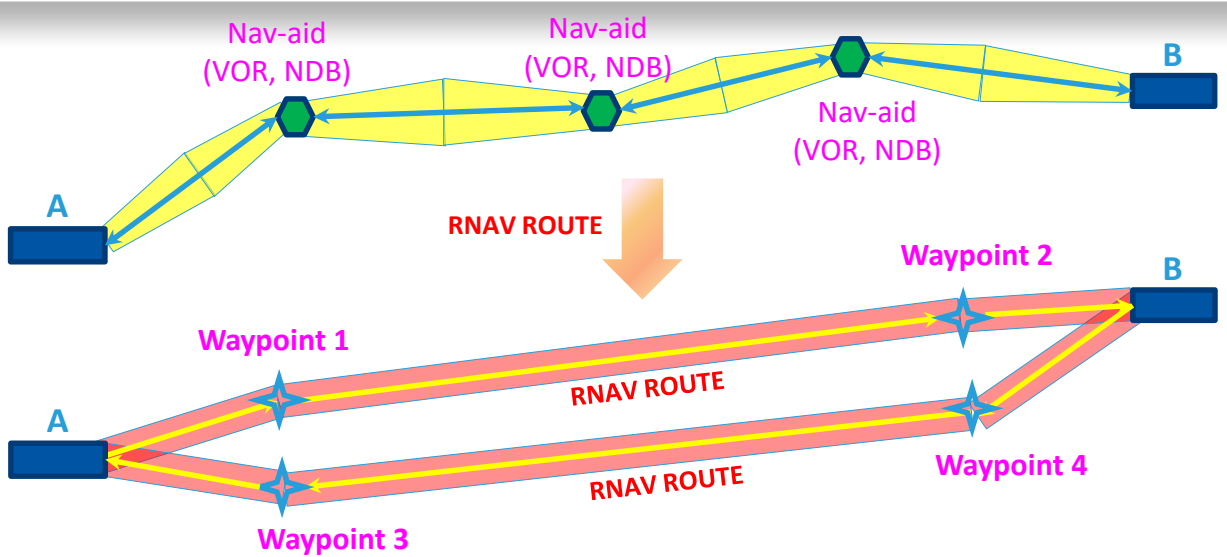
Navigation Specification

❖ **RNAV and RNP**



The Key Difference : On-Board Performance Monitoring and Alerting (OPMA)

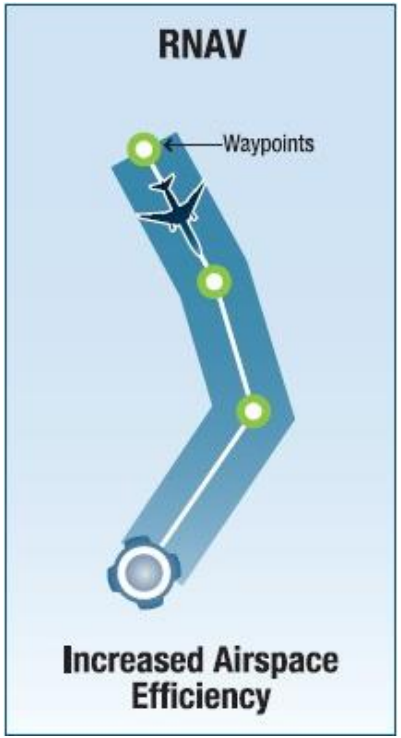
Area Navigation (RNAV)

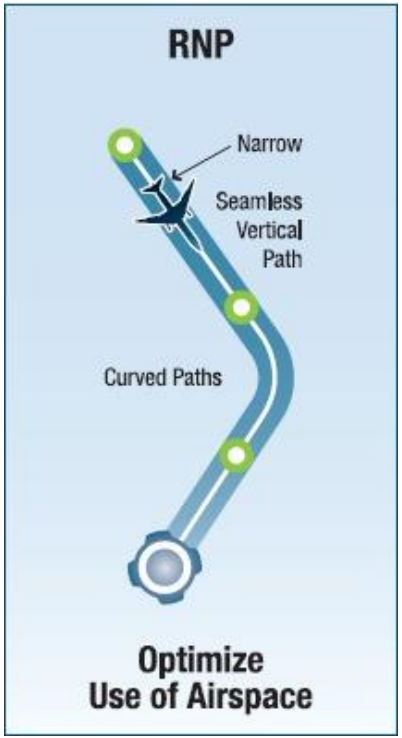


- Area Navigation (RNAV) is a method of navigation which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within limits of the capability of self-contained aids or a combination of these.

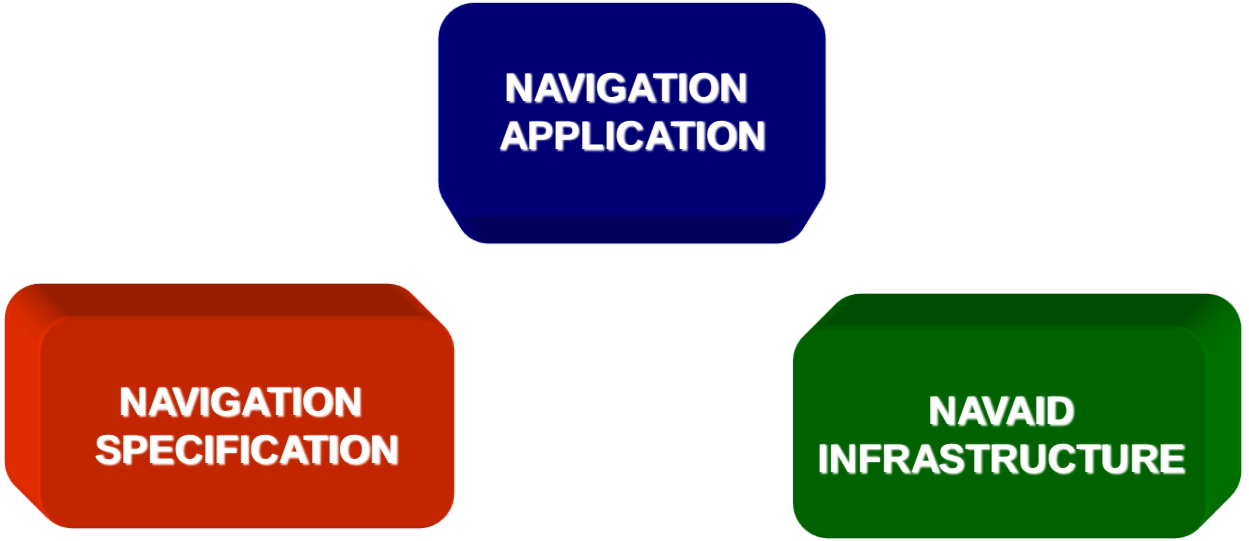
- RNAV allows for shorter and straighter route, increased capacity due to closely spaced routes and reduced obstacle protection area.

Conventional, RNAV & RNP





Components of PBN Concept
(ICAO PBN Manual Doc 9613)



Navigation Infrastructure

- Ground-based Navigation Aids
  - VOR-DME, DME-DME, (Not NDB)
- Space-based
  - GNSS
- Airborne
  - INS/IRS

NAVAID INFRASTRUCTURE

GNSS Satellite constellations

- GPS
- Glonass
- Galileo
- Beidou

Several types of errors :

- Satellite clock & ephemeris
- Ionosphere
- Troposphere

And integrity

Augmentations

GPS

Glonass

Galileo

Beidou

Three types of augmentations

ABAS 

Aircraft Based Augmentation System

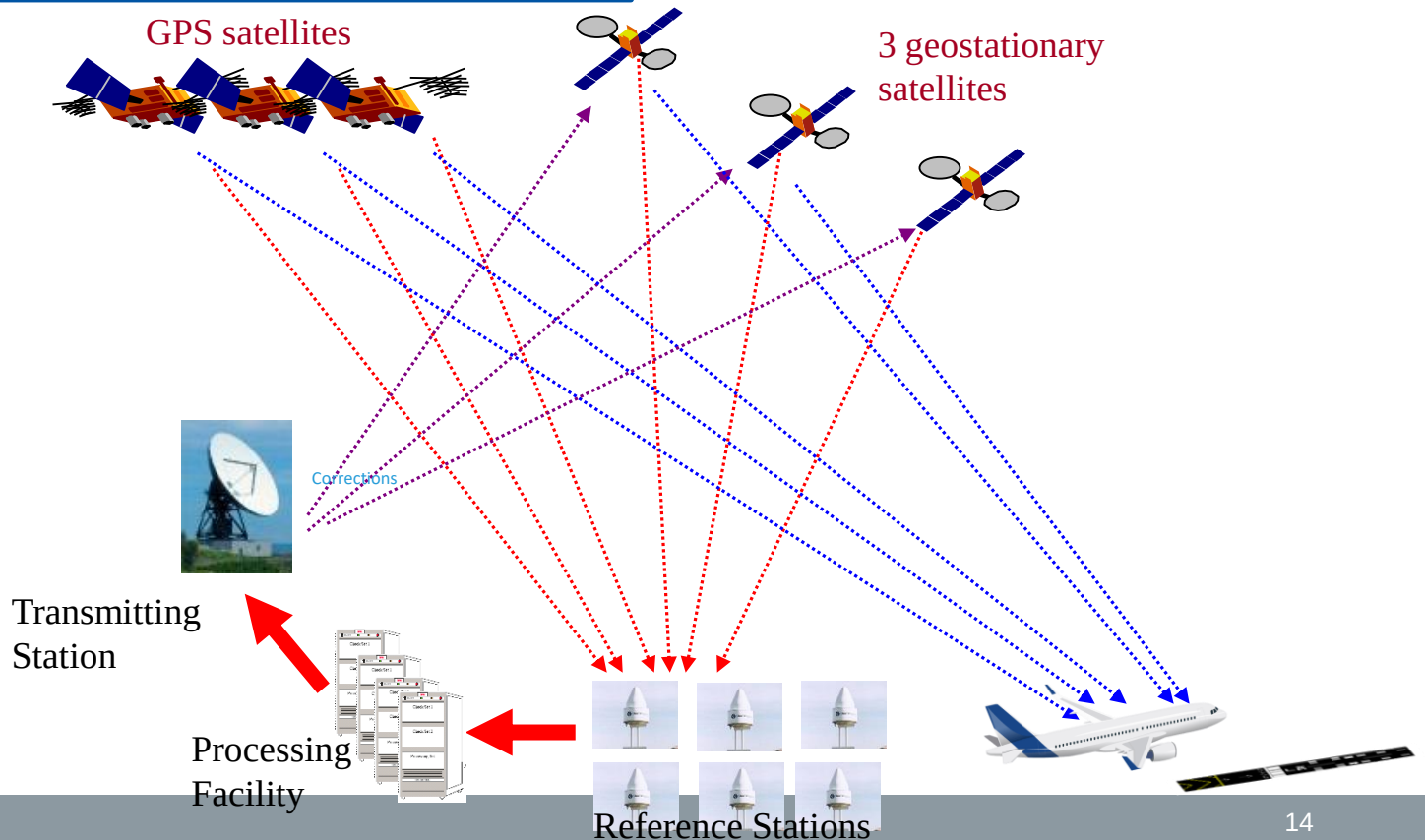
GBAS 

Ground Based Augmentation System

SBAS 

Satellite Based Augmentation System

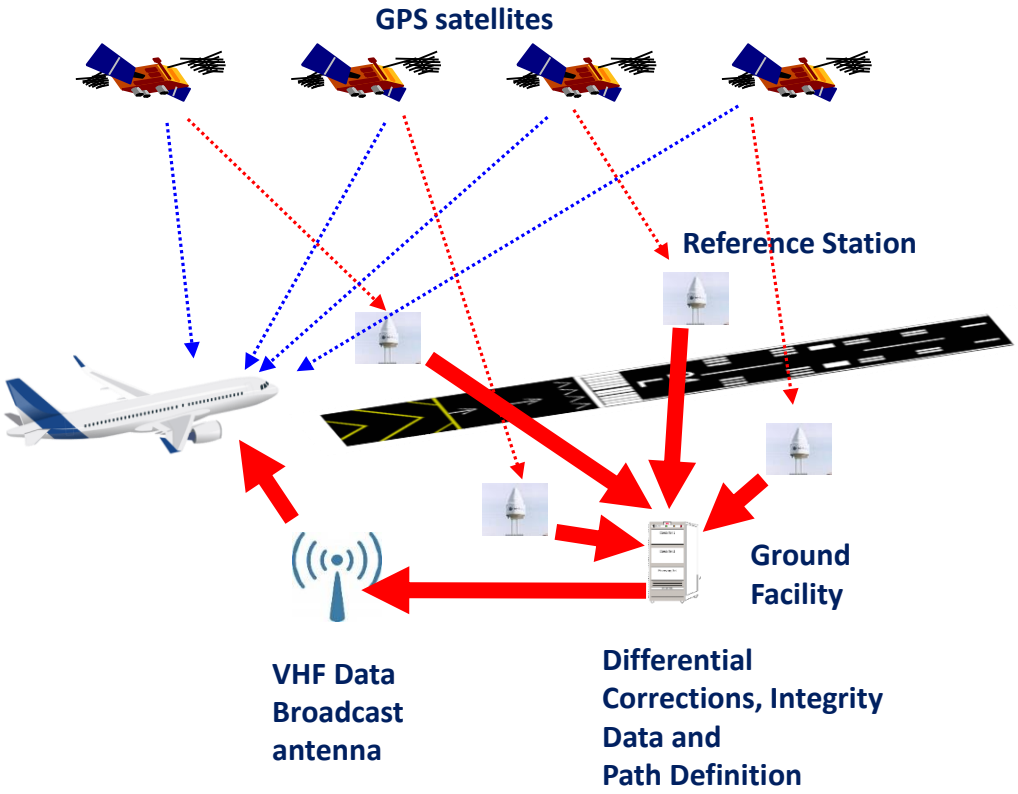
SBAS architecture



Navigation Infrastructure

➢ GBAS Structure

- Coverage : about 23NM from the transmitter
- Precision : CAT I, CAT II&III



GBAS / SBAS expected benefits

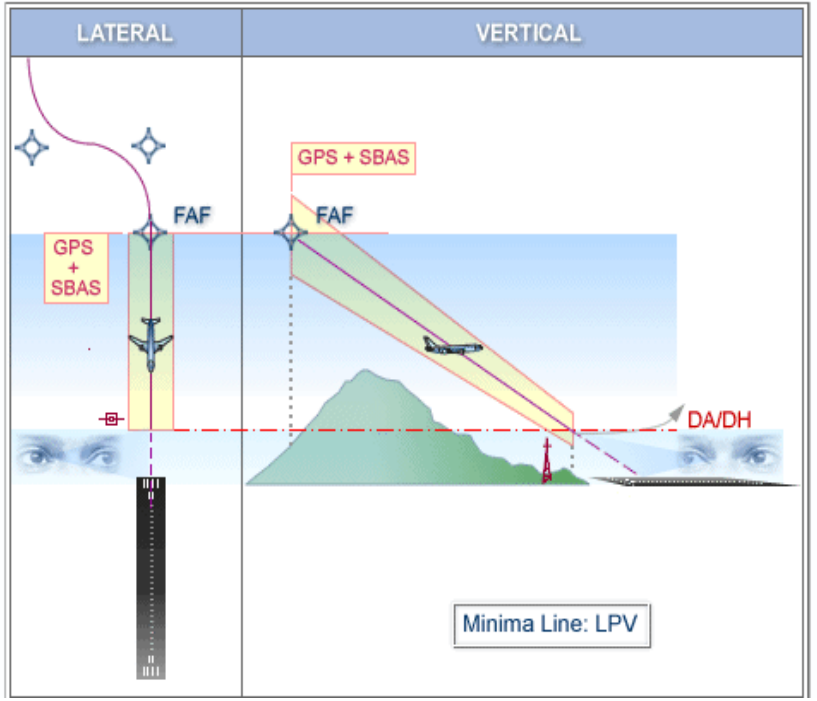
- Main benefit on the final segment

Horizontal and Vertical geometric guidance

ILS like display in the cockpit

with a Decision Altitude / Height

Independent of QNH setting and of temperature



GBAS / SBAS expected benefits

- Can bring operations
  - SBAS : down to CAT I (**APV 250 ft and SBAS CAT I 200 ft**)
  - GBAS : CAT I to CAT III (special study for Ionosphere)
- Can serve
  - SBAS : All IFR runway ends on a whole continent
  - GBAS : All IFR runway ends at the same airport

Navigation Infrastructure

❖ Signal-in-space performance requirements (Annex 10)

Typical operation	Accuracy horizontal 95% (Notes 1 and 3)	Accuracy vertical 95% (Notes 1 and 3)	Integrity (Note 2)	Time-to-alert (Note 3)	Continuity (Note 4)	Availability (Note 5)
En-route	3.7 km (2.0 NM)	N/A	$1 - 1 \times 10^{-7}$/h	5 min	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
En-route, Terminal	0.74 km (0.4 NM)	N/A	$1 - 1 \times 10^{-7}$/h	15 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
Initial approach, Intermediate approach, Non-precision approach (NPA), Departure	220 m (720 ft)	N/A	$1 - 1 \times 10^{-7}$/h	10 s	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 0.99999
Approach operations with vertical guidance (APV-I)	16.0 m (52 ft)	20 m (66 ft)	$1 - 2 \times 10^{-7}$ in any approach	10 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Approach operations with vertical guidance (APV-II)	16.0 m (52 ft)	8.0 m (26 ft)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999
Category I precision approach (Note 7)	16.0 m (52 ft)	6.0 m to 4.0 m (20 ft to 13 ft) (Note 6)	$1 - 2 \times 10^{-7}$ in any approach	6 s	$1 - 8 \times 10^{-6}$ per 15 s	0.99 to 0.99999

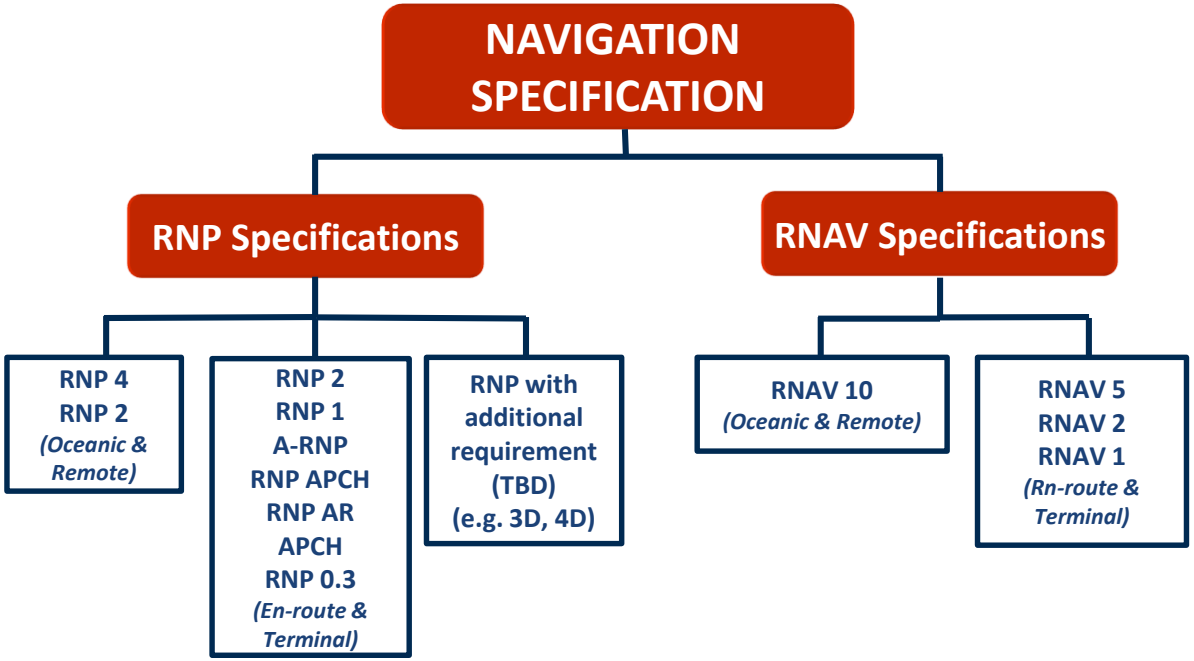
NOTES.—

1. The 95th percentile values for GNSS position errors are those required for the intended operation at the lowest height above threshold (HAT), if applicable. Detailed requirements are specified in Appendix B and guidance material is given in Attachment D, 3.2.
2. The definition of the integrity requirement includes an alert limit against which the requirement can be assessed. For Category I precision approach, a vertical alert limit (VAL) greater than 10 m for a specific system design may only be used if a system-specific safety analysis has been completed. Further guidance on the alert limits is provided in Attachment D, 3.3.6 to 3.3.10. These alert limits are:

Navigation Infrastructure

- **Future GNSS environment**
  - **Use of dual-frequency multi-constellations (DFMC)**
    - **Improve GNSS performance and robustness**
    - **Reduce the susceptibility to interference**
  - **DFMC GNSS could start in the 2025-2028 timeframe.**

Navigation Specification (ICAO PBN Manual Doc 9613)



Navigation Specification (PBN Manual, Doc 9613)

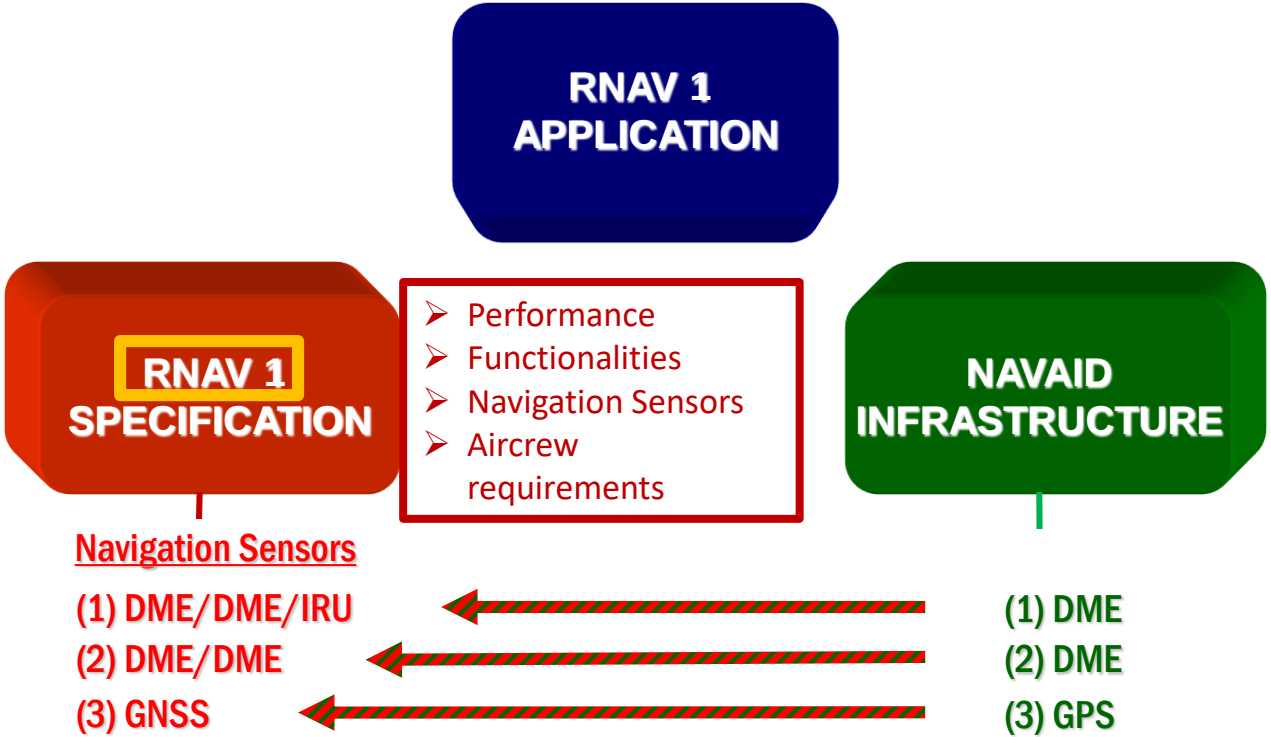
Doc 9613 Part / Chapter	Navigation Specification	Flight phase							
		En-route oceanic/remote	En-route continental	Arrival	Approach				DEP
					Initial	Intermediate	Final	Missed[1]	
B Ch.1	RNAV 10	10							
B Ch.2	RNAV 5[2]		5	5					
B Ch.3	RNAV 2		2	2					2
B Ch.3	RNAV 1		1	1	1	1		1	1
C Ch.1	RNP 4	4							
C Ch.2	RNP 2	2	2						
C Ch.3	RNP 1[3]			1	1	1		1	1
C Ch.4	Advanced RNP[4]	2[5]	2 or 1	1	1	1	0.3	1	1
C Ch.5	RNP APCH[6]				1	1	0.3[7]	1	
C Ch.6	RNP AR APCH				1-0.1	1-0.1	0.3-0.1	1-0.1	
C Ch.7	RNP 0.3[8]		0.3	0.3	0.3	0.3		0.3	0.3

Navigation Application

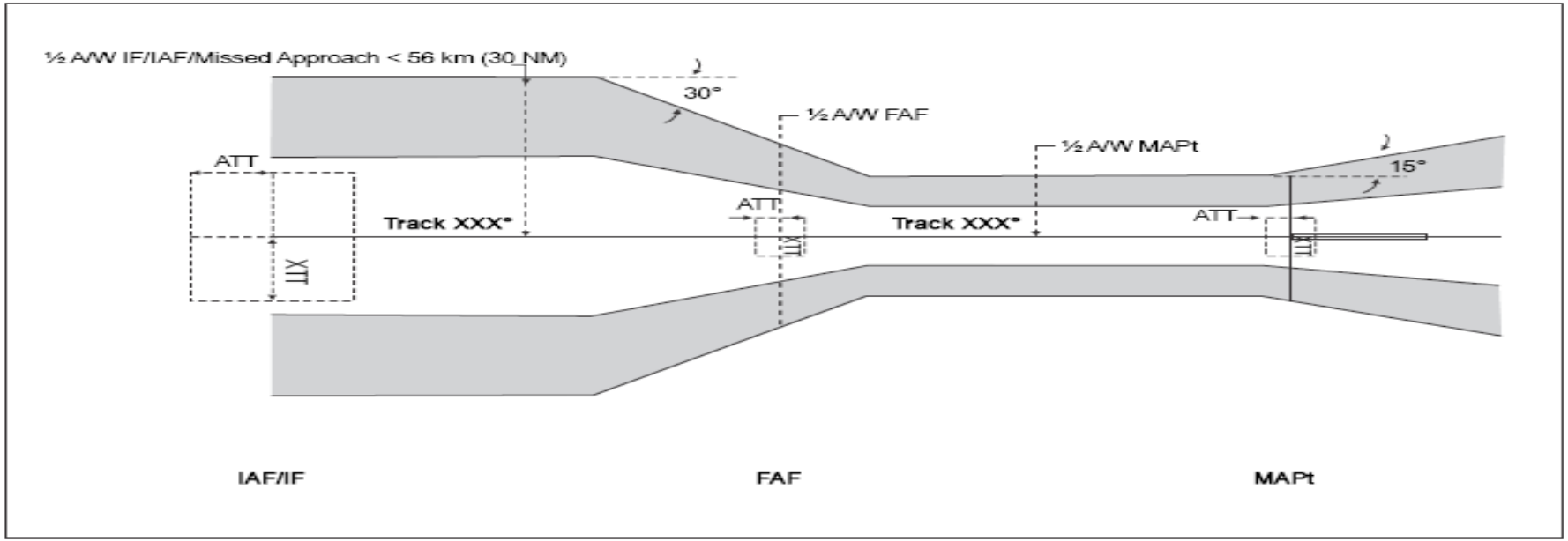
❖ Navigation Specification vs. Navigation Infrastructure

	GNSS	IRU	DME/DME	DME/DME/IRU	VOR/DME
RNAV-10	X	X			
RNAV-5	X	X	X	X	X
RNAV -1 and RNAV -2	X		X	X	
RNP-4	X				
RNP-2	X				
RNP-1	X				
Advanced RNP	X				
RNP APCH	X				
RNP AR APCH	X				
RNP 0.3	X				

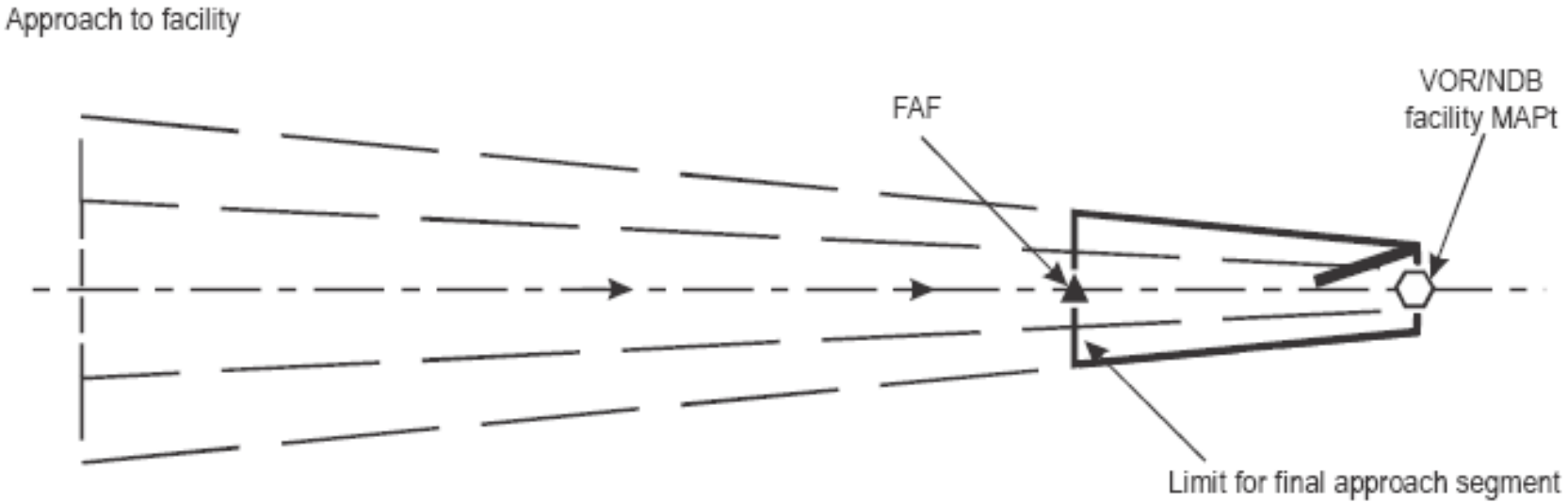
Example : RNAV1 Application



RNP APCH protection Area (ICAO Doc 8168 Vol-II)



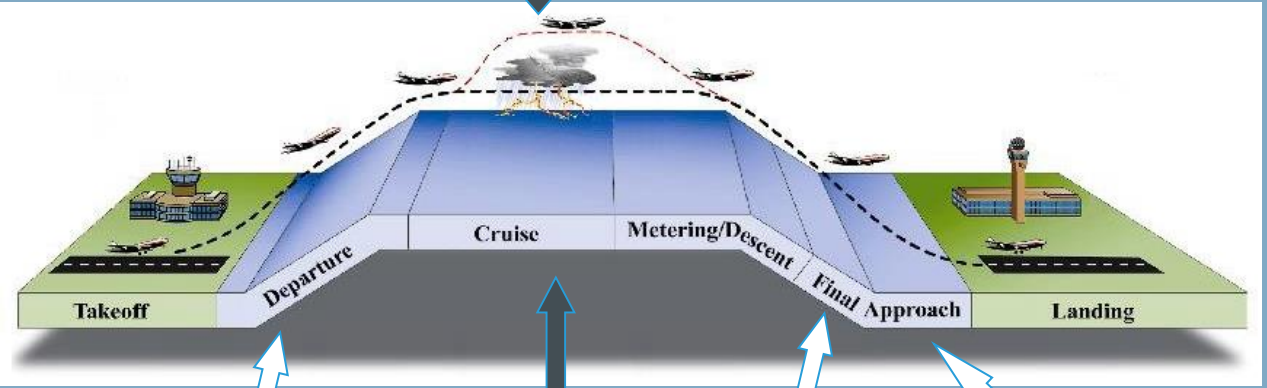
VOR/NDB protection Area (ICAO Doc 8168 Vol-II)



Navigation Application

OCEANIC / Enroute Remote (nonSUR)

RNAV 10, RNP 4, RNP 2, A-RNP(2)

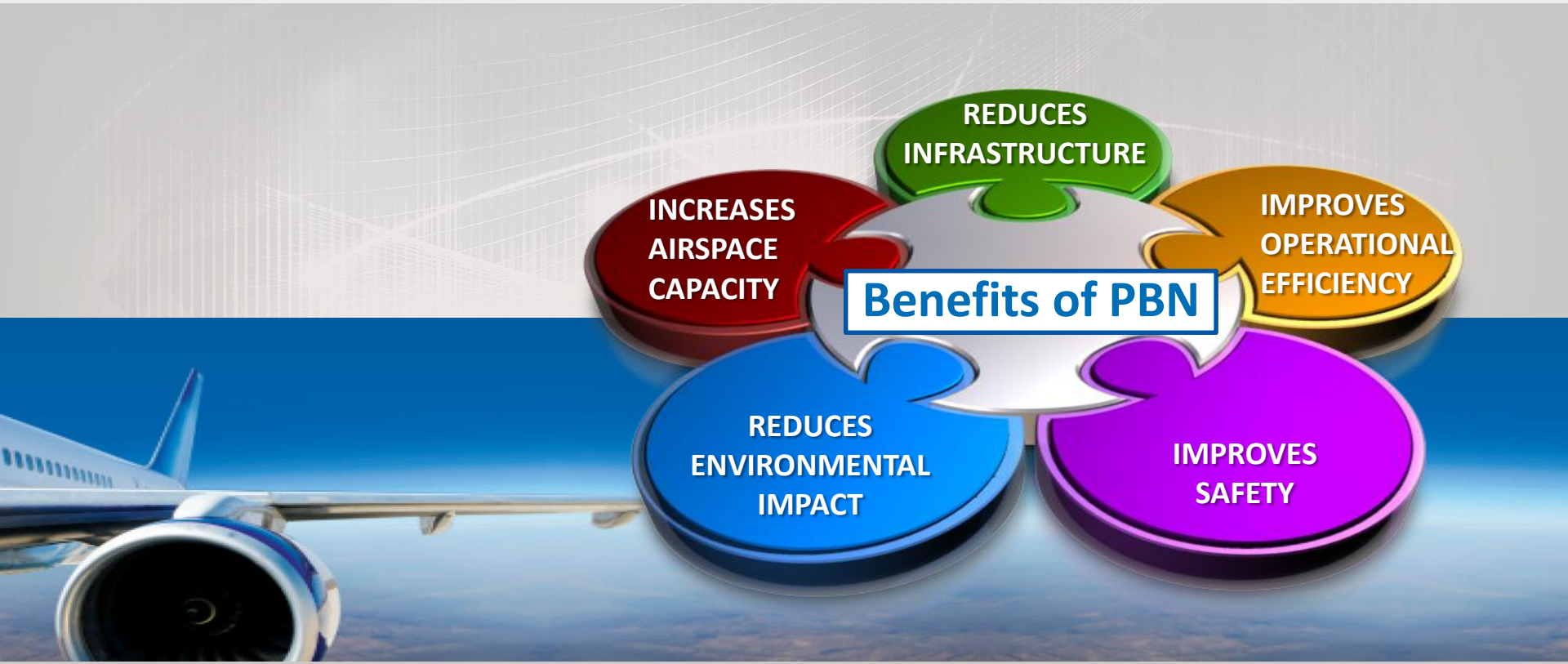


RNAV 1/2 &
RNP 1 SIDs
A-RNP(1) SIDs

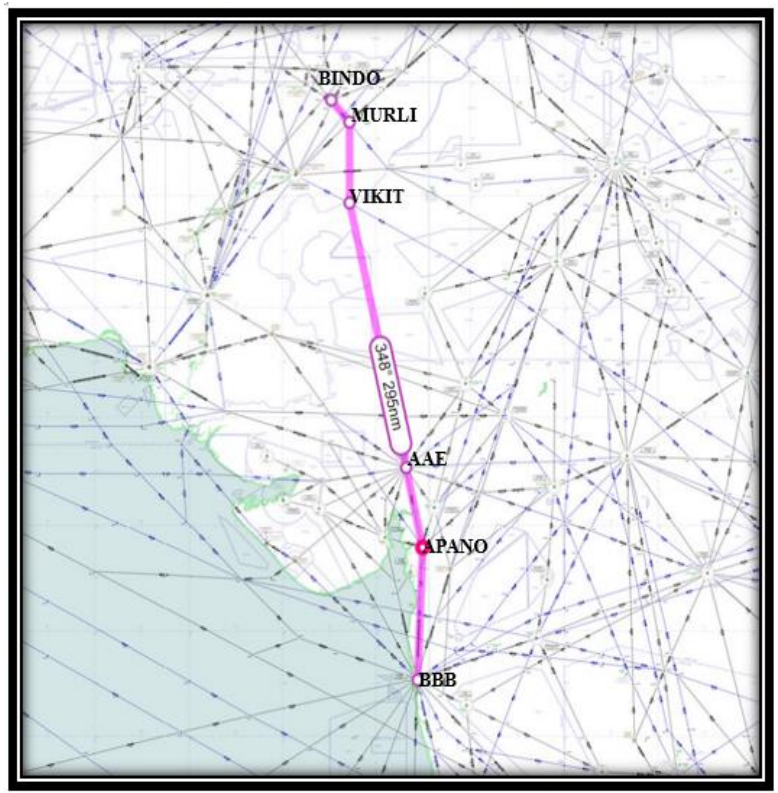
RNAV 5/2/1
RNP 2
A-RNP(2, 1)
En-route Continental

RNAV 1/2 &
RNP 1 STARs
A-RNP(1) STARs

RNP APCH
A-RNP(0.3, 1)
RNP-AR APCH


REDUCES INFRASTRUCTURE
INCREASES AIRSPACE CAPACITY
IMPROVES OPERATIONAL EFFICIENCY
Benefits of PBN
REDUCES ENVIRONMENTAL IMPACT
IMPROVES SAFETY

IND 08 of Asia/Pacific Region ATS Route Catalogue



This route proposal was requested by IATA with potential city-pair between Mumbai and North America.

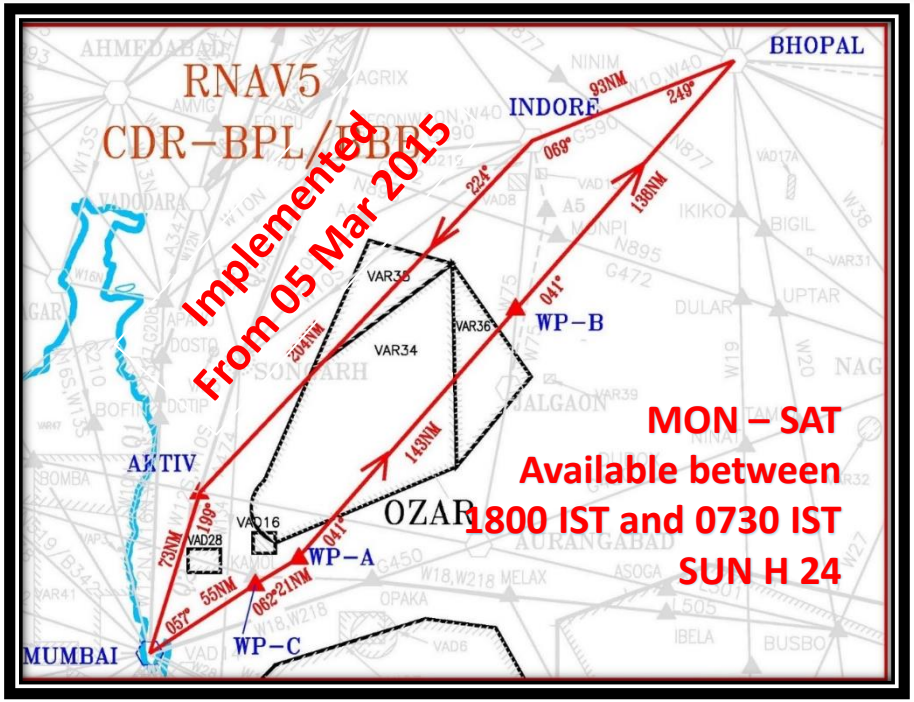
Expected benefits/savings per flight:

- 67 NM (equivalent to approximately 10 minutes).
- 700 kg of fuel.
- 2,205 kg of CO_2 emissions.

Expected benefits/savings annually:

- 72,800 kg of fuel.
- 229,330 kg of CO_2 emissions.

Benefits of PBN

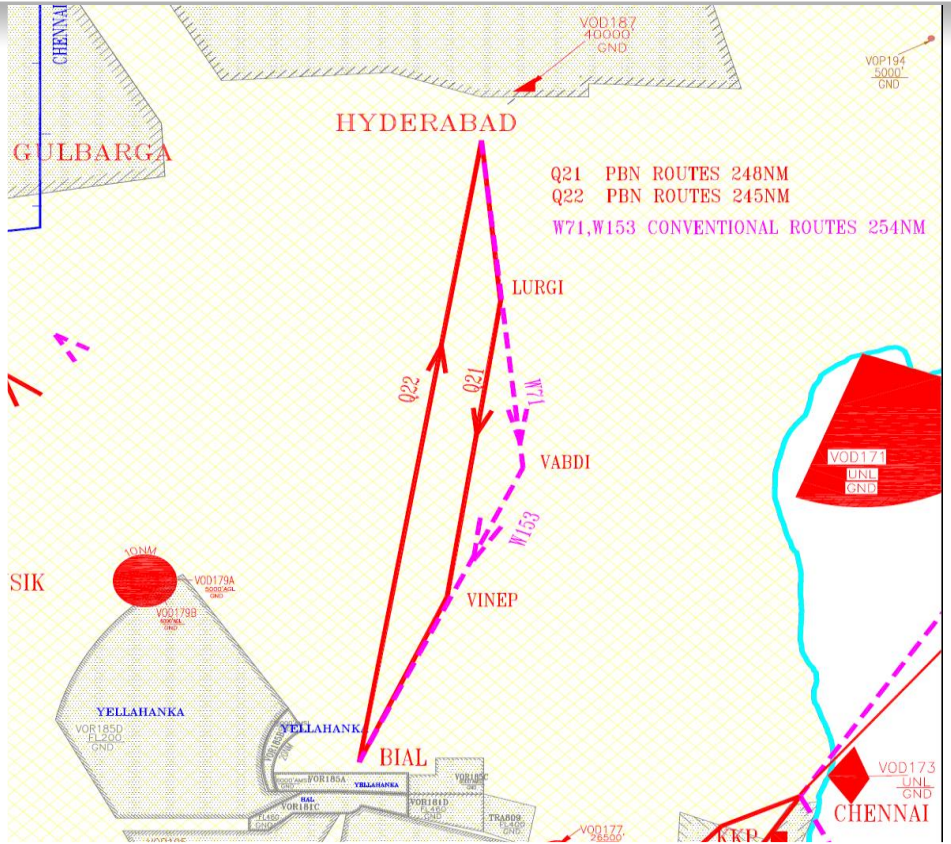


Jet airways : Annual Savings INR 18 m
Indigo : Annual Savings INR 22 m

CDR 1 : Mumbai – Bhopal (RNAV5 Q16/17)

Previous Routing	W10S	W10N
Route Distance	378 NM	422NM
CDR Route Distance	370 NM	357NM
No. of Flights Per Annum	**469**	**469**
Reduction in Route Distance - Flying Time	8 NM 1 min’	65NM 9 min’

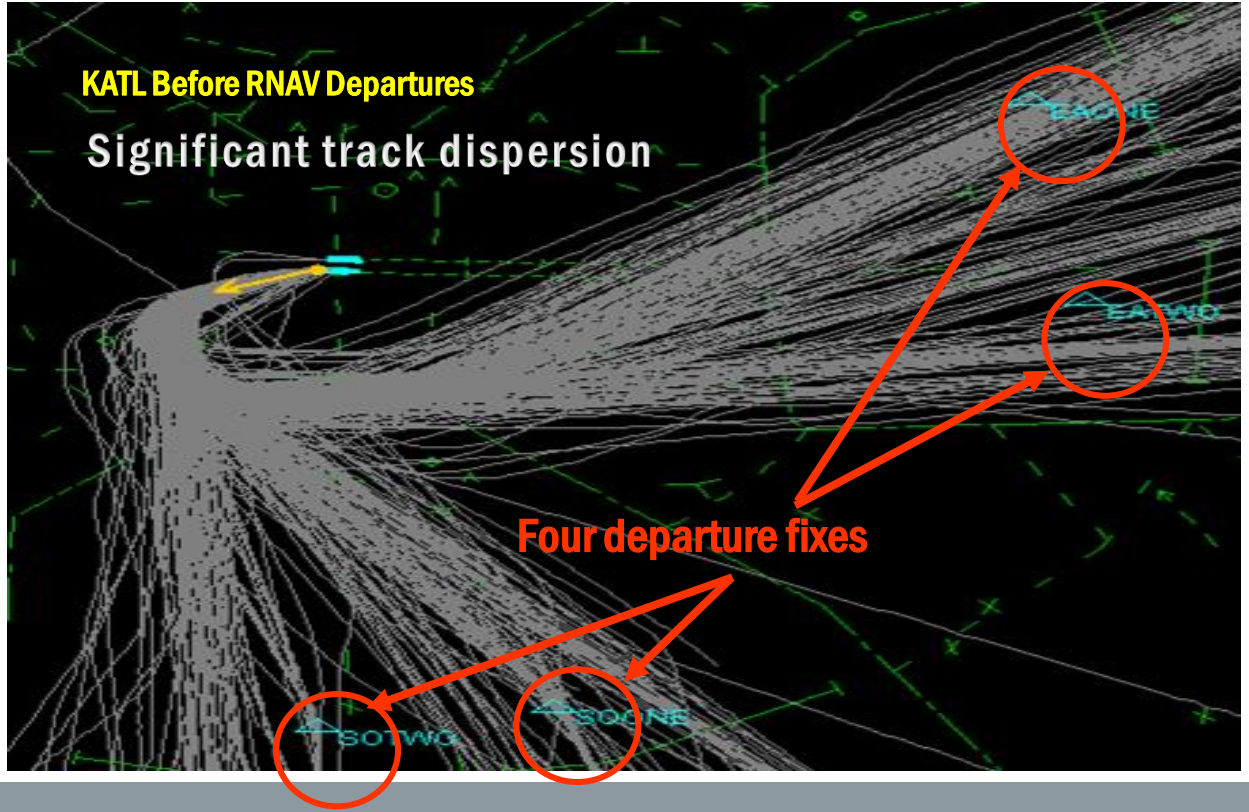
Benefits of PBN



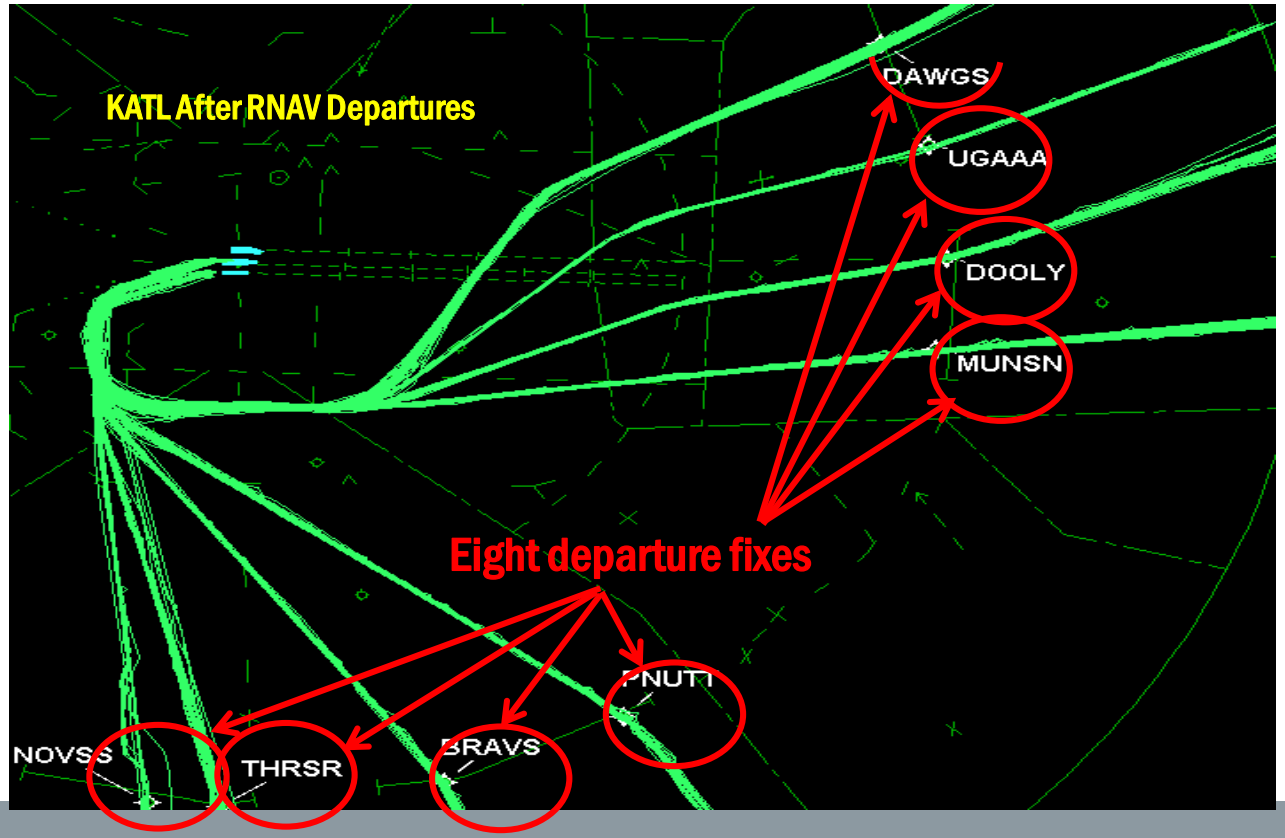
Hyderabad – Bengaluru (RNP 2 Q21/22)

Previous Routing	W71	W153
Route Distance	254 NM	254NM
PBN Route Distance	Q21 248 NM	Q22 245 NM
No. of Flights Per Annum	3285	3285
Reduction in Route Distance	6 NM	9 NM

- RNAV Departures at Atlanta USA

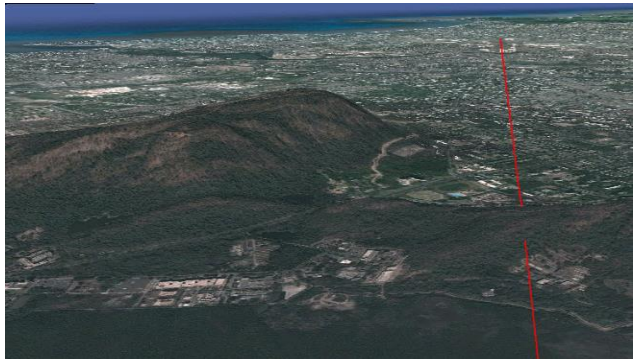


- RNAV Departures at Atlanta USA



RNP-AR RWY32 - Mumbai

- Mumbai airport is 2nd busiest international airport in India.
- Four runways - RWY 09/27 & RWY14/32 in cross-runway configuration.
- RWY27 is primary runway.
- RWY32 is secondary runway but its use is constrained by following:
  - Trombay Hill located 3.5NM from THR RWY32 .
  - No precision approach (PA)
  - VOR Procedure (NPA) available with descent gradient of 5.7% (3.26^0),
  - OCA
    - 650Ft with Step-down fix
    - 1330Ft without step-down fix

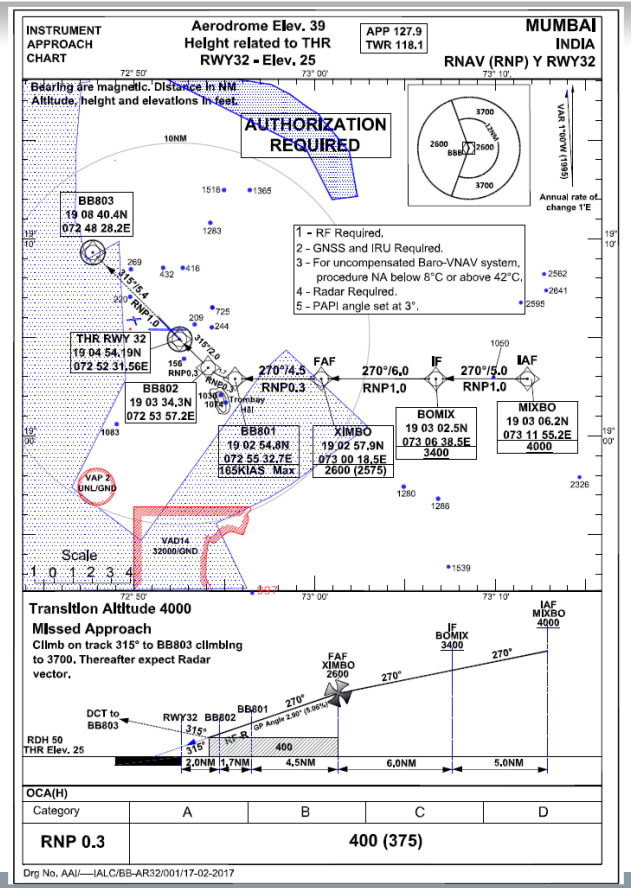


RNP-AR RWY32 - Mumbai

- Due to reduced obstacle protection/evaluation area and curved (RF Leg) final approach segment, Trombay hill is completely avoided and reduction in OCA becomes feasible.

- Benefits of the procedure:
  - Better access and enhanced usability of RWY32.
  - Enhanced safety
  - Reduced OCA (**400 ft**) and lower AOM
  - Stabilized approach at 2.9 deg with CDFA
  - Noise reduction
  - Fuel emission reduction

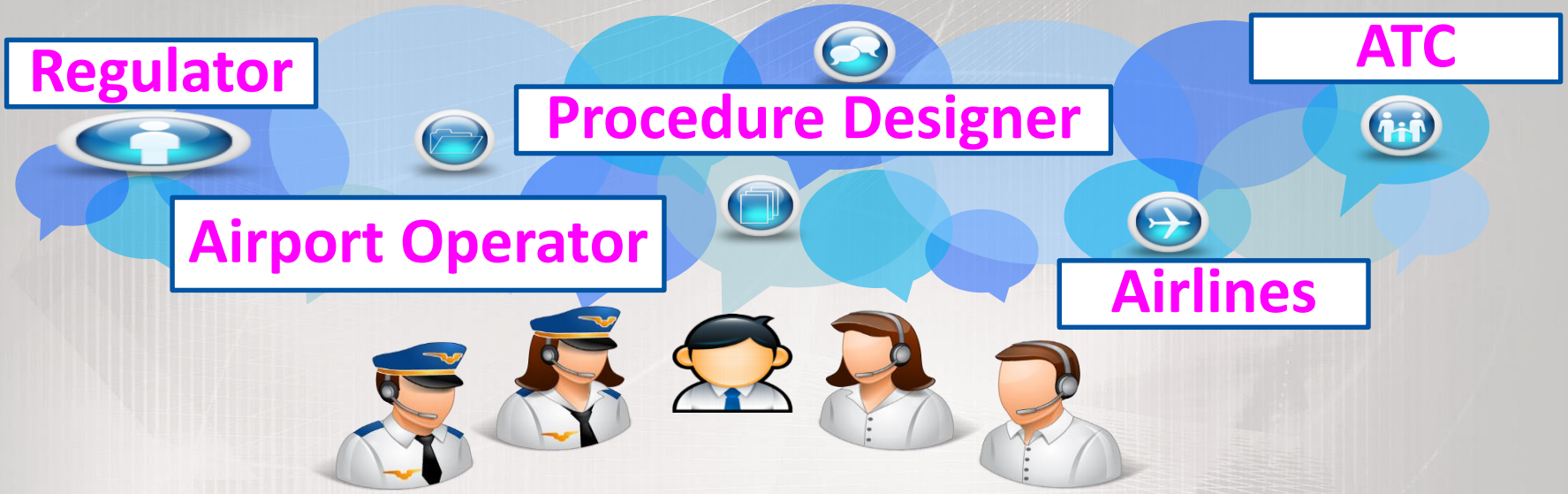
Benefits of PBN



RNP-AR RWY32 - Mumbai

Implementation challenges

Implementation challenges



Need to involve all stakeholders

REGIONAL TARGETS

ICAO Assembly Resolution A37-11
PBN Global Goals

States complete a PBN implementation plan to achieve:

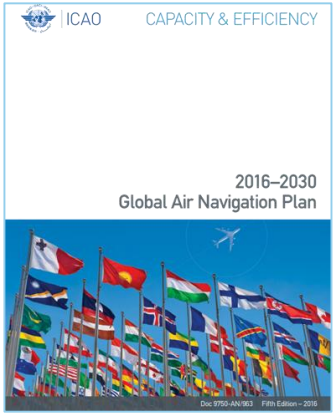
- **Implementation of RNAV and RNP operations for en route and terminal areas.**
- **Implementation of approach procedures with vertical guidance (APV) (Baro-VNAV and/or augmented GNSS), including LNAV-only minima.**
- **Target date - 2016**

Global Air Navigation Plan (GANP)

❖ **ICAO's GANP Priorities**

1. PBN as the highest priority

2. Environmental gains through PBN terminal procedures – CDO and CCO
   - Significant fuel saving and environmental benefit



APAC Seamless ANS Plan

❖ **Asia/Pacific ASBU Block 0 and Block 1 Priority (Ver. 3.0)**

Functional Category	Element	Priority
Operational	APTA-B0/1-2: Basic PBN SID and STAR procedures, PBN non-precision (PARS 7.4, 7.5, 7.10, 7.13,7.14,7.21)	1
	APTA-B0/3 and 6: SBAS/GBAS CAT I precision approach procedures, and PBN Helicopter PinS Operations (PARS 7.5,7.6, 7.10,7.14,7.21)	3
	APTA-B0/4-5, 7-8: CDO (Basic) and CCO (Basic) & PBAOM (PARS 7.14,7.19,7.21)	2
CNS Technology and Services	NAVS-B0/1-4: SBAS, GBAS, ABAS,MON (PARS 7.7)	2

APAC Seamless ANS Plan V3.0

- **Performance Improvement Plan**
  - **PARS* Phase II (Expected implementation by 7 Nov 2019)**

Terminal

- **RNAV 1 or RNP 1 SID/STAR**

Approach

- **GBAS; or ILS/MLS (with APV as a backup); or APV (Baro-VNAV or SBAS); or straight-in RNP APCH (LNAV)**

2. For rotary wing operations

- **PBN SID/STAR, Approach, or PBN PinS Operations**

3. All Cat T airspace to be designated as non-exclusive or exclusive PBN airspace

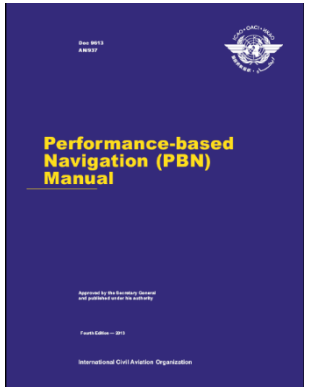
Preferred Aerodrome/Airspace and Route Specifications (PARS**)*

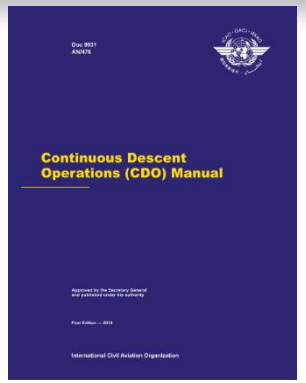
APAC Seamless ANS Plan V3.0

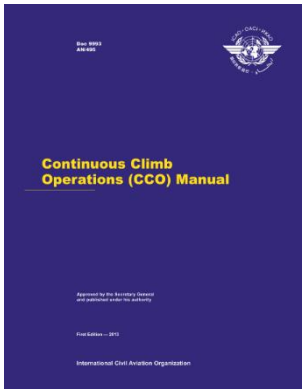
- **Performance Improvement Plan**
  - **PARS Phase II (Expected implementation by 7 Nov 2019)**
    1. **All Cat R and S upper controlled airspace should be designated as non-exclusive or exclusive PBN airspace to allow operational priority for PBN approved aircraft, except for State aircraft**
    2. **All new ATS Routes should be PBN routes:**
       - **Category R airspace - RNP 4, RNP 10 (RNAV 10) (RNP 2 oceanic is acceptable)**
       - **Category S airspace - RNAV 2 or RNP 2**
  - **PARS Phase III (Expected implementation by 03 Nov 2022)**
    - **CDO/CCO operations and performance-based aerodrome operating minima**

PBN Documents

- **ICAO PBN Manual (Doc 9613)**
  - **Volume I**
    - Part A – PBN Concept
    - Part B – Implementation Guidance
  - **Volume II**
    - Part A – General
    - Part B – Implementing RNAV Operations
    - Part C – Implementing RNP Operations

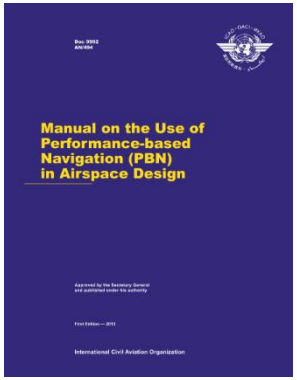




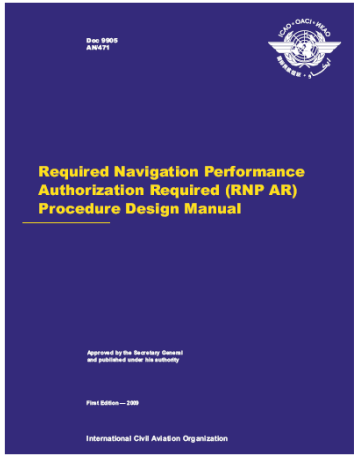


PBN Documents

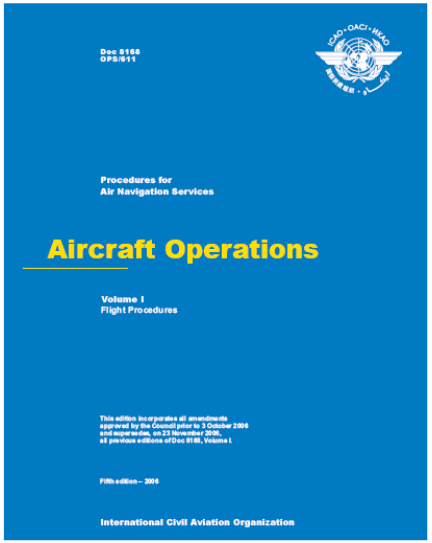
- ICAO PBN Airspace Design Manual (Doc 9992)
  - Chapter 1- Background
  - Chapter 2 – Process
- ICAO CDO Manual (Doc 9931)
  - Part A – CDO Overview
  - Part B – Implementation Guidance
- ICAO CCO Manual (Doc 9993)
  - Part A – CCO Overview
  - Part B – Implementation Guidance



Other Important ICAO Documents



- **PANS-OPS (Doc 8168)** – Flight Procedure Design
  Vol-I , Vol-II & Vol III
- **RNP AR Manual** – Doc 9905
- Quality Assurance Manual for Flight Procedure Design (Doc 9906)
  - Volume 1 — Flight Procedure Design Quality Assurance System
- GNSS Manual (Doc 9849)



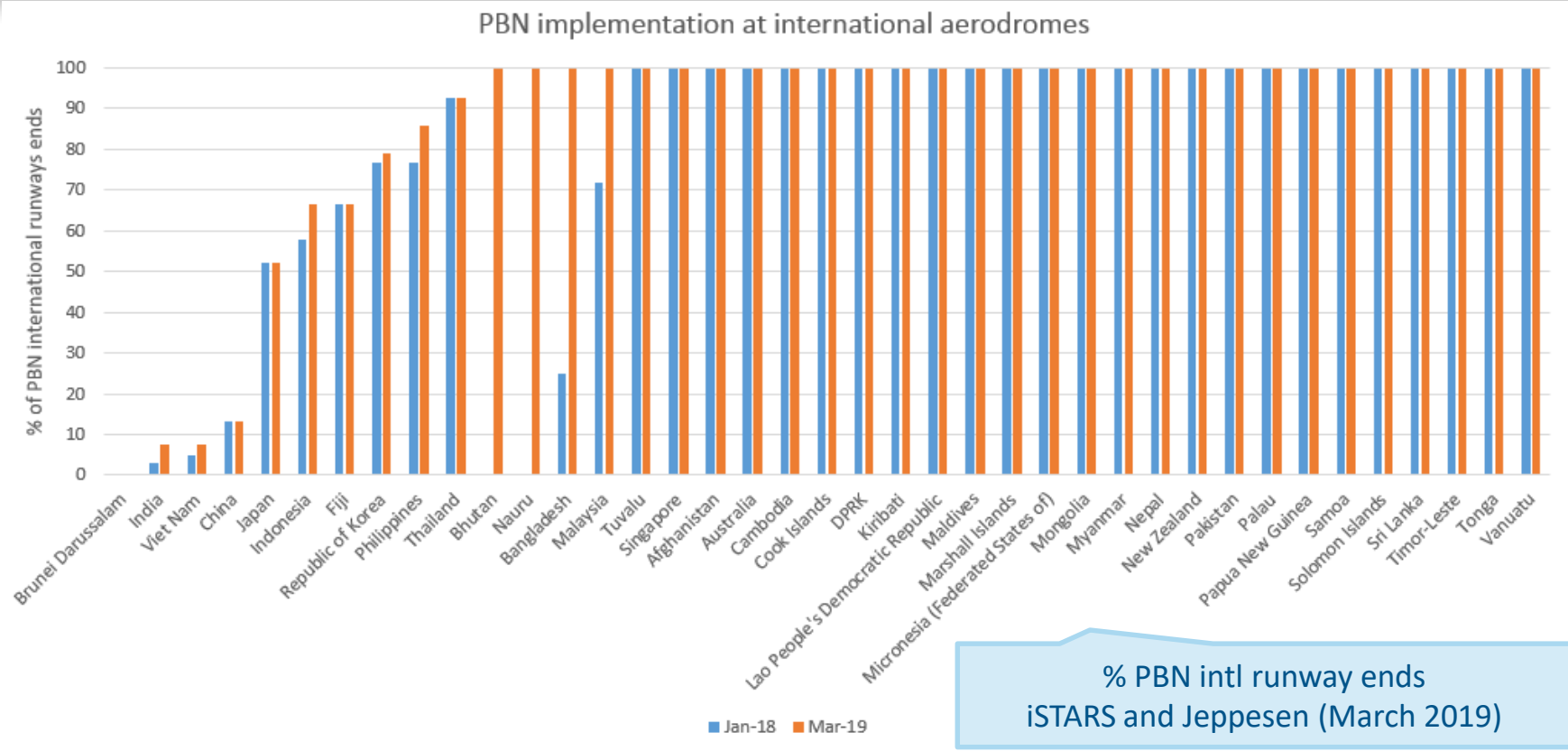
PBN Implementation Status - APAC

PBN Implementation status updated as on Dec 2019 is available on ICAO portal
https://portal.icao.int/space/Pages/PBN-Status.aspx

States in APAC	PBN Runway Ends	Intr. Runway Ends	PBN Runway Ends (%)
38	297	493	60.2%

PBN Implementation status as per PBNICG last meeting in April 2019

	PBN Approach	APV		PBN SID	PBN STAR
		LNAV/VNAV	LPV		
Global (%)	69	49.1	29.7	41.3	38.8
Asia/Pacific (%)	56.6	33.0	0	61.4	61.8



% PBN intl runway ends
iSTARS and Jeppesen (March 2019)

WHAT ICAO CAN OFFER

Workshop/Seminar/Webinar to enhance awareness on PBN for the stakeholders.

Technical assistance in Procedure Design, Airspace design, training in Flight procedure design and Operational Approvals through Flight Procedure Program(FPP) and COSCAPs.

PBN Go team to assist states in Gap Analysis and recommendation for implementation of PBN. Analyzes and evaluates all aspects- needs, issues and concerns and delivers an achievable strategic plan aligned with Regional Plan

Useful information about PBN in the APAC region

REGIONAL PBN DOCUMENTS :
HTTPS://WWW.ICAO.INT/APAC/PAGES/EDOCS.ASPX

REGIONAL WORKING GROUPS :

- **PBN IMPLEMENTATION COORDINATION GROUP (PBNICG)**
  DATE OF NEXT MEETING POSTPONED
- **GBAS/SBAS IMPLEMENTATION TASK FORCE (GBAS SBAS ITF)**
  1ST MEETING ONLINE MEETING 23-24 JUNE

ALL MEETING DOCUMENTS ARE AVAILABLE HERE :
HTTPS://WWW.ICAO.INT/APAC/MEETINGS/PAGES/DEFAULT.ASPX

Point of contact :

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APAC-RSO@ICAO.INT

COVID-19 related information

- ICAO has developed this COVID-19 Recovery Platform to collate the forecasts, guidance, tools, and resources which are needed by national regulators pursuing pandemic responses.
  https://www.icao.int/covid/Pages/default.aspx

- COVID-19 BCP Measures & Guidelines Information Sharing
  https://www.icao.int/APAC/Pages/COVID-19-BCP.aspx

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- First meeting of the ICAO APAC COVID-19 Contingency and Recovery Planning Group (ACCRPG/1)
  https://www.icao.int/APAC/Meetings/Pages/2020-ACCRPG1.aspx

Q&A SESSION

ICAO


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South American (SAM) Office Lima
ICAO Headquarters Montréal
Western and Central African (WACAF) Office Dakar
European and North Atlantic (EUR/NAT) Office Paris
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THANK YOU