Workshop on PBN Implementation in En-route Environment

18 April 2024, Bangkok

Enroute PBN Implementation

V. K. Mishra

Regional Officer, PBN, ICAO APAC RSO Beijing

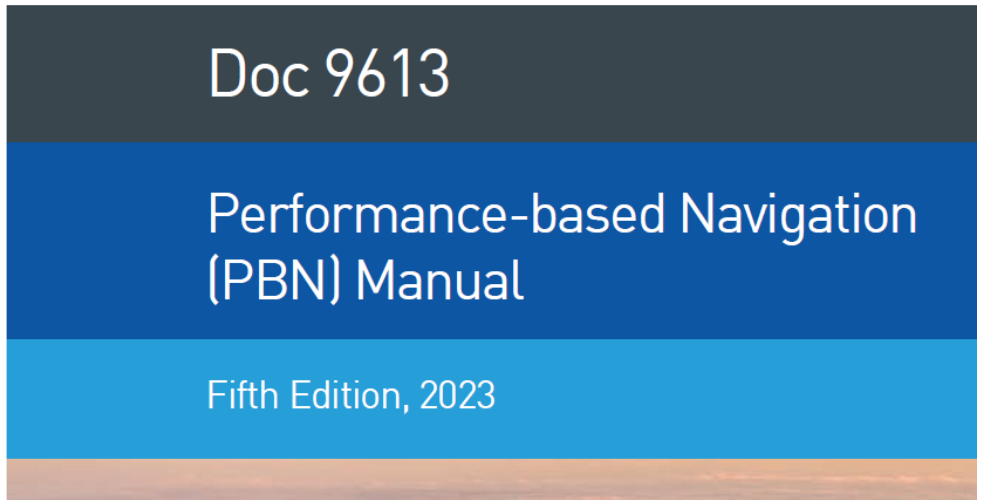
vkmishra@icao.int

ICAO

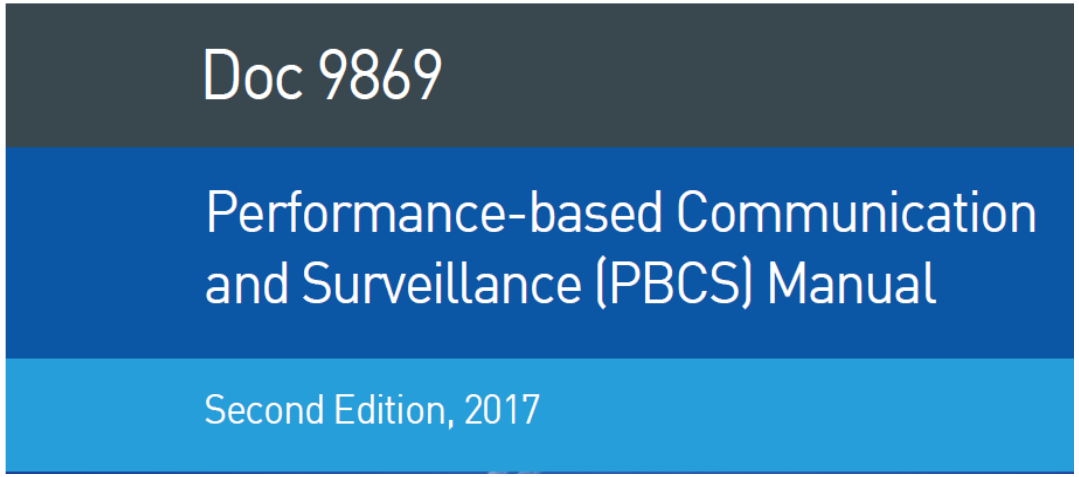
PBN Implementation in Enroute

ICAO Documents

ICAO

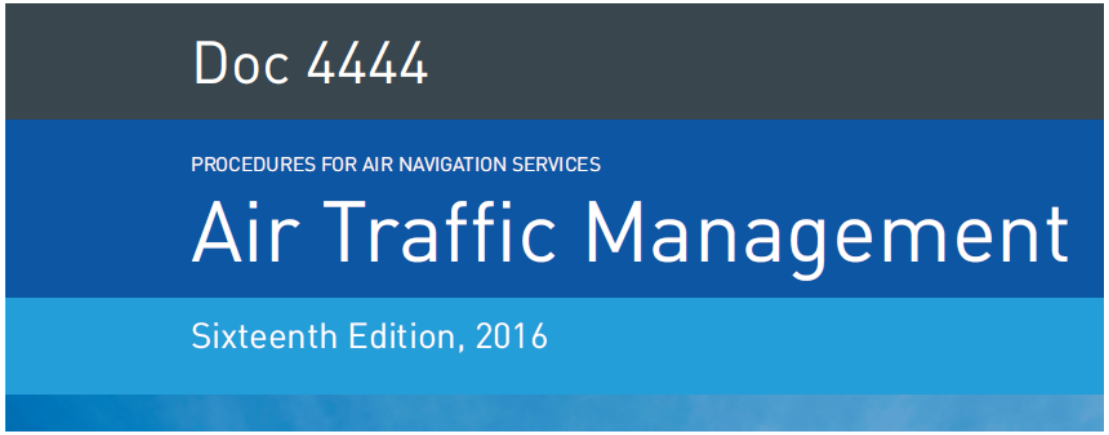


ICAO



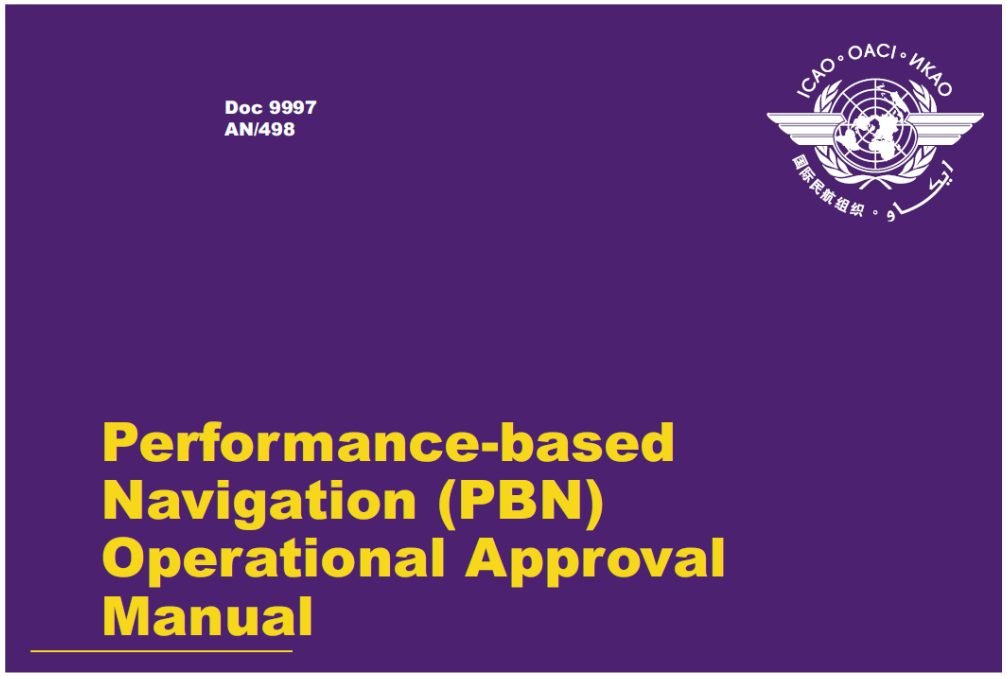
PBN Implementation in Enroute

ICAO Documents



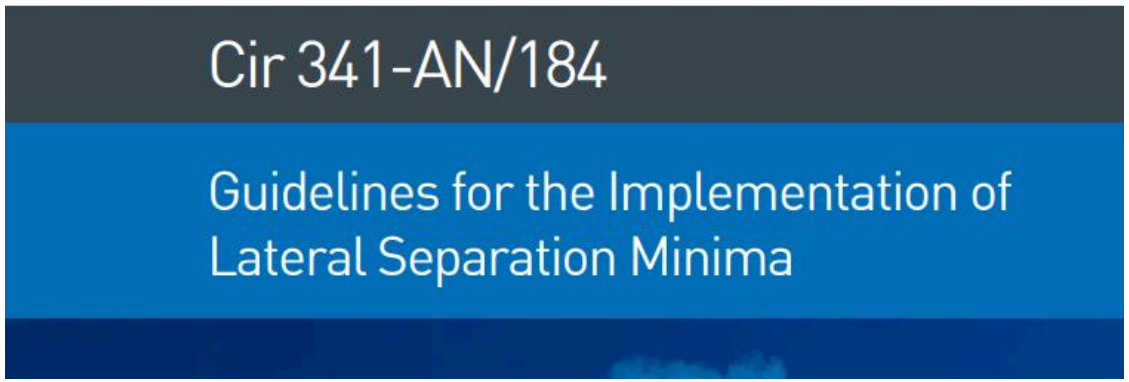
PBN Implementation in Enroute

ICAO Documents



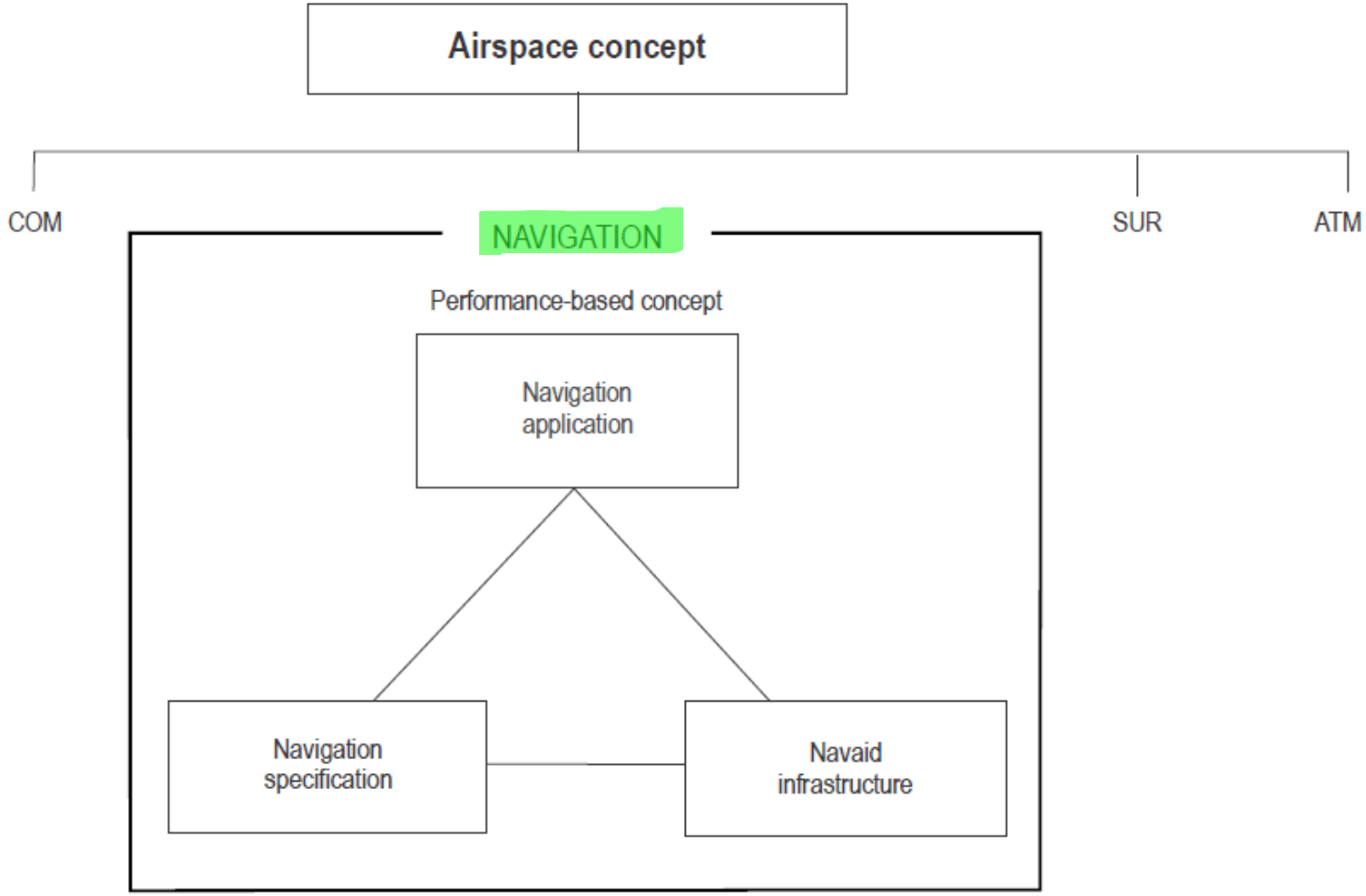
PBN Implementation in Enroute

ICAO Documents



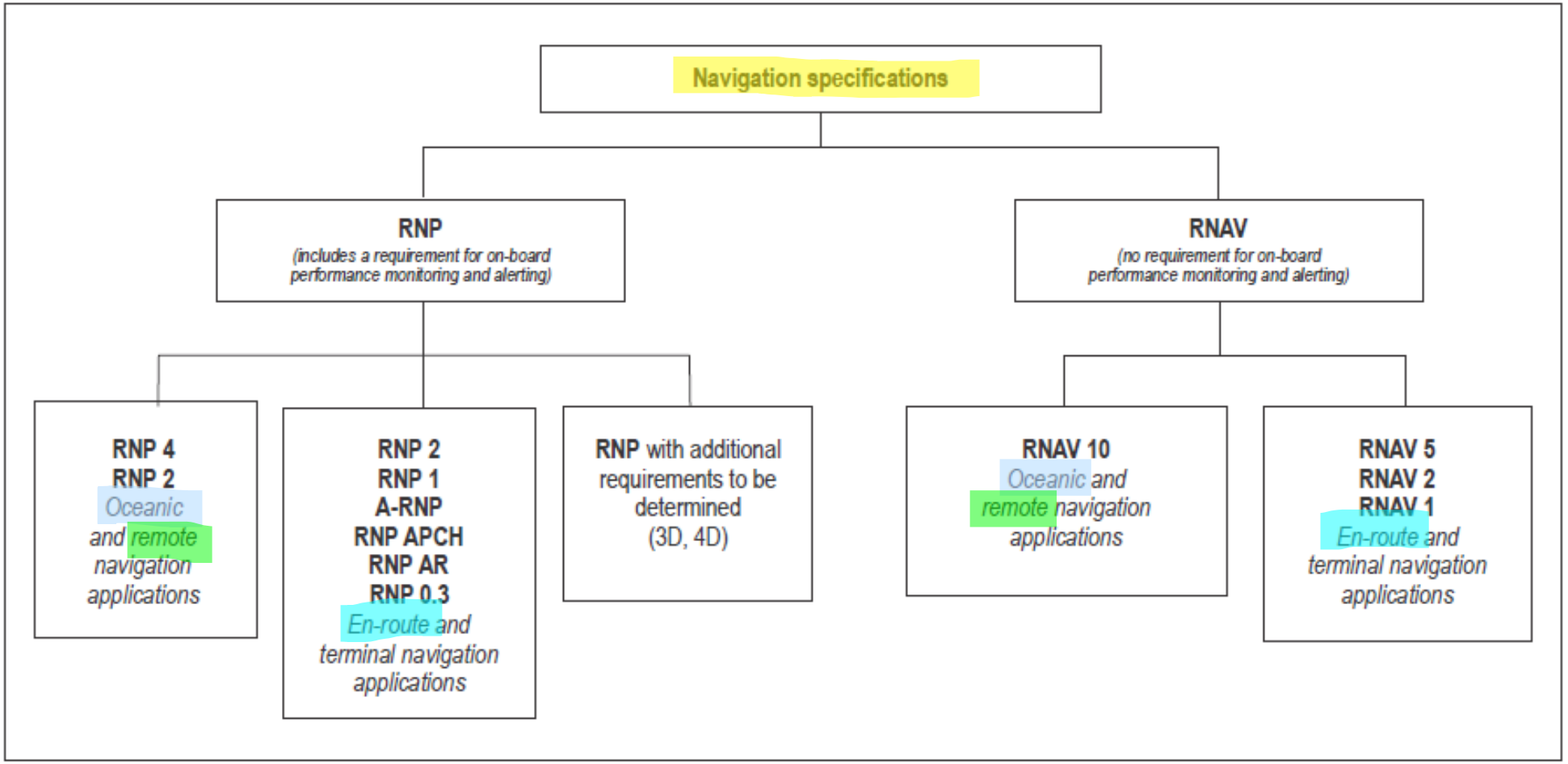
PBN Implementation in Enroute

PBN Concept



PBN Implementation in Enroute

PBN Concept



PBN Implementation in Enroute

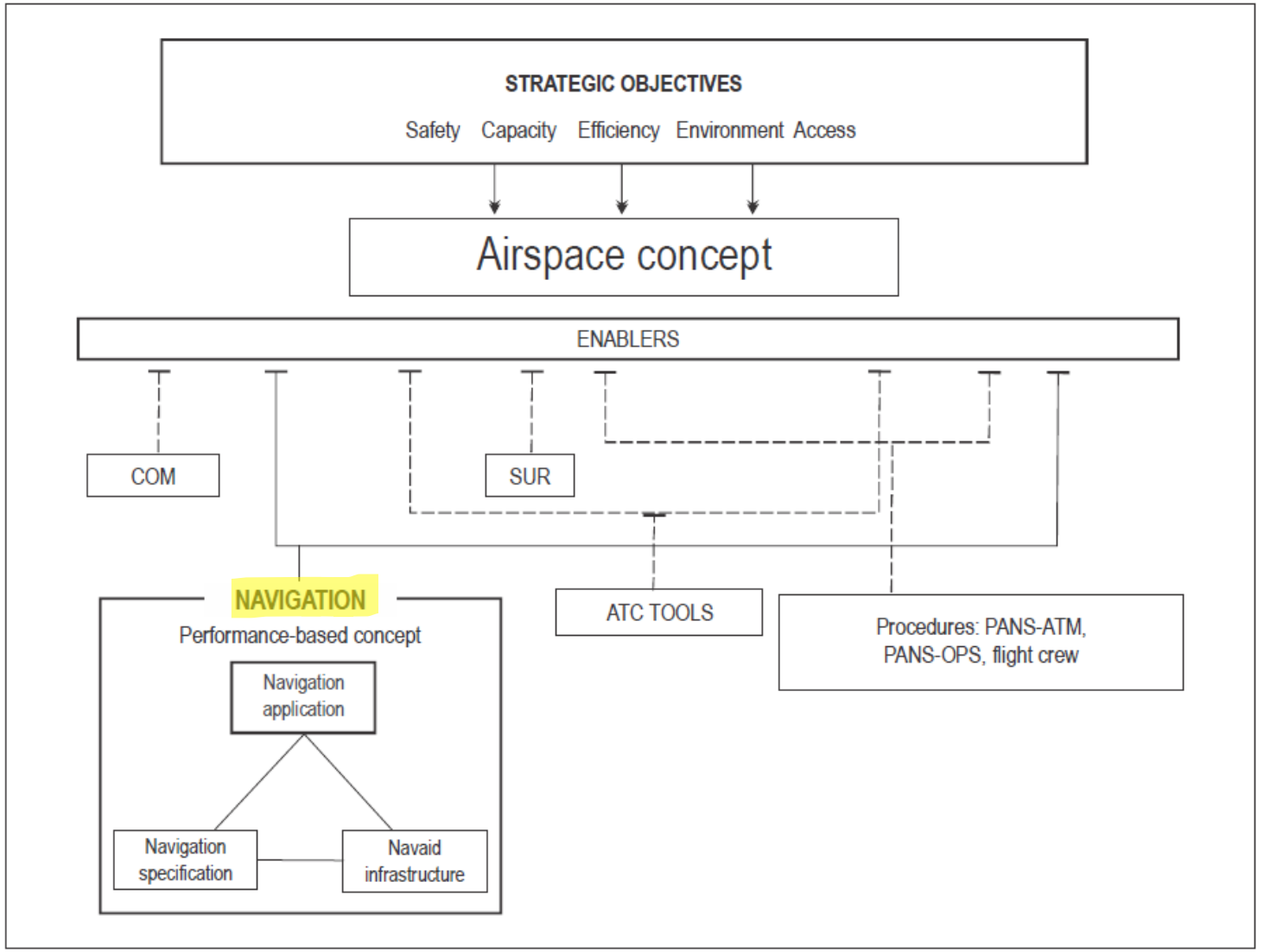


Figure I-2-2. Relationship: PBN and airspace concept

PBN Implementation in Enroute

AIRSPACE CONCEPTS BY AREA OF OPERATION

Oceanic and remote continental

- Supported by three navigation applications: RNAV 10, RNP 4 and RNP 2.
- Rely primarily on GNSS.

Continental en-route

- Supported by RNAV 5, RNAV 2 & RNP 2
- RNAV applications support airspace concepts that include ATS surveillance and direct VHF controller/pilot voice communications, ATS surveillance is not a pre-requisite
- RNAV applications can support airspace concepts in a procedural environment, subject to a safety assessment.

PBN Implementation in Enroute

AIRSPACE CONCEPTS BY AREA OF OPERATION

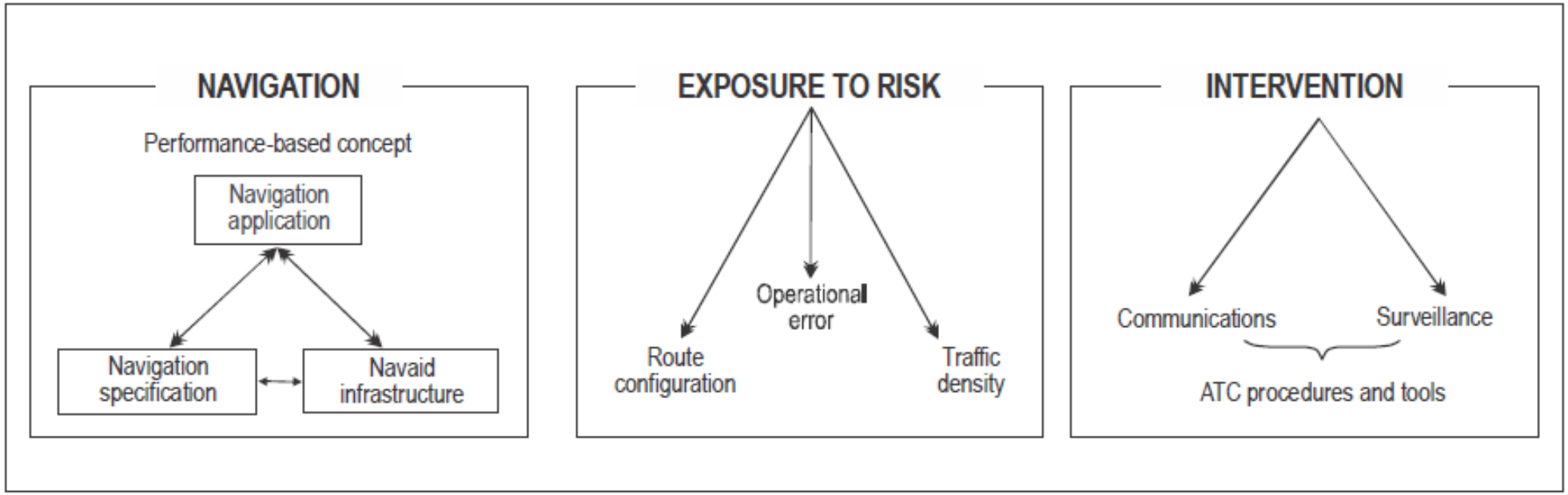


Figure I-3-2. Generic model used to determine separation and ATS route spacing

PBN Implementation in Enroute

PBN	NAVIGATION Performance-based concept Navigation application Navigation specification ↔ NAVAID infrastructure	EXPOSURE TO RISK Operational error Route configuration Traffic density	INTERVENTION Communication Surveillance ATC procedures and tools
Determination of **separation minima** *(1)* for tactical use *without* ATC surveillance	✓	✓ (2)	✗
Determination of **separation minima** *(1)* for tactical use *with* ATC surveillance	✗	✗ (2) and (3)	✓
Determination of **route spacing** *without* ATC surveillance	✓	✓	✗
Determination of **route spacing** *with* ATC surveillance	✓	✓	✓

*✓ relevant; ✗ Largely irrelevant; **(1)** In context, separation minima based on NAVAID or navigation sensor or PBN; **(2)** traffic density = single aircraft pair; **(3)** separation minima determined as a function of performance of ATC surveillance system.*

Figure I-3-3. Factors affecting the determination of separation and route spacing

PBN Implementation in Enroute

Table II-A-1-1. Navigation specification, flight phase, navigation application, and associated RNAV/RNP value (lateral navigation accuracy) (NM)

Part, chapter	*Navigation specification*	*Navigation application, flight phase and RNAV/RNP value (NM)*							
		ATS or user-defined routeing		*Arrival procedures*	*Approach procedures*				*Departure procedures*
		En-route oceanic/remote	*En-route continental*	*Arrival*	*Initial*	*Intermediate*	*Final*	*Missed*[1]	*Departure*
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[3]	2						
C, Ch.3	RNP 1[7]			1	1	1		1	1
C, Ch.4	Advanced RNP (A-RNP)	2[3]	2 or 1	0.3	0.3	0.3		1[9]	0.3
C, Ch.5	RNP APCH[4]				1	1	0.3[5]	1[8]	
C, Ch.6	RNP AR				1-0.1	1-0.1	0.3-0.1	1-0.1	1-0.3
C, Ch.7	RNP 0.3[6]		0.3	0.3	0.3	0.3		0.3	0.3

PBN Implementation in Enroute

5.4.1.2.1.6 *Lateral separation of aircraft on parallel or non-intersecting tracks or ATS routes.* Within designated airspace or on designated routes, lateral separation between aircraft operating on parallel or non-intersecting tracks or ATS routes shall be established in accordance with Table 5-2:

Table 5-2. Lateral separation of aircraft on parallel or non-intersecting tracks or ATS routes

Minimum Spacing Between Tracks		*Performance Requirements*			*Additional Requirements*
Airspace where SLOP is not authorized, or is only authorized up to 0.5 NM	*Airspace where SLOP up to 2 NM is authorized*	*Navigation*	*Communication*	*Surveillance*	
93 km (50 NM)	93 km (50 NM)	RNAV 10 (RNP 10) RNP 4 RNP 2	Types of communication other than direct controller-pilot VHF voice		
37 km (20 NM)	42.6 km (23 NM)	RNP 4 RNP 2	RCP 240	RSP 180	Conformance monitoring shall be ensured by establishing an ADS-C event contract specifying a lateral deviation change event with a maximum of 5 NM threshold and a waypoint change event
37 km (20 NM)	42.6 km (23 NM)	RNP 2 or GNSS equipage	Types of communication other than direct controller-pilot VHF voice		While one aircraft climbs/descends through the level of another aircraft remaining in level flight
27.8 km (15 NM)	33.4 km (18 NM)	RNP 2 or GNSS equipage	Direct controller-pilot VHF voice communications		
16.7 km (9 NM)	22.3 km (12 NM)	RNP 4 RNP 2	RCP 240	RSP 180	While one aircraft climbs/descends through the level of another aircraft remaining in level flight
13 km (7 NM)	19 km (10 NM)	RNP 2 or GNSS equipage	Direct controller-pilot VHF voice communications		While one aircraft climbs/descends through the level of another aircraft remaining in level flight

PBN Implementation in Enroute

PERFORMANCE-BASED LONGITUDINAL SEPARATION MINIMA

5.4.2.9.2 The following separation minima may be used for aircraft cruising, climbing or descending on:

a) the same track; or

b) crossing tracks, provided that the relative angle between the tracks is less than 90 degrees.

Separation minima	*RNP*	*RCP*	*RSP*	*Maximum ADS-C periodic reporting interval*
93 km (50 NM)	10	240	180	27 minutes
	4	240	180	32 minutes
55.5 km (30 NM)	2 or 4	240	180	12 minutes
37 km (20 NM)	2 or 4	240	180	192 seconds (3.2 minutes)
5 minutes	2 or 4 or 10	240	180	14 minutes

PBN Implementation in Enroute

RNP 10 Implementation

- The existing RNP 10 designation is inconsistent with PBN RNP and RNAV navigation specifications.
- RNP 10 does not include requirements for on-board performance monitoring and alerting.
- For purposes of consistency with the PBN concept, RNP 10 is referred to as RNAV 10.
- Supports 50 NM lateral and e 50 NM longitudinal distance-based separation minima in procedural oceanic or remote area airspace.
- The designation of the airworthiness and operational authorization as well as airspace/route designation remains “RNP 10”.

PBN Implementation in Enroute

RNP 10 Implementation

- RNP 10 was developed for operation in oceanic and remote areas and does not require any ground-based NAVAID infrastructure or assessment.
- Types of communication other than direct controller-pilot VHF voice
- When GNSS is used as the sole basis for both ATS surveillance and aircraft navigation, the risks and requirement for mitigation techniques associated with the loss of GNSS potentially resulting in the loss of both navigation and surveillance capability, should be considered.
- The minimum route spacing for RNP 10 is 50 NM.

PBN Implementation in Enroute

RNP 10 Authorization

The following steps must be completed before conducting RNP 10 operations:

a) aircraft equipment eligibility must be determined and documented;

b) operating procedures for the navigation systems to be used and the operator navigation database process must be documented;

c) pilot training based upon the operating procedures must be documented, if necessary;

d) the above material must be accepted by the state regulatory authority; and

e) operational authorization must then be obtained in accordance with national operating rules.

PBN Implementation in Enroute

Aircraft requirements

- RNP 10 requires that aircraft operating in oceanic and remote areas be equipped with at least two independent and serviceable LRNSs comprising an inertial navigation system(INS) or a GNSS system.
- Aircraft approved to use GNSS as a primary means of navigation for oceanic and remote operations, also meet the RNP 10 requirements without time limitations.
- Aircraft equipped with dual inertial navigation systems(INS) have been determined to meet RNP 10 requirements for up to 6.2 hours of flight time.
- The timing starts from when the inertial navigation systems are placed in navigation mode or at the last point at which the inertial navigation systems receive a position update.
- Aircraft equipped with a single inertial navigation system and a single GPS meet the RNP 10 requirements without time limitations.

PBN Implementation in Enroute

RNAV 5

RNAV 5 operations are based on the use of RNAV equipment, which automatically determines the aircraft position using input from one or a combination of the following types of position sensors with the means to establish and follow a desired path:

a) VOR/DME;

b) DME/DME;

c) INS or IRS; and

d) GNSS.

Direct pilot to ATC (voice) communications is required

ATS surveillance service may be used to assist contingency procedures, to mitigate the effect of blunder errors and to reduce route spacing

PBN Implementation in Enroute

RNAV 5

Route spacing of 16.5 NM for straight unidirectional tracks and 18 NM route spacing for straight bidirectional tracks

- **Minimum air traffic services requirements**
- **NAV – RNAV 5. The NAVAID infrastructure must be sufficient to support RNAV 5 operations.**
- **COM – Direct VHF controller/pilot voice communications.**
- **SUR – Procedural pilot position reports.**
- **INS may be used either as a stand-alone inertial navigation system or as an approved inertial sensor integrated as part of a multi-sensor RNP system.**
- **INS may support RNAV operations for a maximum of two hours from the last full inertial alignment or the last position update performed on the ground.**
- **When GNSS is used, en-route RAIM levels are required for RNAV 5 and can be verified either through NOTAMs (where available) or through prediction services.**

PBN Implementation in Enroute

RNAV 1 AND RNAV 2

- RNAV 1 and 2 specification is applicable to all ATS routes, including routes in the en-route domain
- Sensors -GNSS, DME/DME and DME/DME/inertial
- Where DME is the only navigation service used for position updates, gaps in DME coverage can prevent position update. Integration of approved inertial navigation systems can permit extended gaps in coverage.
- The growth in position error after reverting to INS can be expected to be less than 2 NM per 15 minutes.
- Most modern RNAV systems prioritize input from GNSS and then DME/DME positioning
- Direct pilot to ATC (voice) communications is required.
- ATS surveillance service may be used to assist contingency procedures to mitigate the effect of blunder errors and to reduce route spacing

PBN Implementation in Enroute

RNAV 1 AND RNAV 2

- The available NAVAID infrastructure should be clearly designated on all appropriate charts (such as GNSS, DME/DME or DME/DME/inertial).
- Any DME facilities that are critical to RNAV 1 or RNAV 2 operations should be identified in the relevant publications.
- Route spacing for RNAV 1 and RNAV 2 depends on the route configuration, air traffic density and the availability of ATS surveillance to provide intervention capability.
- RAIM levels required for RNAV 1 and RNAV 2 can be verified either through NOTAMs (where available) or through prediction services
- The prediction service may be provided by the ANSP, avionics manufacturer, other entities or through an airborne receiver RAIM prediction capability
- In the event of a predicted, continuous loss of appropriate level of fault detection of more than five minutes for any part of the RNAV 1 or RNAV 2 operation, the filed flight plan should be revised.

PBN Implementation in Enroute

RNAV 1 AND RNAV 2

- **RNAV operations where RNP is specified on parallel tracks or ATS routes - Within designated airspace or on designated routes, where RNP is specified, lateral separation between RNAV-equipped aircraft may be obtained by requiring aircraft to be established on the centre lines of parallel tracks or ATS routes spaced at a distance which ensures that the protected airspace of the tracks or ATS routes does not overlap.**
- **XTT, ATT, area semi-width for RNAV 1 and RNAV 2 in en-route phase of flight (NM)**

½ A/W = XTT X 1.5 + BV
where:
1.5 XTT corresponds to a 3σ lateral TSE value
BV = buffer value = 2nm for Enroute

En-route/STAR/SID (>30 NM ARP)		
XTT	*ATT*	*½ A/W*
2.00	1.60	5.00

PBN Implementation in Enroute

RNP 4

- Supports 30 NM lateral and the 30 NM longitudinal distance-based separation minima in a procedural oceanic or remote area airspace.
- Does not require any ground-based NAVAID infrastructure.
- GNSS is the primary navigation sensor to support RNP 4.
- CPDLC and either ADS-C or ADS-B, or CPDLC (ATN) and ADS-B may be used.
- At least two fully serviceable independent long range navigation systems (LRNSs) capable of navigating to RNP 4

PBN Implementation in Enroute

RNP 4

- GNSS must be used and can be used as either a stand-alone navigation system or as one of the sensors in a multi-sensor system.
- The navigation database should be obtained from a supplier that complies with RTCA DO 200()/EUROCAE document ED 76(), Standards for Processing Aeronautical Data.
- CPDLC and ADS-C systems is required when the separation standard is 30 NM lateral and/or longitudinal.
- RNP 4 may be used to support the application of separation standards/route spacing less than 23 NM in continental airspace provided a State has undertaken the necessary safety assessments with appropriate communication & surveillance.

PBN Implementation in Enroute

RNP 2

- RNP 2 is primarily intended for a diverse set of en-route applications, particularly in geographic areas with little or no ground NAVAID infrastructure.
- Use of RNP 2 in continental applications requires a lower continuity requirement than used in oceanic/ remote applications
- Can be applied for applications in oceanic, continental and in remote airspace.
- Remote airspace may require different considerations for aircraft eligibility based on whether the remote areas are covered by ATS surveillance.
- RNP 2 can be associated with FRT
- RNP 2 specification is based upon GNSS.

PBN Implementation in Enroute

RNP 2

- To have the means to predict the availability of GNSS fault detection, such as ABAS receiver autonomous integrity monitoring (RAIM).
- In the event of a predicted, continuous loss of appropriate level of fault detection of more than five minutes for any part of the RNP 2 operation, the operator should revise the filed flight plan.
- RNP 2 should not be used in areas of known GNSS signal interference.
- Route Spacing of 18 NM with SLOP and 15 NM without SLOP with DCPC.
- Route Spacing of 23 NM with SLOP and 20 NM without SLOP with PBCS.

PBN Implementation in Enroute

RNP 2

- The need for direct pilot to ATC (voice) communications and ATS surveillance will be determined by the airspace concept and the operating environment.
- The ATS surveillance service may compliment contingency procedures to mitigate the effect of blunder errors and to reduce route spacing.
- When GNSS is used as the sole basis for both ATS surveillance and aircraft navigation, the risks and requirement for mitigation techniques associated with loss of GNSS potentially resulting in the loss of both navigation and surveillance capability, should be considered. This should typically be addressed through the regional or local State safety case prepared in support of the application.
- Pilots must not fly a published RNP 2 route unless they can retrieve the route by name from the on-board navigation database and confirm it matches the charted route.

PBN Implementation in Enroute

RNP 1

- RNP 1 is primarily intended for SIDs/STARs, in geographic areas having an extensive, modest or no ground NAVAID infrastructure.
- May be used for extended terminal operations, where it may be applied in the en-route continental flight phase on ATS routes.
- RNP 1 specification is based upon GNSS.
- It should not be used in areas of known navigation signal (GNSS) interference.
- RNP 1 SIDs/STARs are primarily intended to be conducted in direct very high frequency (VHF) controller/pilot voice communications environments
- ATS surveillance service may be used to assist contingency procedures, to mitigate the effect of blunder errors and to reduce route spacing.

PBN Implementation in Enroute

RNP 1

- Can RNP 1 be used for enroute airspace for route design?
- Can RNAV 5 be used in oceanic airspace?
- What are the criteria to determine lateral spacing between two RNP Routes?
- Can parallel routes 7NM apart be implemented if routes are available only under surveillance and vhf? What will be nav spec of such routes?

Thank You!

ICAO