PBN For Enroute

PBN Concept

Asia and Pacific Regional Sub-Office

What is PBN?

- PBN stands for “Performance Based Navigation”.
  - Comprised of RNAV and RNP
    - RNAV (Area Navigation) is a method of navigation which permits aircraft operation on any desired flight path:

      - Within the coverage of station-referenced NAVAIDs, or

      - Within the limits of the capability of self-contained system, or

      - A combination of these capabilities

    - RNP is a RNAV System with On-board Performance Monitoring and Alerting(OPMA)
  - Area navigation is the key enabler for the Performance Based navigation (PBN)

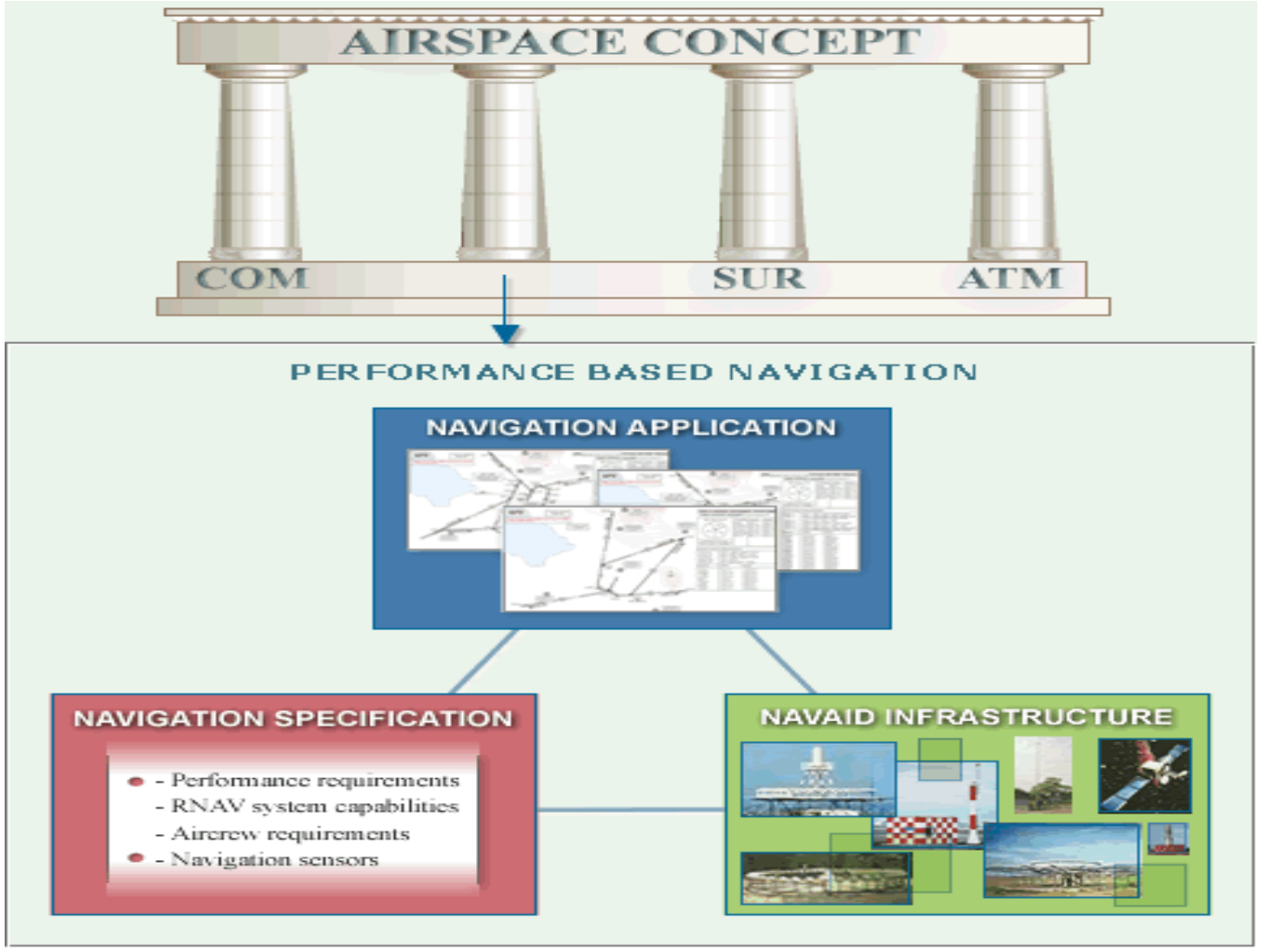
What is PBN?

- PBN specifies SYSTEM PERFORMANCE REQUIREMENTS for aircraft operating on air traffic routes, instrument approach procedures, or in a designated airspace.
- The performance requirements for PBN are defined:
  - Accuracy: Defined as difference between the actual and estimated position and should be 95% performance per flight hour along the intended operation.
  - Integrity: The degree of confidence that can be placed on the RNAV system's position estimations or the probability of an undetected failure per flight hour.
  - Continuity: The ability of the navigation system to provide its service without interruption during an operation or the probability of a system failure during the intended operation.
  - Availability: the ability to perform its function at the initiation of the intended operation.

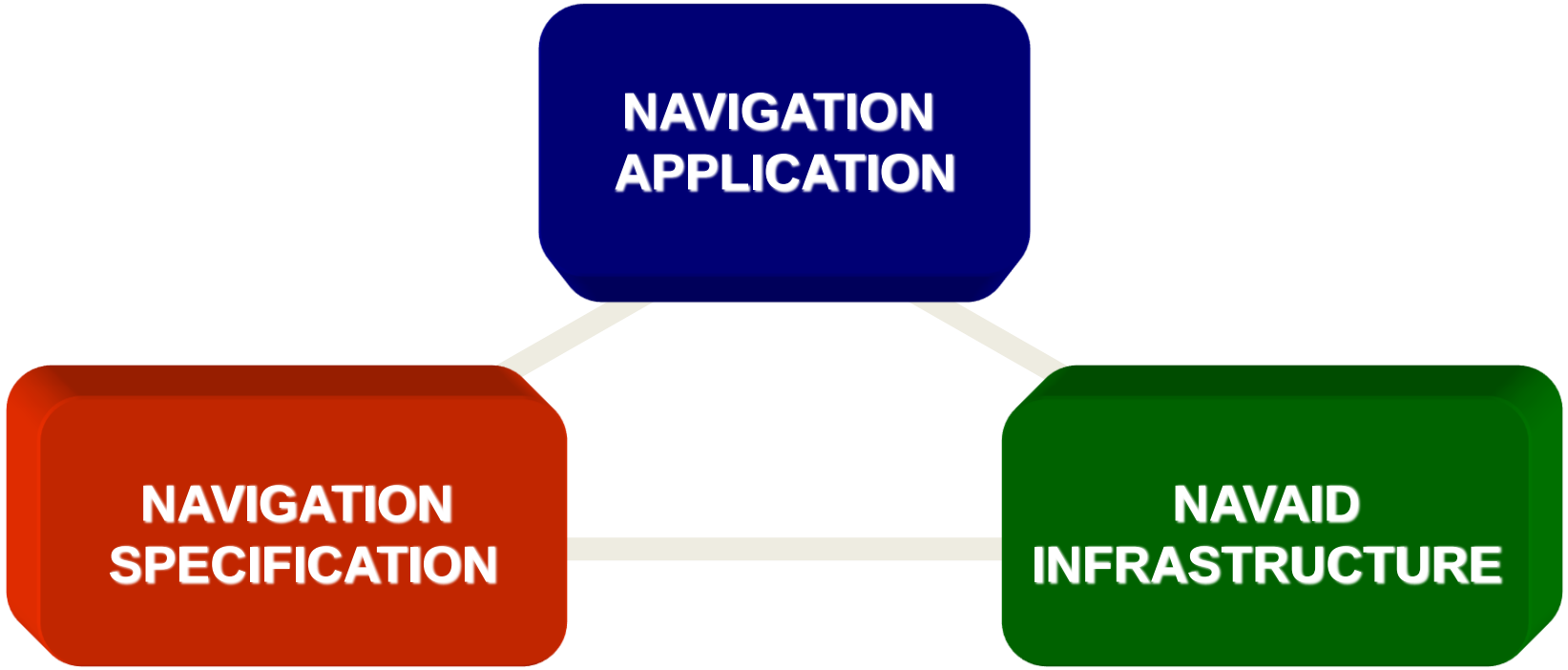
Why PBN in Enroute?

- **The Assembly Resolution A37-11 PBN Global Goals**
  - Urges all States to implement RNAV and RNP ATS routes and approach procedures in accordance with the ICAO PBN concept
- **Beijing Declaration**
  - to implement PBN by 2022
- **ASBU/Seamless ANS Plan**
  - FRTO-B1/2 - Required Navigation Performance (RNP) routes
  - RNP routes should be deployed within en-route airspace where Free Route Airspace (FRA) is not planned or if FRA is deployed the RNP routes should ensure the connectivity between FRA and TMAs.
- **Improving Safety**
  - Reduces airspace conflicts between adjacent airports and prohibited or special use airspace
- **Increasing Airspace Capacity**
  - Increases airspace traffic capacity through shorter & more efficient routes and smoother flows

PBN as the 'N' Element of Airspace Concept



Components of PBN Concept



Navigation Infrastructure

- Ground-based Navigation Aids (NAVAIDs)
  - VOR, DME, (Not NDB)
- Space-based NAVAIDs
  - GNSS
    - GPS, GLONASS, Galileo, BEIDU (COMPASS)
- (Self contained NAVAIDs)
  - INS/IRS, FMS

Navigation Infrastructure

Satellite constellations

- GPS
- Glonass
- Galileo
- Beidou

Several types of errors :

- Satellite clock & ephemerid
- Ionosphere
- Troposphere

And lack of integrity

Navigation Infrastructure

Global Navigation Satellite System (GNSS)

GPS

Glonass

Galileo

Beidou

Three types of augmentations

\+

ABAS 

Aircraft Based Augmentation System

GBAS 

Ground Based Augmentation System

SBAS 

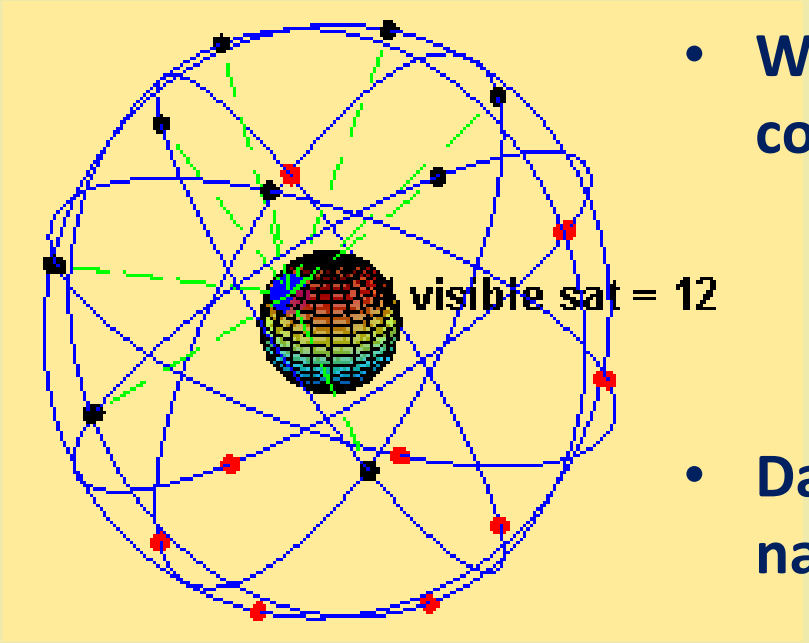
Satellite Based Augmentation System

Navigation Infrastructure

❖ GNSS - GPS

- A 24 satellite constellation

- Position computed in WGS84



- Worldwide coverage

- Accuracy of 10 meters or better

- Database navigation

Navigation Infrastructure

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

Table 3.7.2.4-1 Signal-in-space performance requirements

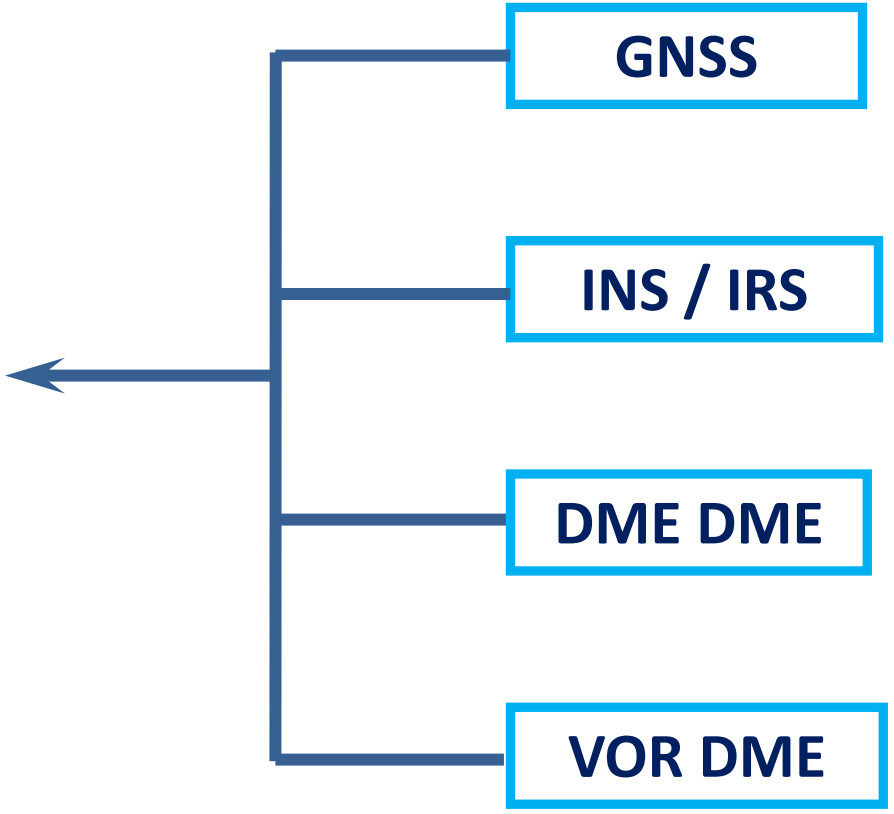
Typical operation	Accuracy horizontal 95% (Notes 1 and 3)	Accuracy vertical 95% (Notes 1 and 3)	Integrity (Note 2)	Time-to-alert (Note 3)	Continuity (Note 4)	Availability (Note 5)
En-route	3.7 km (2.0 NM)	N/A	$1 - 1 \times 10^{-7}$/h	5 min	$1 - 1 \times 10^{-4}$/h to $1 - 1 \times 10^{-8}$/h	0.99 to 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

Navigation Infrastructure

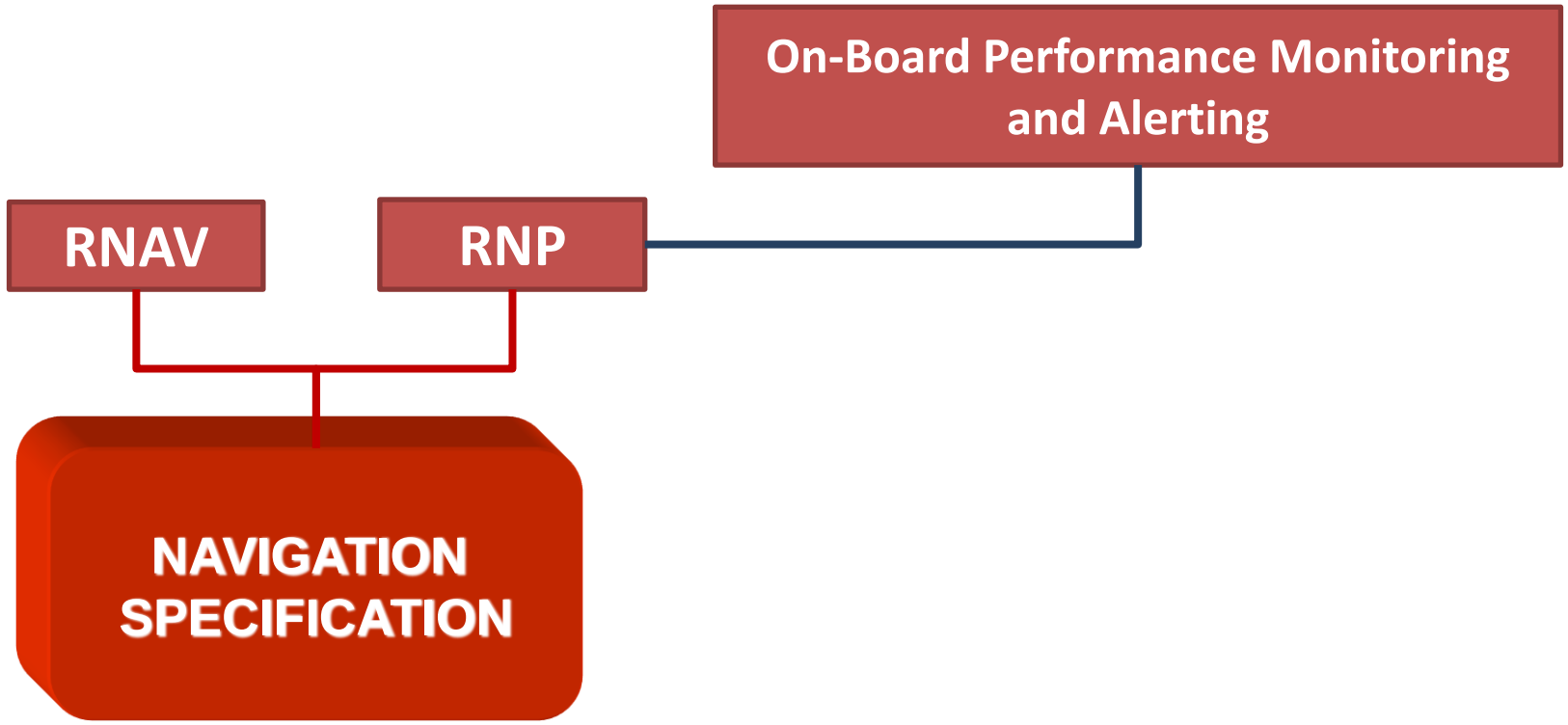
- **Augmentation System**
  - **Satellite Based Augmentation System(SBAS) – covers a large area of a continent**
    - **WAAS – USA**
    - **EGNOS – Europe**
    - **GAGAN - India**
    - **MSAS – Japan**
    - **SDCM – Russia**
    - **KASS - Republic of Korea (by 2023)**
    - **BDSBAS - China (by 2025)**
    - **SouthPAN- Australia-New Zealand(2028)**
  - **Aircraft Based Augmentation System (ABAS)**
    - **RAIM (Receiver Autonomous Integrity Monitoring) - compares a series of position estimations within the GPS unit using redundant (extra) satellite signals.**
    - **AAIM (Aircraft Autonomous Integrity Monitoring)- links the GPS receiver to other aircraft systems such as IRS**

Navigation Infrastructure

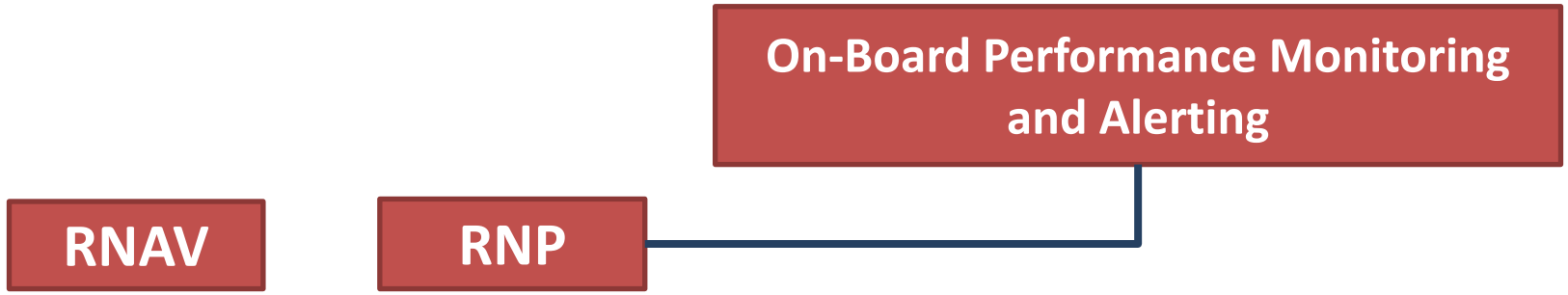
- FMS



Navigation Specification



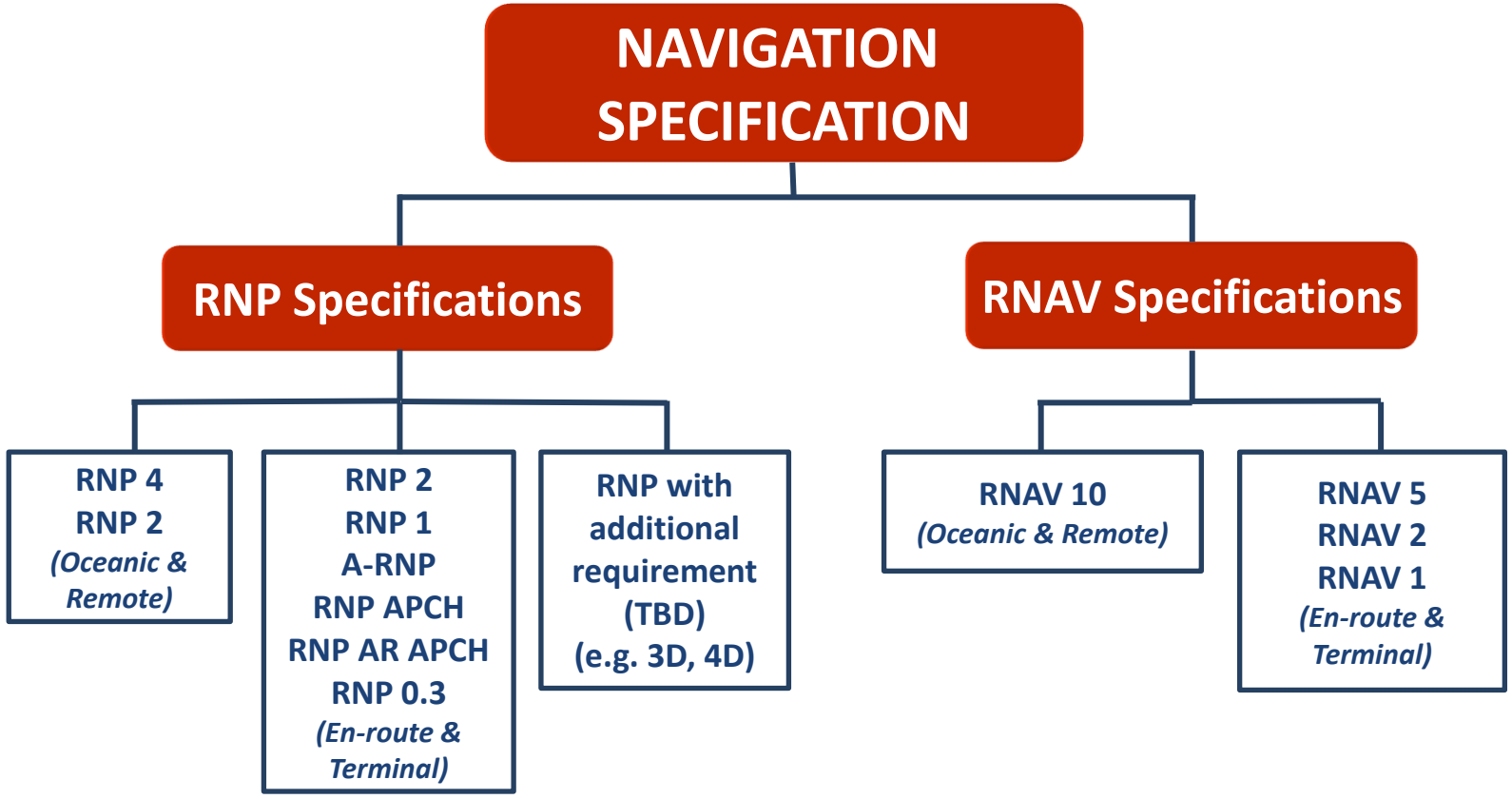
Navigation Specification



- **On-board performance monitoring and alerting capabilities provide:**
  - **Display and indication of both the required and the estimated navigation system performance**
  - **Monitoring of the system performance and alerting the crew when RNP requirements are not met**

The Key Difference : On-Board Performance Monitoring and Alerting

Navigation Specification



Navigation Specification (PBN Manual, Doc 9613)

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

		Navigation application, flight phase and RNAV/RNP value (NM)							
		ATS or user-defined routeing		*Arrival procedures*	*Approach procedures*				*Departure procedures*
Part, chapter	*Navigation specification*	*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

Navigation Specification (PBN Manual, Doc 9613)

Table II-A-1-4. Navigation specifications and (Required or Optional) NAVAID infrastructure

	GNSS	GNSS/inertial navigation system[3]	DME/DME	DME/DME/ inertial navigation system[3]	VOR/DME
RNAV 10[1, 4]	O	O			
RNAV 5[1]	O	O	O	O	O
RNAV 2[1] & 1[1]	O		O	O	
RNP 4	R				
RNP 2	R		O[2]	O[2]	
RNP 1	R		O[2]	O[2]	
ADVANCED RNP	R		O[2]	O[2]	
RNP APCH	R				
RNP AR	R	R			
RNP 0.3	R				

Notes.

1. At least one NAVAID is required for the promulgated associated navigation application.

4. DME and/or VOR may be used to check aircraft navigation accuracy prior to entry into oceanic airspace. DME and/or VOR may also be used to extend the RNAV 10 navigation capability by updating the navigation system, when enroute.

Area Width
(Doc 8168 Vol-II)

The ½ A/W of the obstacle clearance area in all RNAV and RNP applications (except RNP AR) is based upon the following:

½ A/W = 1.5*XTT + BV

Where XTT is the 2σ cross-track tolerance value (known as TSE) and BV is the "buffer value

Phase of flight	*Navigation specification*	*XTT*
En-route and terminal (>56 km (30 NM) from ARP)	RNAV 5	4.65 km (2.51 NM)
En-route and terminal (>56 km (30 NM) from ARP)	RNAV 1 and 2	3 704 m (2.00 NM)
Terminal (<56 km (30 NM) from ARP) to the IAF	RNAV 1 and 2	1 852 m (1.00 NM)

Area Width
(Doc 8168 Vol-II)

Table III-1-2-2. XTT, ATT and area semi-width for RNP 4 in the en-route phase of flight (NM)

En-route/STAR/SID (>30 NM ARP)		
XTT	*ATT*	*½ A/W*
4.00	3.20	8.00

Table III-1-2-4. XTT, ATT, area semi-width for RNP 2 in en-route phase of flight (NM)

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

Area Width
(Doc 8168 Vol-II)

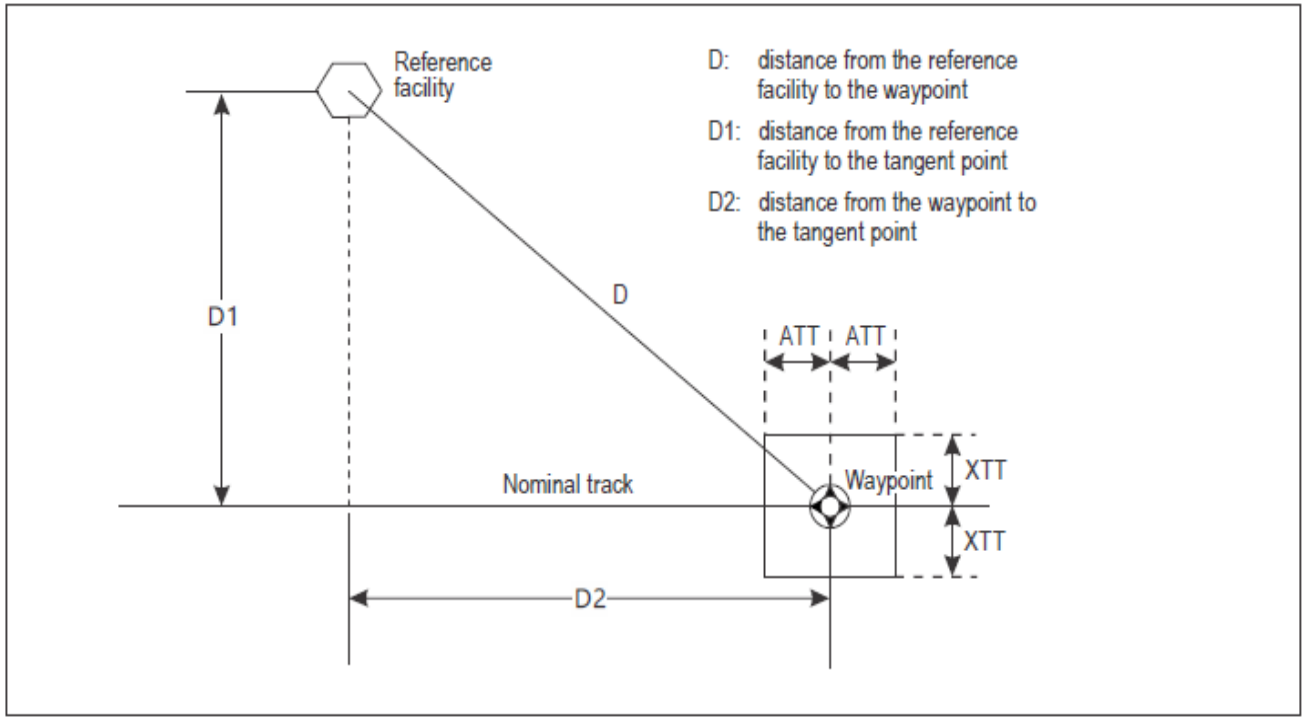
Table III-1-3-8. XTT, ATT, area semi-width for DME RNAV (RNAV 5) in the en-route phase of flight (NM)
Table based on availability of two DME update stations

En-route/STAR/SID (>30 NM ARP)		
XTT	*ATT*	*½ A/W*
For all altitudes		
3.30	2.15	6.95

Area Width
(Doc 8168 Vol-II)

Table III-1-4-2. XTT, ATT, area semi-width for VOR/DME RNAV in the en-route phase of flight (RNAV 5) (NM)

D1	*D2*	*0*	*10*	*20*	*30*	*40*	*50*	*60*	*70*	*80*
0	XTT	2.5	2.6	2.9	3.3	3.8	4.3	4.9	5.5	6.1
	ATT	0.3	0.7	1.4	2.1	2.8	3.5	4.2	4.9	5.6
	½ A/W	5.8	4.9	4.8	4.9	5.6	6.4	9.3	9.2	9.5
10	XTT	2.5	2.6	3.0	3.5	4.0	4.7	5.4	6.1	6.8
	ATT	0.3	0.9	1.6	2.4	3.2	4.0	4.7	5.5	6.3
	½ A/W	5.8	6.0	6.5	7.2	8.1	9.0	10.0	11.1	12.2
20	XTT	2.5	2.7	3.0	3.5	4.1	4.7	5.4	6.1	6.8
	ATT	0.3	0.9	1.7	2.4	3.2	4.0	4.8	5.6	6.3
	½ A/W	5.8	6.0	6.5	7.2	8.1	9.1	10.1	11.1	12.2
30	XTT	2.5	2.7	3.0	3.5	4.1	4.7	5.4	6.1	6.8
	ATT	0.3	0.9	1.7	2.5	3.2	4.0	4.8	5.6	6.4
	½ A/W	5.8	6.0	6.5	7.3	8.1	9.1	10.1	11.2	12.3
40	XTT	2.5	2.7	3.0	3.5	4.1	4.8	5.4	6.2	6.9
	ATT	0.3	0.9	1.7	2.5	3.3	4.1	4.8	5.6	6.4
	½ A/W	5.8	6.0	6.5	7.3	8.2	9.1	10.2	11.2	12.3
50	XTT	2.5	2.7	3.0	3.6	4.1	4.8	5.5	6.2	6.9
	ATT	0.3	1.0	1.7	2.5	3.3	4.1	4.9	5.7	6.4
	½ A/W	5.8	6.0	6.6	7.3	8.2	9.2	10.2	11.3	12.4
60	XTT	2.5	2.7	3.1	3.6	4.2	4.8	5.5	6.2	6.9
	ATT	0.3	1.0	1.8	2.6	3.3	4.1	4.9	5.7	6.5
	½ A/W	5.8	6.0	6.6	7.4	8.3	9.2	10.3	11.3	12.4
70	XTT	2.5	2.7	3.1	3.6	4.2	4.8	5.5	6.2	7.0
	ATT	0.3	1.0	1.8	2.6	3.4	4.1	4.9	5.7	6.5
	½ A/W	5.8	6.1	6.6	7.4	8.3	9.3	10.3	11.4	12.4
80	XTT	2.5	2.7	3.1	3.6	4.2	4.9	5.6	6.3	7.0
	ATT	0.4	1.1	1.8	2.6	3.4	4.2	5.0	5.7	6.5
	½ A/W	5.8	6.1	6.7	7.4	8.3	9.3	10.3	11.4	12.5



Area Width
(Doc 8168 Vol-II)

XTT, ATT, area semi-width for DME RNAV (RNAV 2)(NM)
based on availability of more than two DME update stations

En-route/STAR/SID (>30 NM ARP)

XTT	ATT	½ A/W
1.51	1.13	4.26

Area Width
(Doc 8168 Vol-II)

XTT, ATT and area semi-width for DME RNAV (RNAV 1)(NM)
based on availability of more than two DME update stations

En-route/STAR/SID (>30 NM ARP)

XTT	ATT	½ A/W
0.78	0.61	3.18

XTT, ATT and area semi-width for DME RNAV (RNAV 1)(NM)
based on availability of two DME update stations

En-route/STAR/SID (>30 NM ARP)

XTT	ATT	½ A/W
1.24	1.13	3.85

Area Width
(Doc 8168 Vol-II)

Table III-1-2-6. XTT, ATT and area semi-width for RNP-1 (aeroplane) in arrival and departure phases of flight (NM)

STAR/SID (>30 NM ARP)			*STAR/SID (<30 NM ARP)*			*SID (<15 NM ARP)*		
XTT	*ATT*	*½ A/W*	*XTT*	*ATT*	*½ A/W*	*XTT*	*ATT*	*½ A/W*
1.00	0.80	3.50	1.00	0.80	2.50	1.00	0.80	2.00

Table III-1-2-10. XTT, ATT and area semi-width for Advanced RNP in all phases of flight (Aeroplane) (NM)

RNP	*En- route (Continental & Remote)*			*STAR/SID (>30 NM ARP)*			*STAR/SID (<30 NM ARP) IAF/IF/Missed Approach*			*FAF*			*MAPt*			*Missed Approach/ SID (<15 NM ARP)*		
	XTT	*ATT*	*½ A/W*	*XTT*	*ATT*	*½ A/W*	*XTT*	*ATT*	*½ A/W*	*XTT*	*ATT*	*½ A/W*	*XTT*	*ATT*	*½ A/W*	*XTT*	*ATT*	*½ A/W*
2	2	1.6	5.0	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
1	1	0.8	3.5	1	0.8	3.5	1	0.8	2.5	–	–	–	–	–	–	1	0.8	2
0.3	–	–	–	–	–	–	–	–	–	0.3	0.24	1.45	0.3	0.24	0.95	–	–	–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Thank You