PANS-OPS Flight Procedure Design Training for CAAs

23 August – 03 September 2021

03 – PBN concept
(Doc. 9613)

Content

- Regulatory framework

- Why PBN?

- What is PBN about?

- PBN Terminology

- PBN components

- PBN navigation infrastructure

- PBN navigation specifications

- PBN navigation applications

- Relationship between the PBN components

- PBN benefits

African Flight Procedure Programme (AFPP)
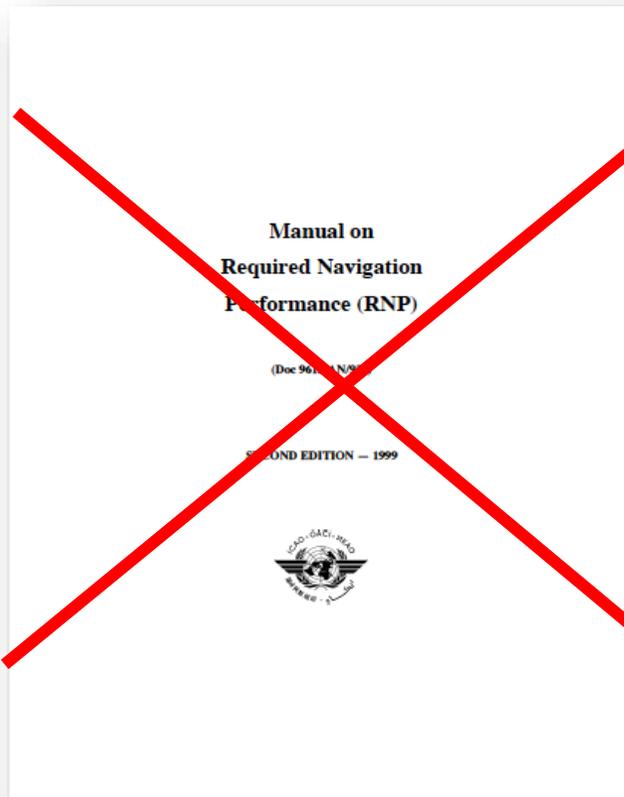
No more RNP
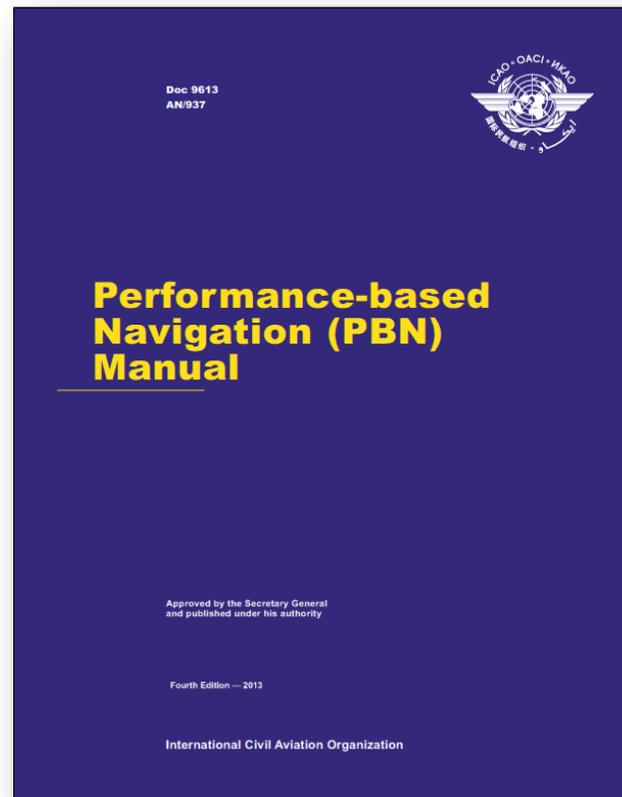
PBN, No more RNP

↗ Doc 9613 - PBN Manual (3rd Ed. 2007), Nav Specs introduced with performance requirements, (Accuracy, Integrity, Continuity, Total System Error) and also FUNCTIONALITY

Volume I:

Concept and Implementation Guidance:
Part A: The PBN concept
Part B: Implementation guidance

Volume II:

Implementing RNAV and RNP ops:
Part A: General
Part B: Implementing RNAV OPS
Part C: Implementing RNP OPS

↗ Doc 9613 – PBN Manual (4th Ed. 2013), new Nav Specs introduced. Additional guidance on implementation and certification provided

❑ Limits of the pre-PBN RNAV:

☞ Only sensor-based;

☞ No clear guidance for aircraft requirements, operating procedures, training requirements;

☞ No clear relationship between on-board avionics and navaids;

☞ Interoperability issues;

☞ Need for global harmonization!
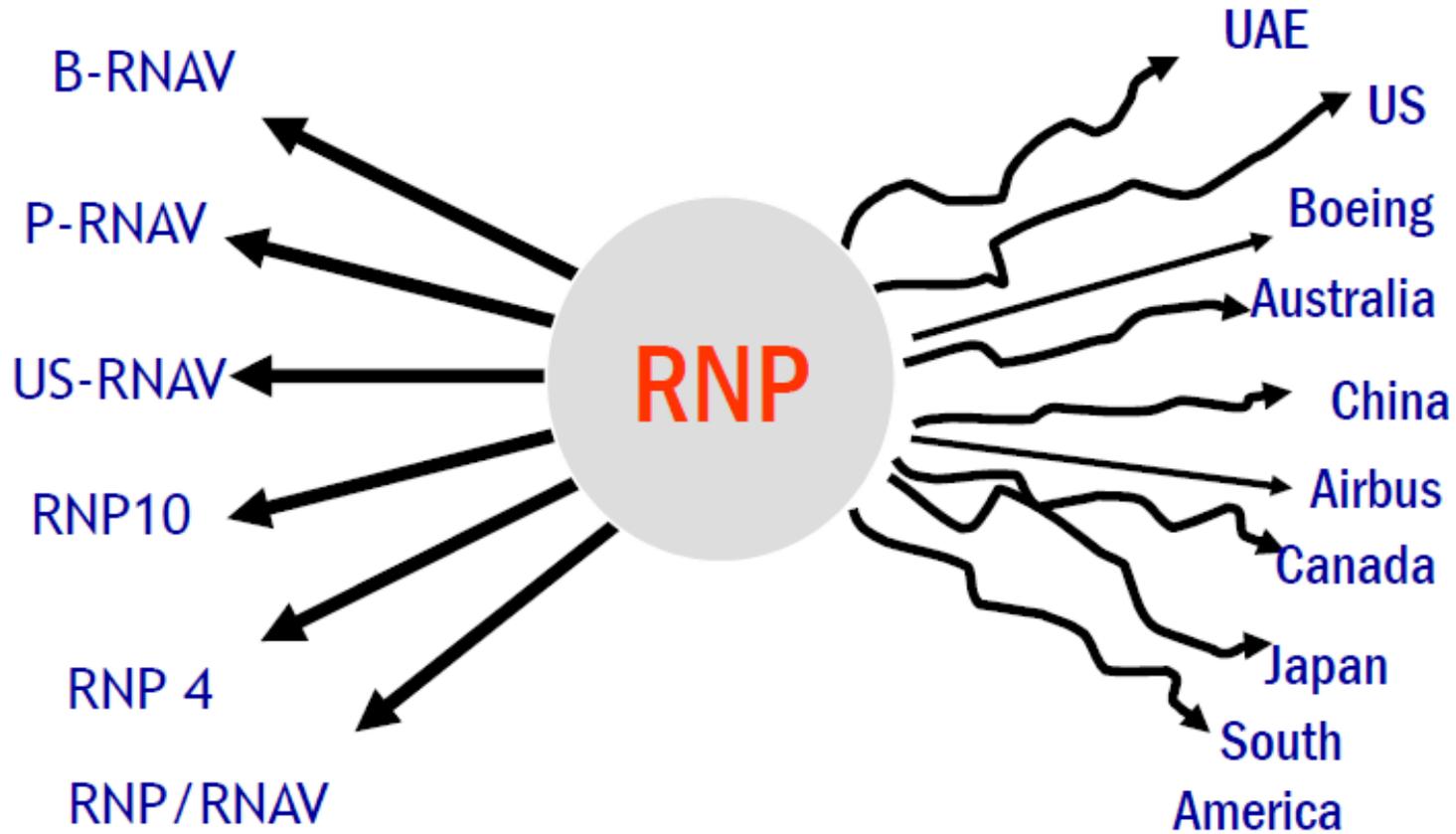
Not safe, not efficient, costly, confusing

NEED FOR GLOBAL HARMONIZATION

Globally Harmonized

❑ PBN is being implemented according to Doc 9613 in the same manner all around the world;

❑ Same design criteria;

❑ Same pilot procedures;

❑ Same ATC separation;

❑ Same phraseology;

❑ Same airspace design principles… this course will address these, should be harmonized as well.

Conventional Routes — Limited Design Flexibility
- Current Ground Navaids

RNAV — Increased Airspace Efficiency
- Waypoints

RNP — Optimized Use of Airspace
- Narrow Obstacle Clearance Areas
- Seamless Vertical Path
- Constant Radius Turn
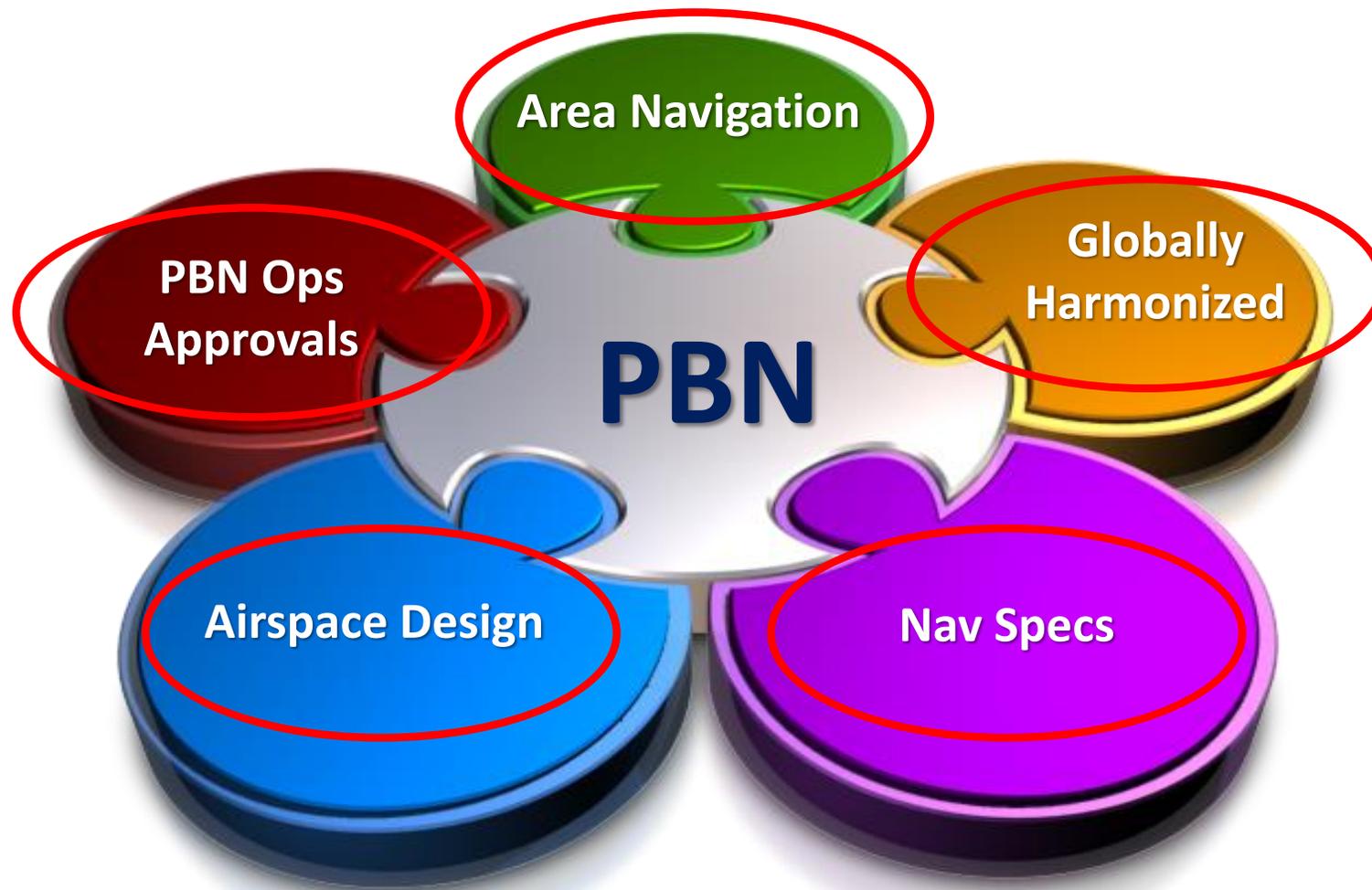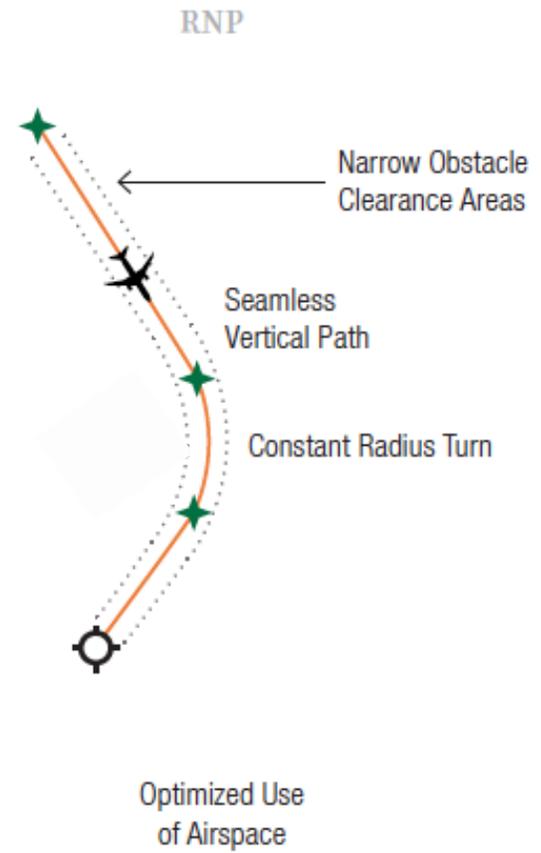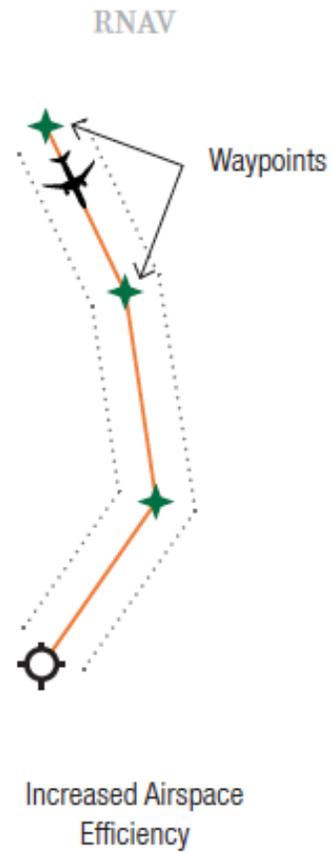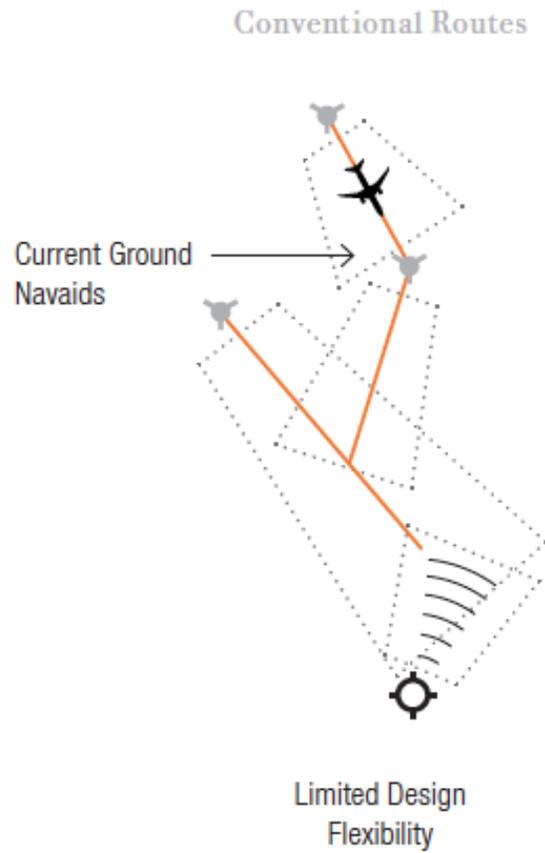
CONVENTIONAL ROUTES COMPARED TO PBN-BASED ROUTES

Review of PBN Theory
PBN TERMINOLOGY

❑Correct terminology is important for clarity:

☞**Area Navigation** is the generic term used for area navigation and should <u>never</u> be abbreviated:

- Area Navigation ≠ RNAV.

☞**RNAV** is used only in reference to **RNAV** specifications or **RNAV** systems.

☞**RNP** is used only in reference to **RNP specifications** or **RNP systems**

- RNP ≠ Required Navigation Performance.

☞"RNP" of "RNAV" is a Nav Spec designator;

☞1, 2 or 4 is a Nav Spec descriptor.

PBN components

ICAO Strategic Objectives

| Safety | Capacity& Efficiency | Security&Facilitation | Economy | Environment |

Airspace concept

Enablers

COM

SUR

Procedures: PANS-ATM, PANS-OPS, Flight crew

NAVIGATION

PBN Concept

Navigation application

Navigation infrastructure
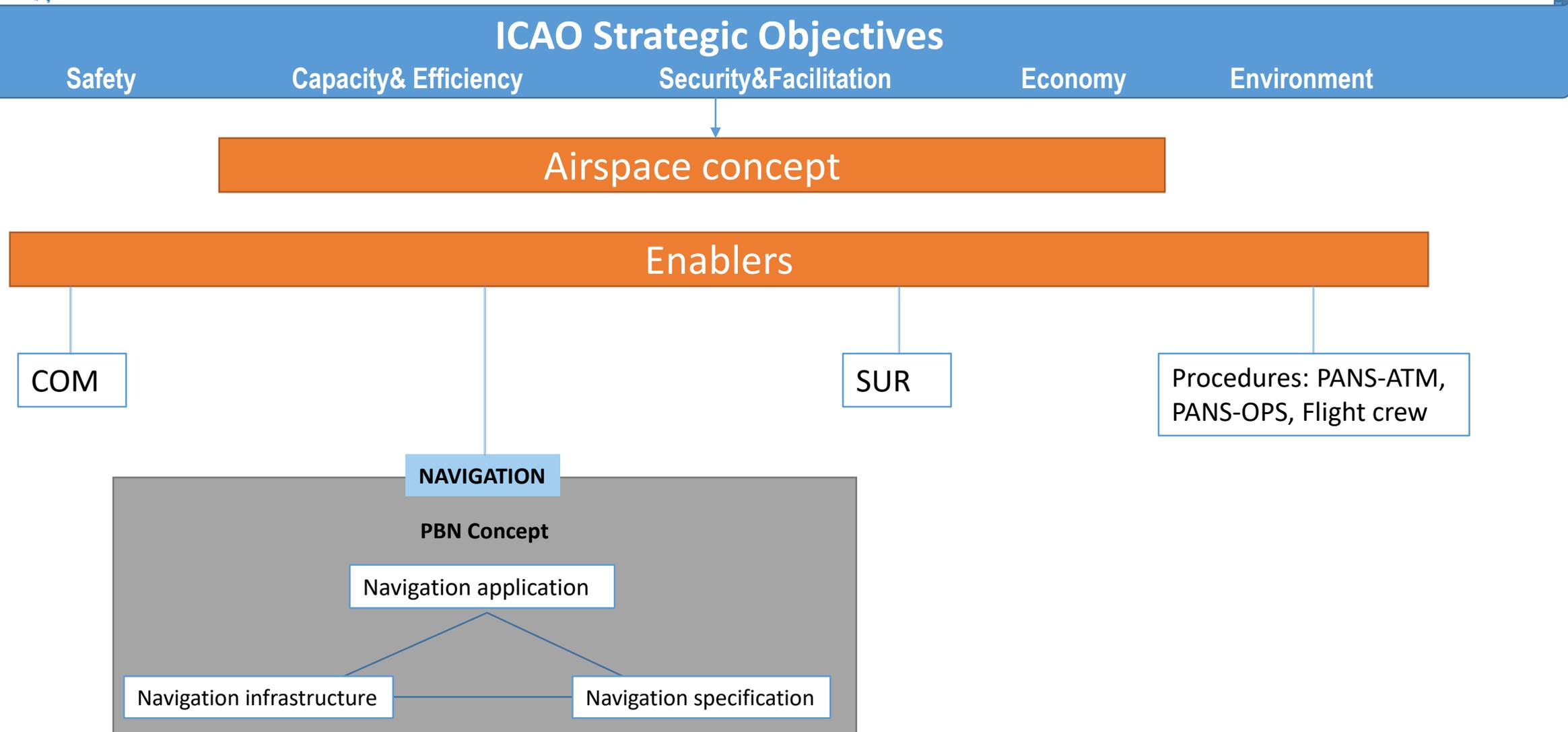
Navigation specification

Components of the PBN
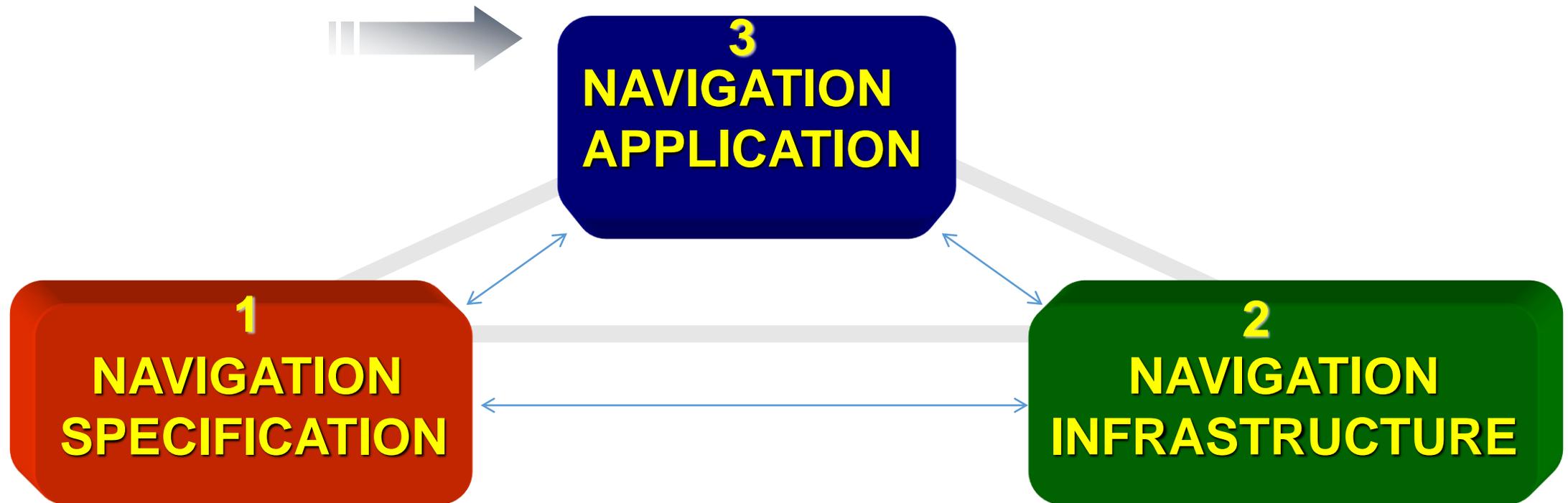
❑Defined in terms of:

☞Performance: **Accuracy, integrity, continuity and availability of the signal.**

❑Specifies:

☞**The required functionalities;**

☞**The navigations sensors;**

☞**The aircrew and ATC requirements;**

☞**The approval process.**

❑Developed for all areas of operation: En-route*, Terminal and Approach.

Functionality

❑ In addition to the performance requirements, PBN also requires certain functionalities:

☞Examples:

- RNP scalability (1.0 to 0.1 NM in any increments);

- Display parameters (moving map);

- Radius to Fix (RF) or other leg types;

- Parallel Offsets;

- Baro-VNAV.

Performance and Functionality

❑ So PBN is about specifying **performance requirements, and functionalities;**

❑ PBN does not rely on any particular nav sensor, like for example a VOR receiver to fly on victor (VOR) airways;

❑ PBN is not <u>sensor</u> specific, it is <u>performance</u> based:

☞Here we mean that performance includes functionality too.

❑ Therefore we can say that PBN is about a shift from **"sensor specific"** to **"performance based".**

NAVIGATION SPECIFICATION

RNAV X

OPMA

RNP X

OPMA

X is the lateral accuracy in NM

Navspec **not requiring** **O**n-board **P**erformance **M**onitoring and **A**lerting system.

Navspec **requiring** **O**n-board **P**erformance **M**onitoring and **A**lerting system.

RNP: OPMA alert

Nominal route

1 NM 95% of the flight time

1 NM 95% of the flight time

RNAV: No OPMA alert
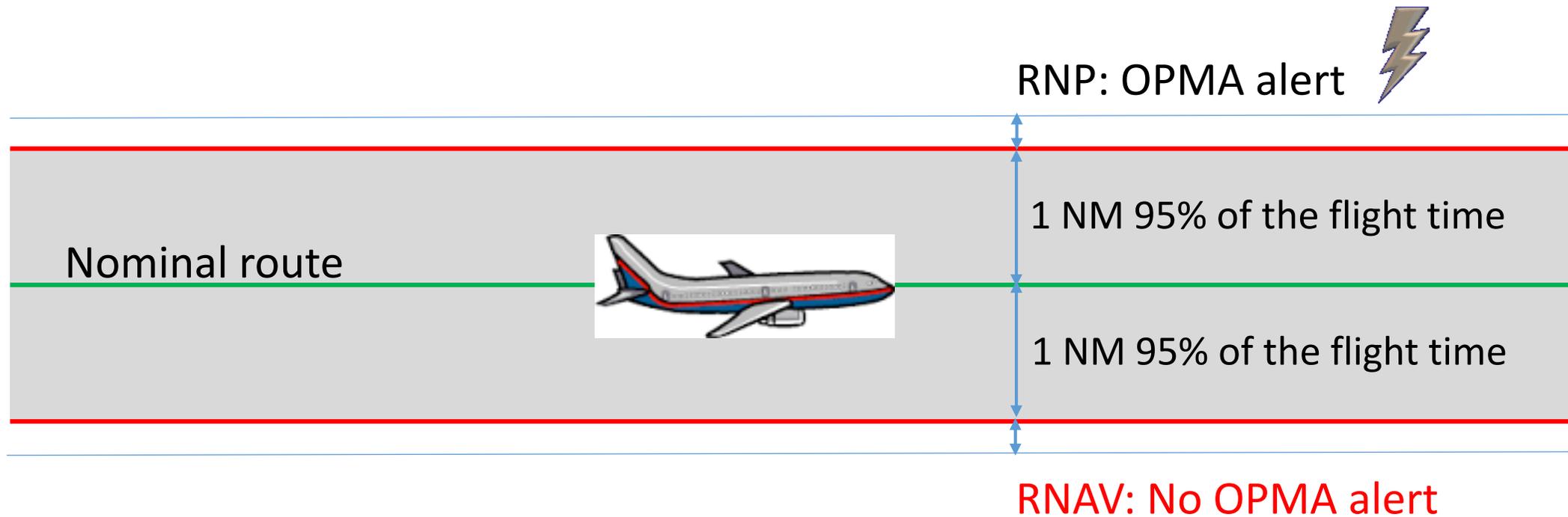
OPMA allows the Crew to DETECT that the RNAV/RNP system no longer meets the REQUIRED PERFORMANCE defined in the navigation specification.

Navigation specifications

RNP specifications
*(includes a requirement for on-board performance monitoring and alerting)*

RNAV specifications
(no requirement for on-board performance monitoring and alerting)

Designation
RNP 4
RNP 2
Oceanic and remote navigation applications

Designation
RNP 2
RNP 1
A-RNP
RNP APCH
RNP AR APCH
RNP 0.3
En-route and terminal navigation applications

Designation
RNP with additional requirements to be determined
(e.g. 3D, 4D)

Designation
RNAV 10
Oceanic and remote navigation applications

Designation
RNAV 5
RNAV 2
RNAV 1
En-route and terminal navigation applications

Navigation infrastructure
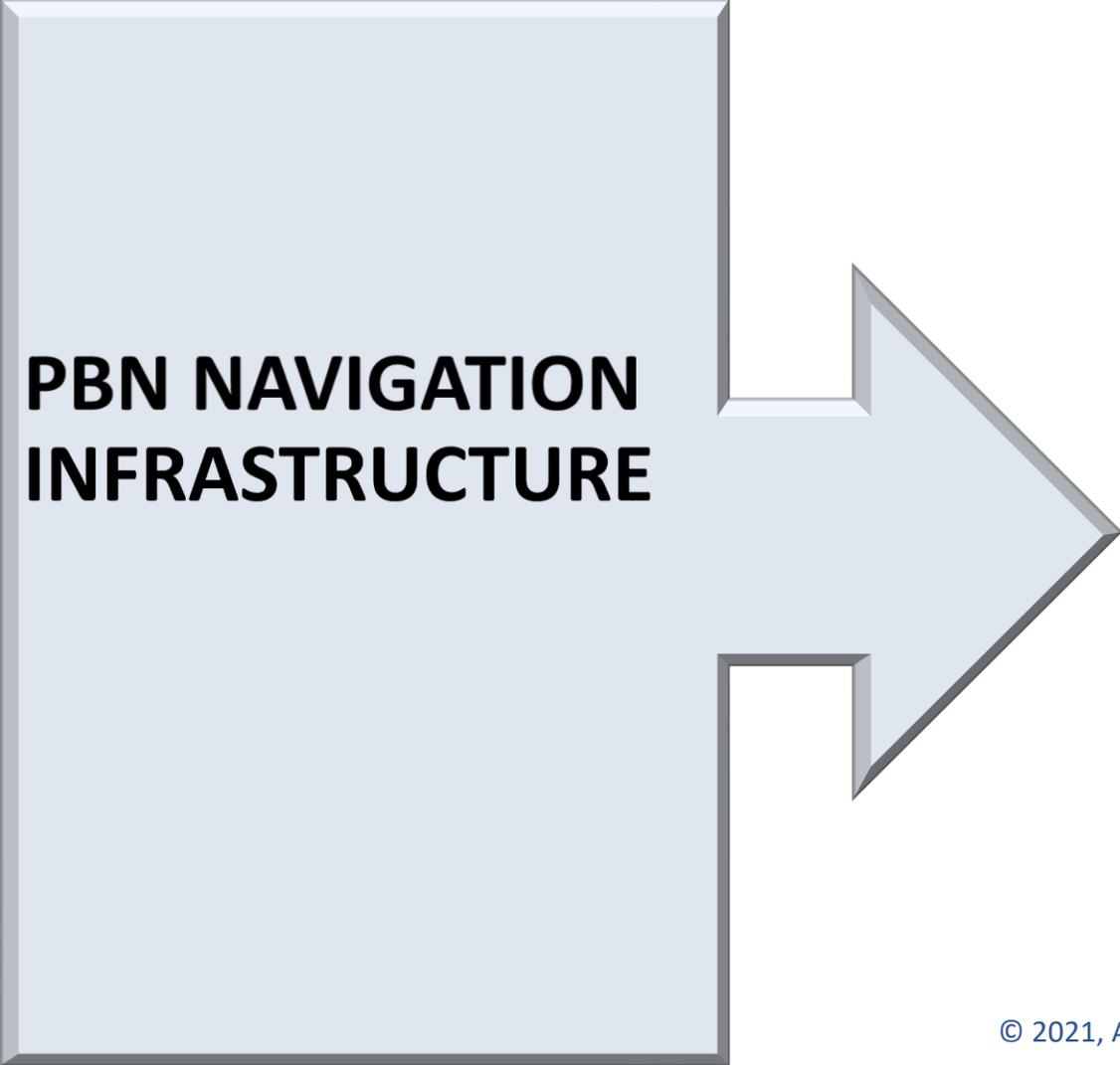
PBN NAVIGATION INFRASTRUCTURE

☐ Ground-based :

☞ VOR-DME, DME/DME, ~~NDB~~

☐ Space-based :

☞ GNSS:

- Augmented GNSS (ABAS, GBAS, SBAS).

• Self-contained:

☞ INS/IRS.

DME DME POSITIONING

DME2

DME4

DME1

d1

DME3
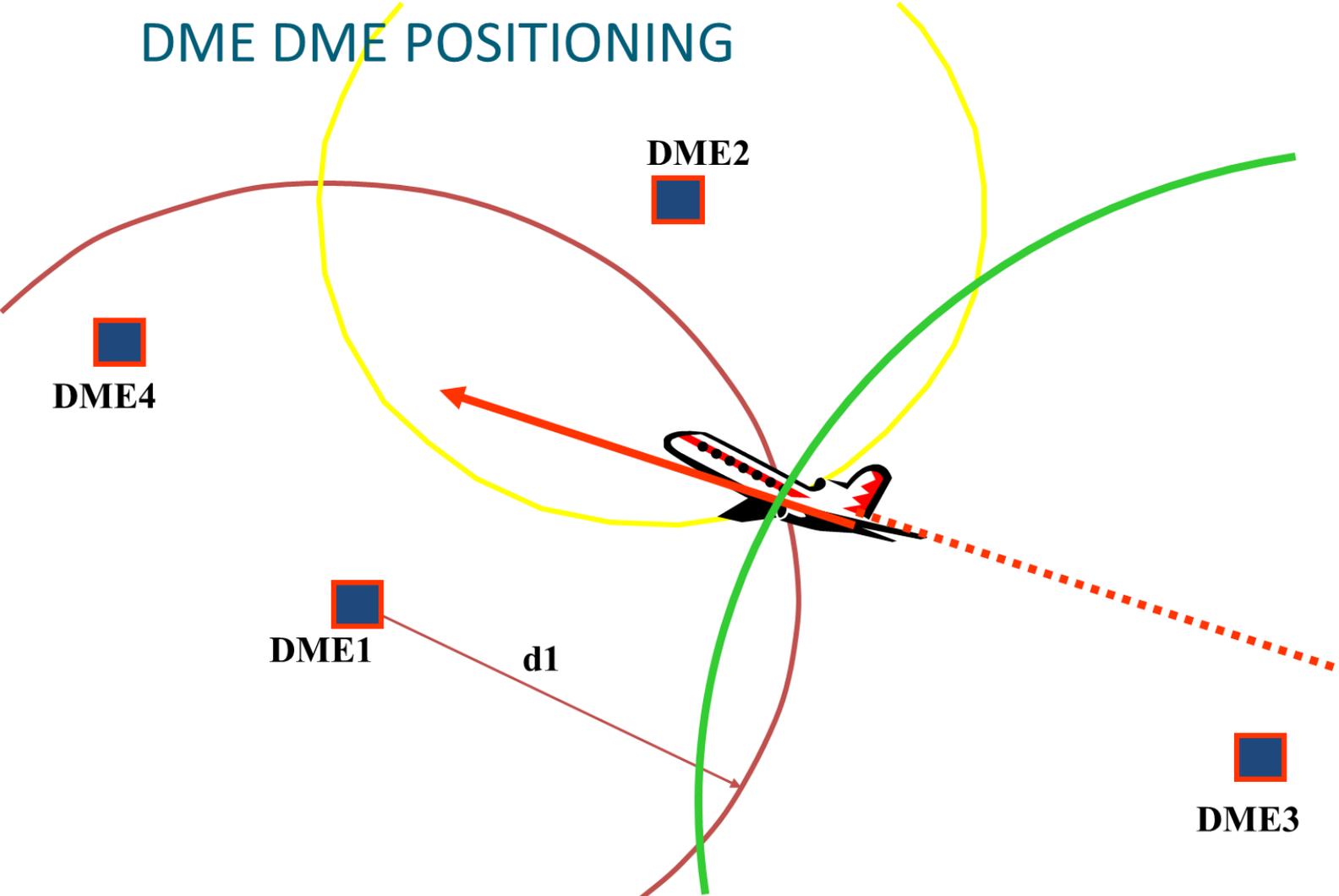
❑ **PBN application** : Use of a **PBN navigation specification** and a **PBN infrastructure** on a given area of operation:

☞ Eg: Use of RNP 1 navspec based on GNSS in terminal operation (SID/STAR).

❑ Four (04) areas of operation (flight phases):

☞ En-route oceanic or remote continental;

☞ En-route continental;

☞ Terminal;

☞ Approach.

Navigation Application

❑ **Some Nav Specs can be "applied" in more than one operating environment, for example…**

☞ **RNAV 5** can be applied on ATS routes in (Continental) En-route airspace or in Terminal airspace beyond 30 NM from the Airport Reference Point (ARP) and above MSA;

☞ **RNP 2** can be applied on ATS routes in Oceanic/Remote, or in (Continental) En-route airspace;

☞ **RNAV 2** can be applied on ATS routes in (Continental) En-route, or on STAR or SID segments beyond 30 NM from ARP;

☞ **A-RNP** can be applied on ATS routes in (Continental) En-route, or in Terminal Areas on STARs or SIDs;

☞ **RNP 1** or **RNAV 1** can be applied on inter-city ATS routes of short distances or in Terminal Areas on STARs or SIDs.

Application by RNAV and RNP

Navigation Application	Navigation specifications	
	RNP	RNAV
En-route oceanic & remote continental	RNP 4, RNP 2	RNAV 10
En-route continental	RNP 2, A-RNP, RNP 0.3	RNAV 5, 2, 1
Terminal	RNP 1, A-RNP, RNP 0.3	RNAV 5, 2, 1
Approach	RNP APCH, RNP 0.3, A-RNP 0.3, RNP AR	

Navigation Application

Departure	En Route	Arrival	Approach
RNAV 1, RNP 1, A-RNP	RNAV 2 and A-RNP, Oceanic: RNP 2, RNP 4, and RNP 10	RNAV 1, RNP 1, A-RNP	
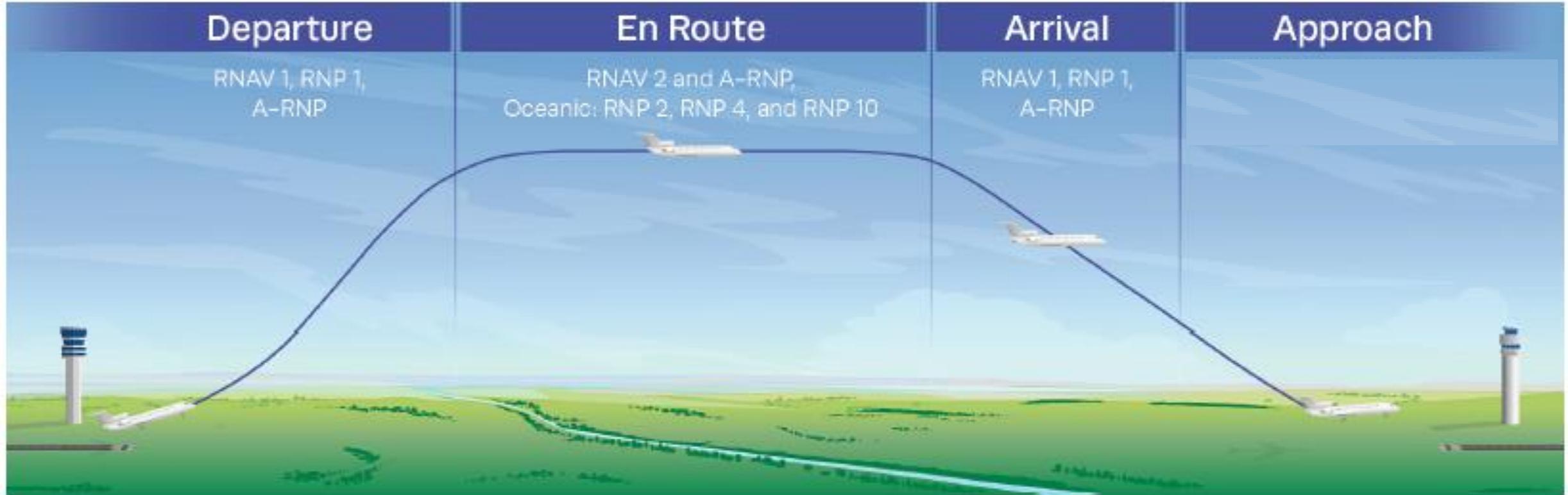
RNAV 10, **RNP 4** ⟶ **RNP APCH**

RNAV 1 SID   RNAV 2   **RNP 1** STAR   **RNP AR APCH**

Relationship between the PBN components

En-route oceanic & remote continental

PBN APPLICATION		RNP 4		RNP 2	RNAV 10
NAVAID		GNSS		GNSS	GNSS, INS
NAVPEC	Sensor	OPMA		OPMA	GNSS, INS
	Performance	TSE ≤ 4 NM		TSE ≤ 2 NM	TSE ≤ 10 NM
	Leg type	CF – DF – TF		DF – TF - FRT	-
	Functionality	Offset – FB turn		Offset – FB turn	-
	Surveillance	Non radar		Non radar	Non radar
COMMUNICATION		Voice	CPDLC + ADSC	Voice	Voice
	Separation Minima	50 NM	30 NM	Variable	50 NM
	Publication	RNP 4		RNP 2	RNP 10 *

Relationship between the PBN components

En-route continental

PBN APPLICATION			RNP 2	RNP 0.3	RNAV 5	
NAVAID			See Previous slide	GNSS	VOR-DME, DME/DME, GNSS, INS/IRS	
NAVPEC	Sensor			OPMA	VOR-DME, DME/DME, GNSS, INS/IRU	
	Performance			TSE ≤ 0.3 NM	TSE ≤ 5 NM	
	Leg type			DF - TF	-	
	Functionality			Offset – FB turn	Offset	
	Surveillance			Not dependent	Non radar	Radar
COMMUNICATION				Not dependent	Voice	
	Separation Minima			Doc. 4444	Variable	
	Publication			-	RNAV 5	

Relationship between the PBN components

En-route continental

PBN APPLICATION		RNAV 2	RNAV 1
NAVAID		GNSS, DME/DME, DME/DME/IRU	GNSS, DME/DME, DME/DME/IRU
NAVPEC	Sensor	GNSS, DME/DME, DME/DME/IRU	GNSS, DME/DME, DME/DME/IRU
	Performance	TSE ≤ 2 NM	TSE ≤ 1 NM
	Leg type	IF CF TF DF VA VM VI CA FA FM	IF CF TF DF VA VM VI CA FA FM
	Functionality	Data base (LOA) – FB turn	Data base (LOA) – FB turn
	Surveillance	Radar	Radar or FOSA
COMMUNICATION		Voice	Voice
	Separation Minima	Radar (at least 8 NM)	Radar
	Publication	RNAV 2 (Critical DME*)	RNAV 1 (Critical DME*)

Relationship between the PBN components

Terminal

PBN APPLICATION			RNAV 2, 1	RNP 1
NAVAID			See previous	GNSS
NAVPEC	Sensor			OPMA
	Performance			TSE ≤ 1 NM
	Leg type			IF CF TF DF VA VM VI CA FA FM
	Functionality			Data base – FB turn
	Surveillance			Non radar
COMMUNICATION				Voice
	Separation Minima			Doc 4444
	Publication			RNP 1

Relationship between the PBN components

Approach

PBN APPLICATION		RNP APCH	RNP AR
NAVAID		GNSS	GNSS
NAVPEC	Sensor	OPMA	OPMA
	Performance	Final 0.3 NM	From 0.3 to 0.1
	Leg type	IF TF DF	IF CF TF DF VA VM VI CA FA FM RF
	Functionality	Data base (LOA) FB turn	Data base (LOA) FB turn VNAV
	Surveillance	Radar or not	Radar or not
COMMUNICATION		Voice	Voice
	Separation Minima	Doc 4444	Doc 4444
	Publication	RNAV (GNSS) RWY XX or RNP RWY XX	RNAV (RNP) RWY xx or RNP RWY XX (AR)

NAVIGATION SENSORS

NAV SPECS	GNSS	INS/IRS	DME/DME	DME/DME/IRU	VOR/DME
RNP (RNAV) 10	X	X			
RNP 4	X				
RNAV 5	X	X	X	X	X
RNAV 1 & 2	X		X	X	
RNP 2	X				
A-RNP	X				
RNP 1	X				
RNP 0.3	X				
RNP APCH	X				
RNP AR APCH	X		(X)		

Review of PBN Theory

DIFFERENCE BETWEEN RNAV AND RNP

What makes RNP different from RNAV?

❑ **RNAV**

☞ Use of ground-based NAVAIDs for navigation allowed;

☞ Cheaper older aircraft (FMS + LNAV);

☞ More aircraft can meet requirements;

☞ Easier to implement, but yields **less efficient procedures.**

❑ **RNP**

☞ FMS requires GNSS (FMS + [LNAV/VNAV]);

☞ Modern, newer airplanes;

☞ Less aircraft can meet these more demanding requirements;

☞ More complex to implement, but yields **more efficient procedures.**

What makes RNP different from RNAV?

❑ We can also use the term **RNAV** to refer to an **RNAV System:**

☞FMS may use INS or DME/DME or DME/DME/IRU or VOR/DME ;

☞No requirement for vertical navigation, and much less functionality.

❑ We can also use the term **RNP** to refer to an **RNP System:**

☞FMS requires GNSS!!

☞Selectable Performance – 2.0, 1.0, 0.75, 0.3, 0.15 NM ;

☞Vertical Navigation (VNAV) and other functionality like RF legs.

❑ **PBN:**

☞ Clarifies RNP and RNAV operations;

☞ Facilitates operational approval process;

☞ Improves safety:

- Reduces CFIT;
- Consistent and predictable flight path;
- Stabilized approach paths.

☞ Improves operating returns by reducing:

- Fuel costs;
- Investment in ground-based system and their maintenance;
- Flight time through direct routes.

☞ Increases airspace capacity:

- More efficient direct routes;
- Reduces airspace conflicts.

☞ Is environmentally friendly:

❑ ATC benefits:
- ☞ Safety culture;
- ☞ Greater predictability;
- ☞ Airspace containement;
- ☞ Fewer missed appraoches;
- ☞ Less transit occupancy time;
- ☞ Best practices involving stakeholders in design.

Radar / Conventional vs. PBN

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Review of PBN Theory
SUMMARY

Summary

- **What is PBN about?**

  - Area Navigation, Globally Harmonized, Implementing Nav Specs.

- **Nav Specs and Application / Airspace Concept:**

  - All the RNAV and RNP Nav Specs / Nav Application, Nav Spec, Nav Infrastructure.

- **PBN Terminology:**

  - Please don't use the abbreviation RNAV for area navigation.

- **Performance and Functionality:**

  - Accuracy, Integrity, Continuity and TSE, RNP route structure.

- **Difference between RNAV and RNP:**

  - RNP requires On-board Performance Monitoring and Alerting (OPMA) system.

Comprehension Check

1. In addition to specifying performance, what else is required by PBN?

   ☞ Functionalities.

2. PBN is about moving from "sensor specific" to…

   ☞ Performance based.

3. What distinguishes RNP Nav Specs from RNAV Nav Specs?

   ☞ RNAV may use ground aids, RNP not! VNAV possible with RNP.

4. What is a Nav Spec descriptor?

   ☞ Follows the PBN designator. Specifies the lateral accuracy.

5. What are the three PBN components?

   ☞ Navspecs, nav infrastructure, nav application.

Comprehension Check

6. What is meant by "Navigation Application"?
   - ☞ Use of a PBN navigation specification and a PBN infrastructure on a given area of operation.

7. Which Nav Specs can be implemented in TMA airspace?
   - ☞ RNAV 5, 2, 1, RNP 1, A-RNP, RNP 0.3

8. Give one advantage and one disadvantage of RNP.
   - ☞ More complex to implement, but yields more efficient procedures.

9. Where in the PBN Manual do you find information about PBN Implementation?
   - ☞ Volume II.

Questions:

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