Performance-based Navigation (PBN) Route Laboratory Workshop

Nairobi, 22 – 26 May 2023

Review of the PBN concept
(Doc. 9613, 5th edition)

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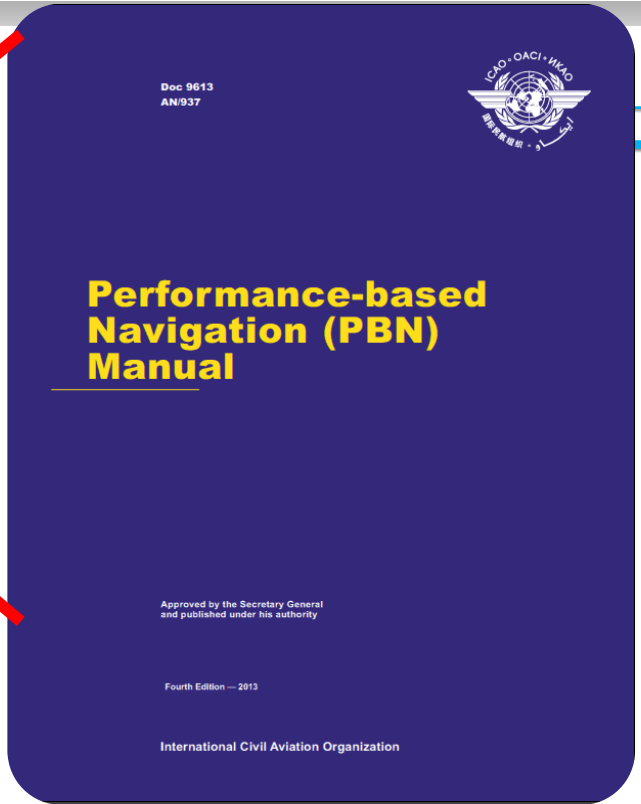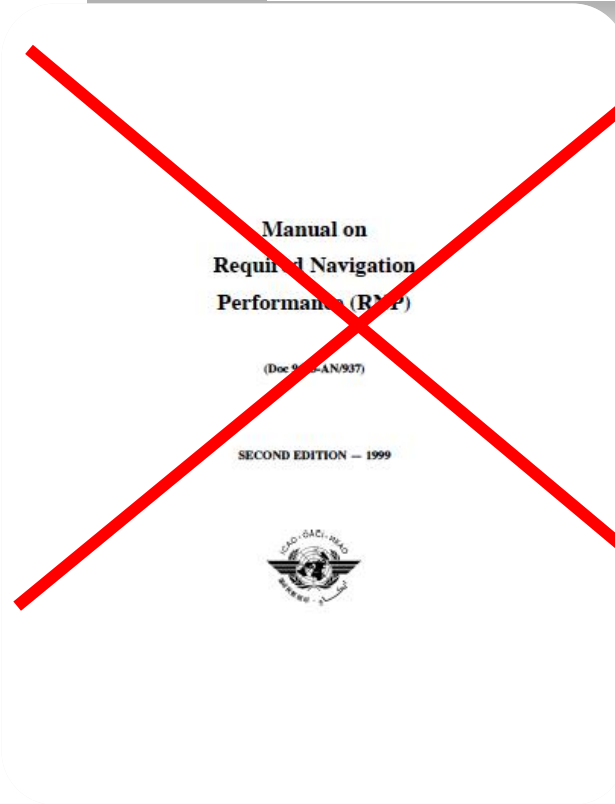
PBN implementation process

Summary

Review of the PBN concept

REGULATORY FRAMEWORK

Doc 9613
AN/937

**Performance-based
Navigation (PBN)
Manual**

Approved by the Secretary General
and published under his authority

Fourth Edition — 2013

International Civil Aviation Organization

Manual on
Required Navigation
Performance (RNP)

(Doc 9613-AN/937)

SECOND EDITION — 1999

RNP Manual

Superseded the RNP Manual

African Flight Procedure Programme (AFPP)

❑ Third edition, 2007:
- ☞ Navspecs introduced with performance requirements (Accuracy, integrity, continuity and functionality.
- ☞ Volume 1: Concept and implementation guidance:
  - ▪ Part A: PBN concept;
  - ▪ Part B: Implementation guidance
- ☞ Volume II: Implementing RNAV & RNP operations:
  - ▪ Part A: General;
  - ▪ Part B: implementing RNAV operations;
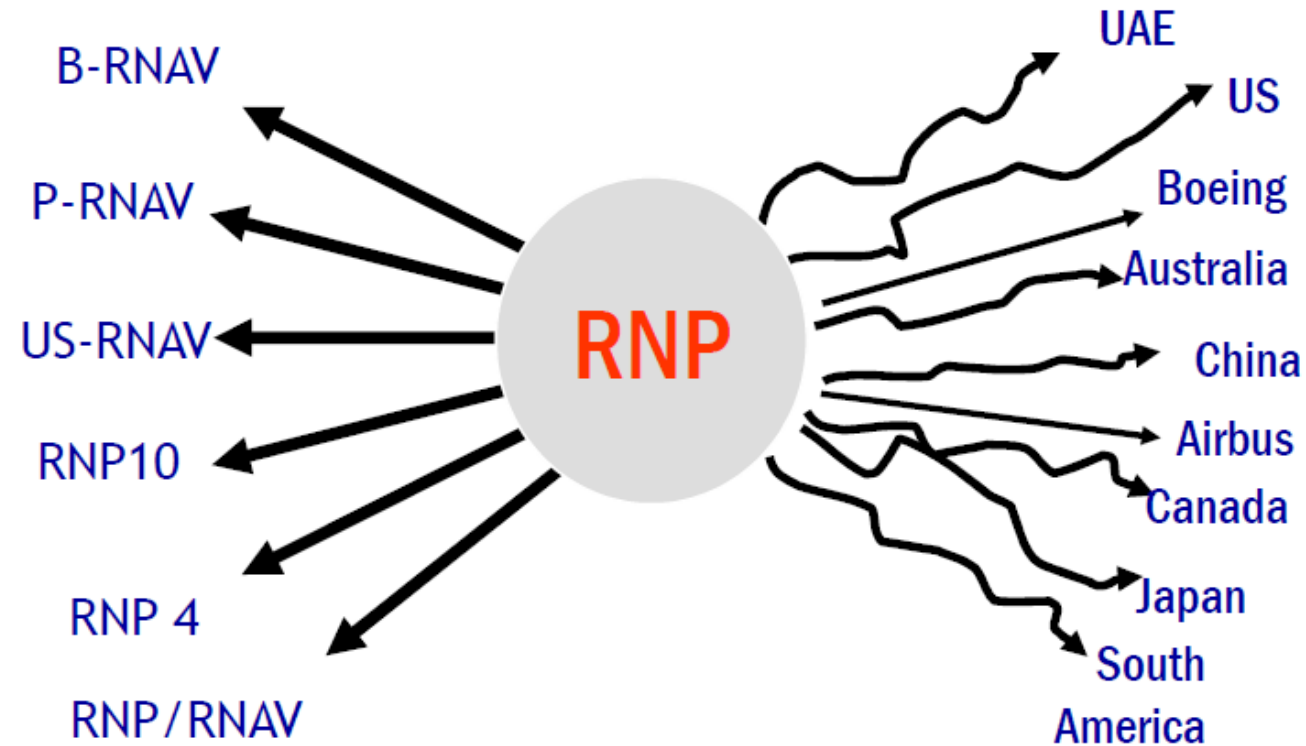 - ▪ Part C: Implementing RNP operations

❑ Fifth edition, 2023 (Advanced unedited)

Review of the PBN concept

WHY PBN?

Not safe, not efficient, costly, confusing

NEED FOR GLOBAL HARMONIZATION

What is PBN about?

❑ Transitioning to area navigation in a globally harmonized manner by means of implementing navigation specifications;

❑ ...transitioning from what?

☞ From conventional navigation to performance-based navigation, or from local or regional area navigation to performance-based area navigation.

❑ ...Why globally harmonized?

☞ To enable airlines to operate seamlessly from one State to another;

☞ Same airspace design principles;

☞ Same phraseology, separation and control procedures;

☞ To reduce the number of operational approvals.

❑ ... How?

☞ By the use of performance and additional requirements.

What is PBN about?

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….

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Review of the PBN concept
PBN TERMINOLOGY

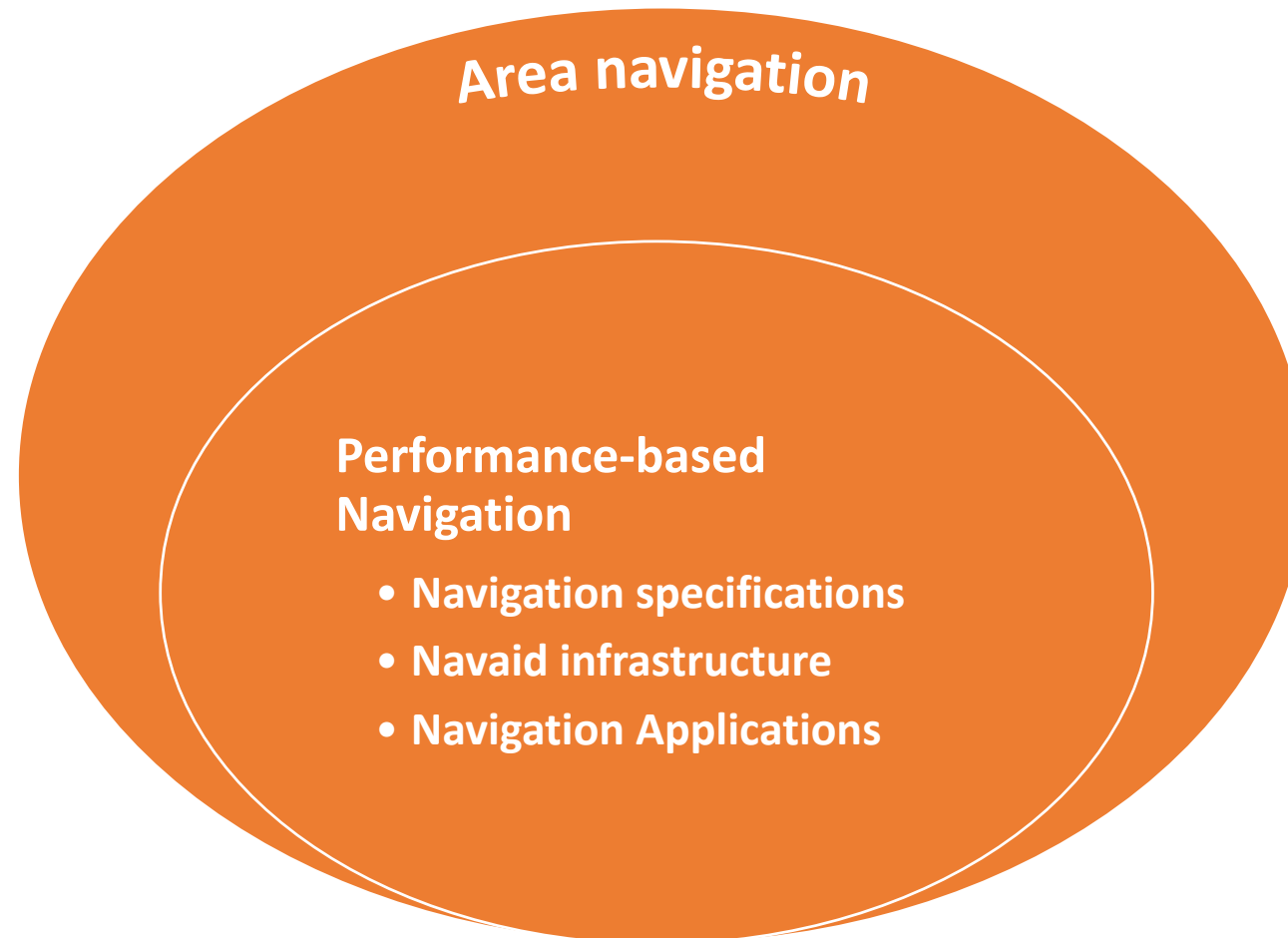❑ **Correct terminology is important for clarity:**

☞ **Area Navigation** is the generic term used for area navigation and should not be abbreviated to avoid confusion:

- **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" and "RNAV" are Navspec designator;

- 1, 2 or 4 is a Navspec descriptors (accuracy).
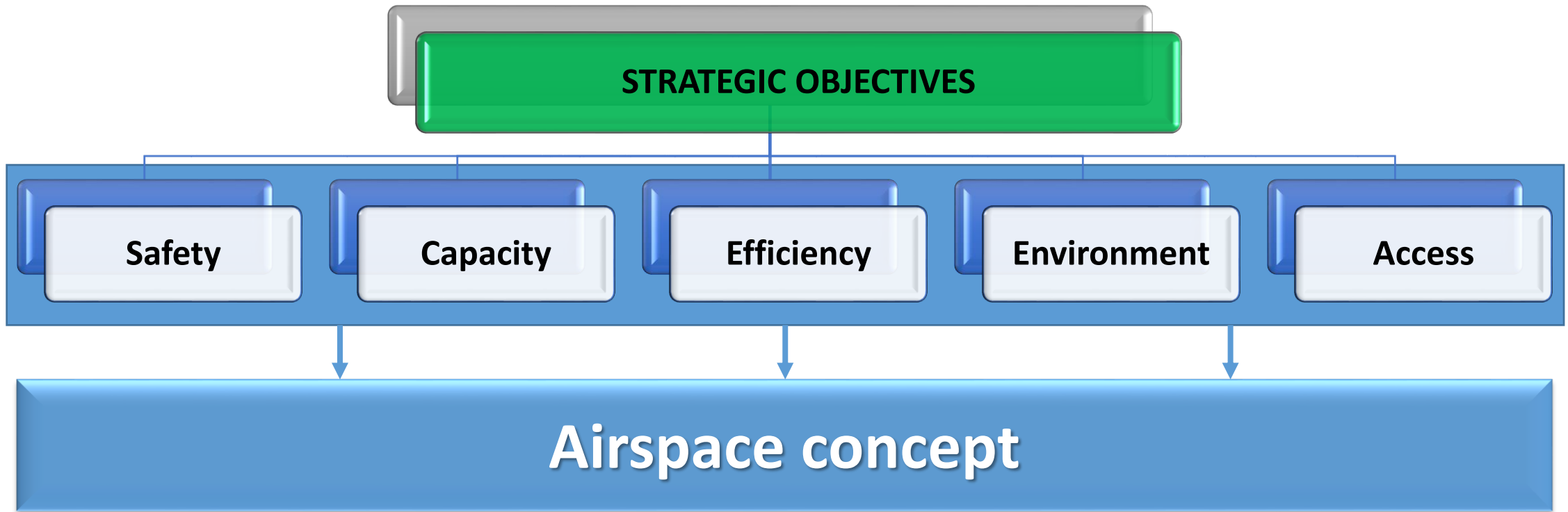
Review of PBN concept

PBN CONCEPT

African Flight Procedure Programme (AFPP)

Area navigation

Performance-based Navigation

- **Navigation specifications**
- **Navaid infrastructure**
- **Navigation Applications**

The airspace concept


```
STRATEGIC OBJECTIVES
```

| Safety | Capacity | Efficiency | Environment | Access |

Airspace concept

African Flight Procedure Programme (AFPP)

Airspace concept

Enablers

COM

SUR

ATC Tools

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

Navigation Performance-based concept

Navigation application

Navigation specification

Navaid infrastructure

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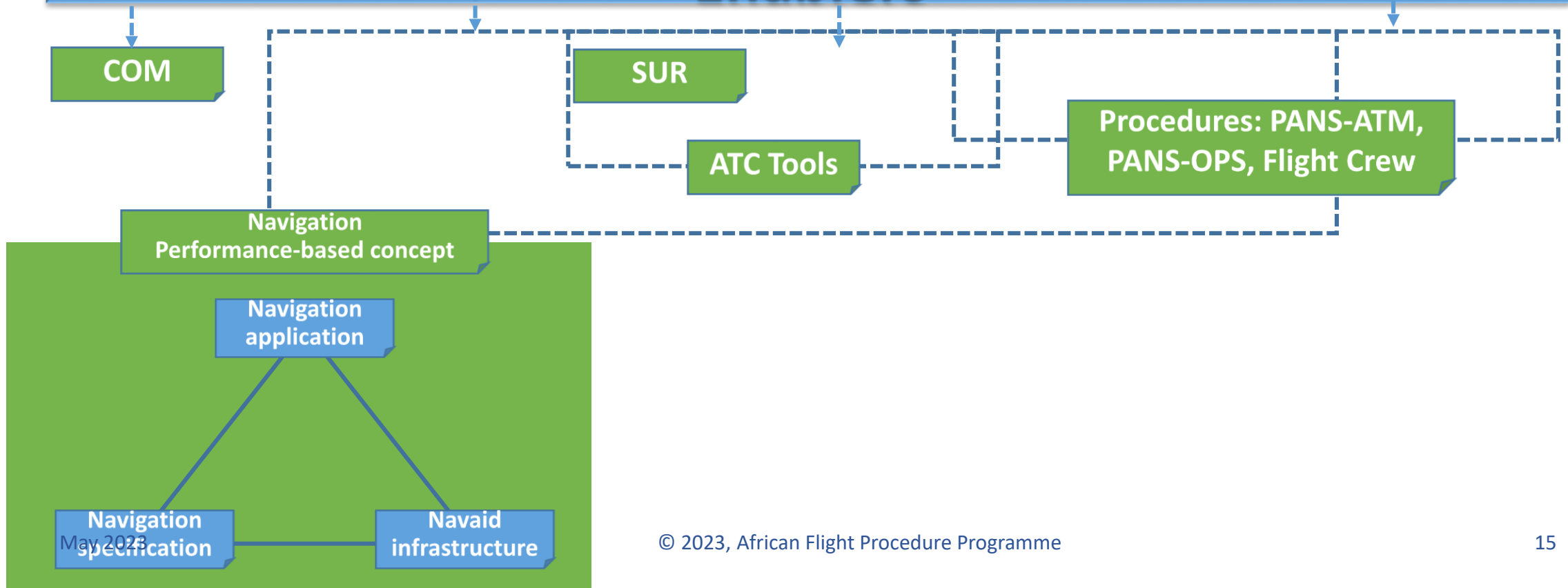
Description of the Performance-based Navigation

❑ PBN concept:

☞ Specifies aircraft RNP or RNAV system performance in terms of: accuracy, integrity, continuity and functionalities:

- Required for the intended operation;

- In a particular airspace concept.

☞ Is supported by appropriate Navaid infrastructure;

☞ Shall comply with WGS-84 data and prescribed data quality (Annex 15).

Description of the Performance-Based Navigation

❑ PBN also defines:
- ☞ Navigation functional requirements:
  - ▪ Bearing & distance to the next waypoint
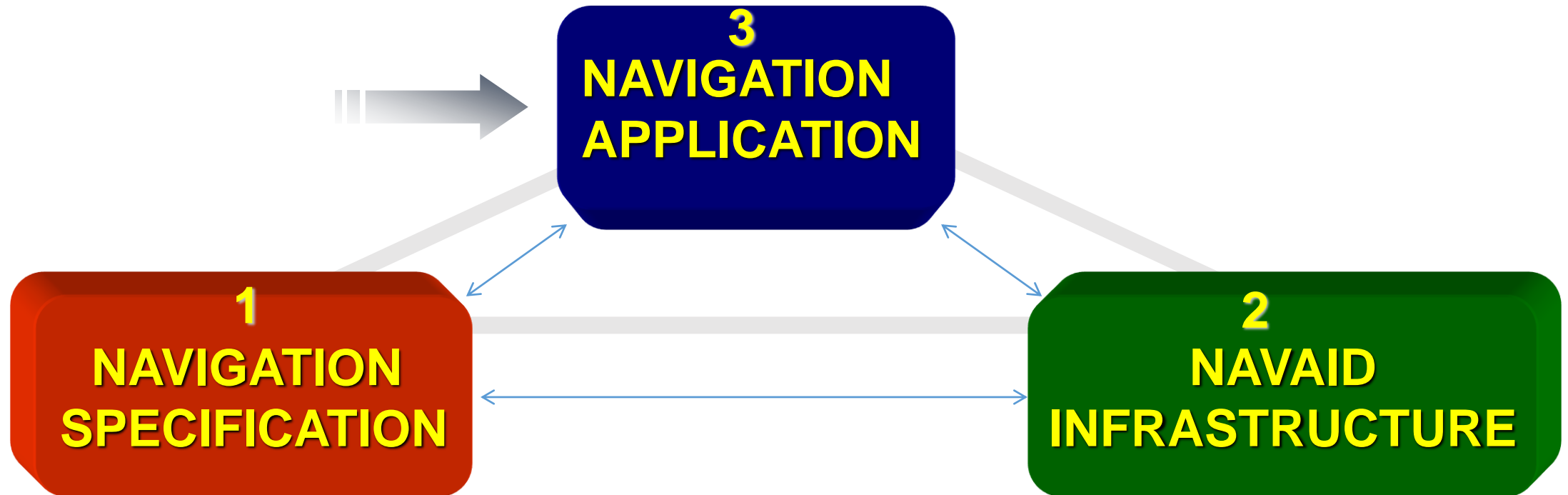 - ▪ Navigation data storage;
  - ▪ Etc.
- ☞ Training requirements:
  - ▪ For ATC and pilots.
- ☞ Additional requirements:
  - ▪ Contingency procedures (flight crew);
  - ▪ ATC procedures.

The PBN Components

May 2023

Navigation specifications

❑ **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.**

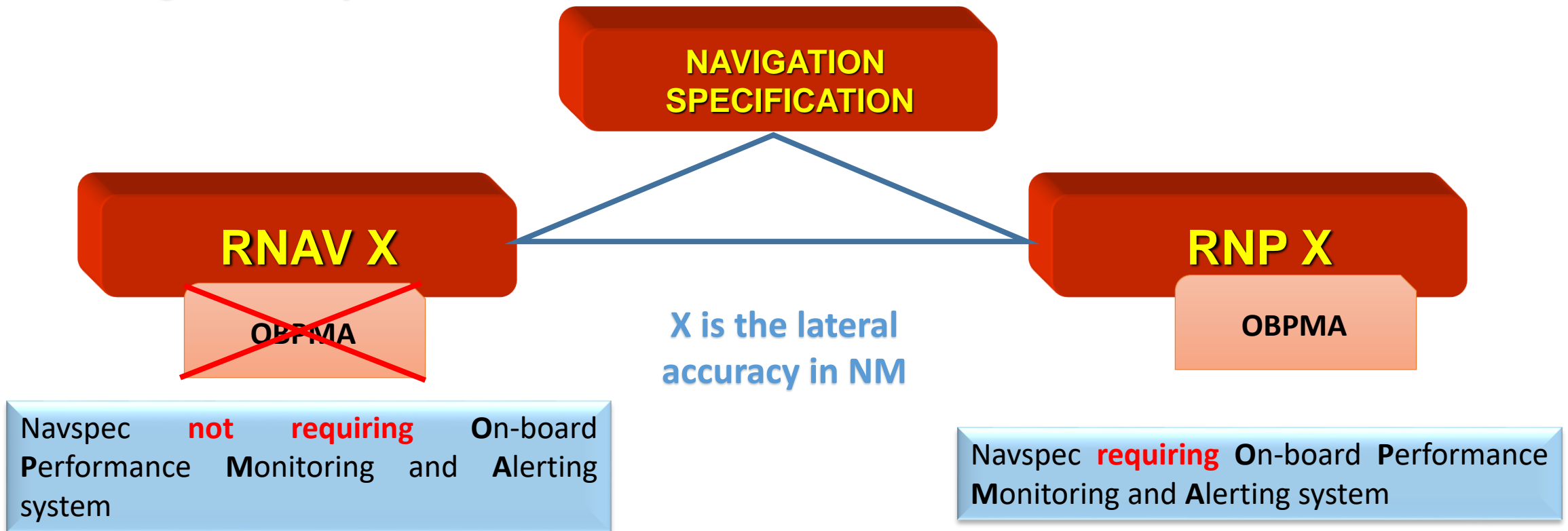❑ **Developed for all areas of operation: En-route, Terminal and Approach.**

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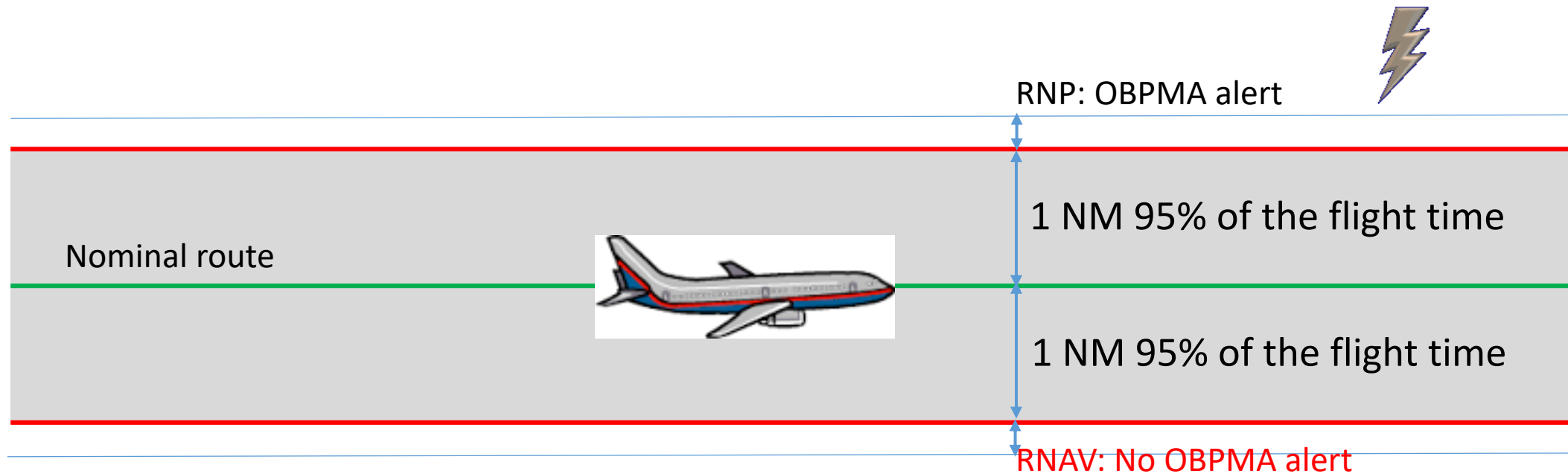
❑ In addition to the performance requirements, PBN also requires certain functionalities:

☞Examples:

- Continuous display of the deviation;
- Display parameters: moving map, bearings and distances, active waypoint;
- Radius to Fix (RF) or other leg types;
- Parallel Offsets;
- Baro-VNAV.

Navigations specifications

NAVIGATION SPECIFICATION

RNAV X

OBPMA

RNP X

OBPMA

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: OBPMA alert

1 NM 95% of the flight time

Nominal route

1 NM 95% of the flight time

RNAV: No OBPMA alert

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

Other requirements

❑ Training and additional requirements are addressed in Doc. 9613, volume II for each navspec.

❑ Operational approval requirements are provided in Doc. 9997.

Navigation infrastructure
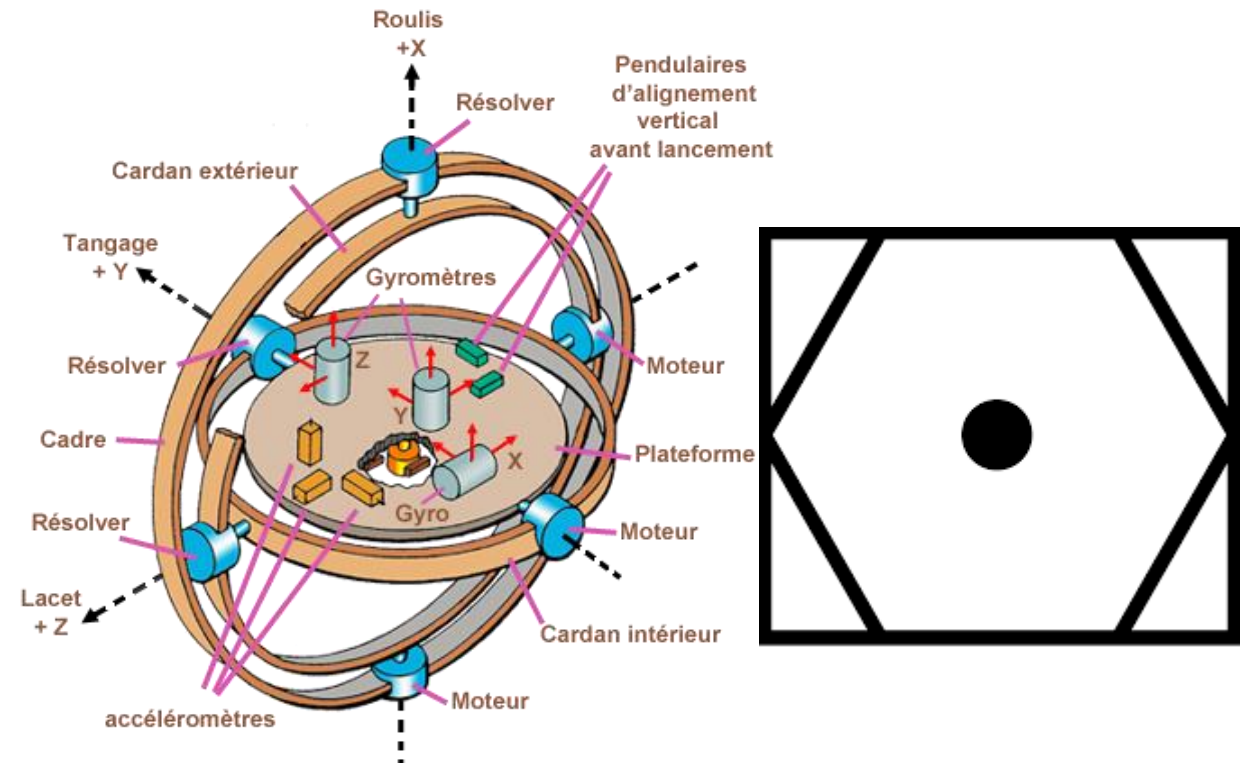
☐ **Ground-based :**

☞ VOR-DME, DME/DME, ~~NDB.~~

☐ **Space-based :**

☞ GNSS.

☐ **Self-contained:**

☞ INS/IRS.

Navigation application

PBN application :

- Use of PBN navigation specification and PBN infrastructures 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):

- Oceanic or remote continental;
- Continental;
- Terminal;
- Approach.

Navigation Application

> **Some Navspecscan be "applied" in more than one area of operation:**

- **RNAV 5** can be applied on ATS routes in (Continental), airspace or in Terminal airspace beyond 30 NM from the Aerodrome 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 en-route, or in Terminal Areas on STARs or SIDs and in Approach;
- **RNP 1** or **RNAV 1** can be applied on inter-city ATS routes of short distances or in Terminal Area on STARs or SIDs.

Navigation applications

Navigation Application	Navigation Specification	
	RNP	**RNAV**
Oceanic and Remote	RNP 4, RNP 2, A-RNP	RNAV 10
Continental	RNP 2, A-RNP, RNP 0.3	RNAV 5, 2, 1
Terminal	RNP 1, A-RNP, RNP 0.3, RNP AR	RNAV 5, 2, 1
Approach	RNP APCH, RNP 0.3, A-RNP 0.3, RNP AR	

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RELATIONSHIPS BETWEEN THE PBN COMPONENTS

Relationship between the PBN components

Oceanic & Remote applications

PBN APPLICATION		RNP 4	RNP 2	RNAV 10
NAVAID		GNSS	GNSS	Dual* independent LRNS (GNSS, INS, .)
NAVPEC	**Sensor**	OBPMA	OBPMA	GNSS, INS
	Performance	TSE ≤ 4 NM	TSE ≤ 2 NM	TSE ≤ 10 NM
	Leg type	CF – DF – TF	DF - TF	-
	Functionalities	Offset – FB turn, DB	Offset – FB turn, DB	-
	Surveillance	Non radar	Non radar	Non radar
Communication		Voice, CPDLC+ADS-C, or CPDLC+ADS-B		Voice*
Route spacing		Doc. 4444	Doc. 4444	50 NM
Publication		RNP 4	RNP 2	RNAV 10 *

Relationship between the PBN components

En-route continental applications

PBN APPLICATION		RNP 2	RNP 0.3	RNAV 5	
NAVAID		See Previous slide	GNSS	VOR-DME, DME/DME, GNSS, INS or IRS	
NAVPEC	Sensor		OBPMA	VOR-DME, DME/DME, GNSS, INS/IRU	
	Performance		TSE ≤ 0.3 NM	TSE ≤ 5 NM	
	Leg type		IF-CF-CA-DF – TF-VA-VM-VI	-	
	Functionalities		DB – FB turn	Offset	
	Surveillance		-	Non radar	Radar*
Communication			-	Voice	
Route spacing			Doc. 4444	30 NM**max	
Publication			-	RNAV 5	

En-route continental (Contd)

PBN APPLICATION		RNAV 2	RNAV 1
NAVAID		DME/DME, GNSS, INS	DME/DME, GNSS, INS
NAVPEC	Sensor	DME/DME, GNSS, INS	DME/DME, GNSS, INS
	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
	Functionalities	Data base (LOA) – FB turn	Data base (LOA) – FB turn
Surveillance		Radar	Radar or FOSA
Communication		Voice	Voice
Route spacing		Radar (at least 8 NM)	Radar
Publication		RNAV 2 (Critical DME*)	RNAV 1 (Critical DME*)

Relationship between the PBN components

En-route and terminal applications : Advanced-RNP

RNP values (NM)	Application
2	En-route Oceanic – Remote and continental
1	En-route continental
0.3	Arrival, Initial, Intermediate and Departure *Note: The final approach segment is excluded*
1	Missed approach

Note 1.— In an IAP, the A-RNP application is only used in the initial and intermediate segments and then in the missed approach. The final approach segment of IAP is defined using the RNP APCH specification. Alternatively, a non- performance-based navigation (PBN) final approach segment may be defined using instrument landing system (ILS) or ground-based augmentation system (GBAS) landing system (GLS).

Relationship between the PBN components

En-route and terminal applications

PBN APPLICATION		A-RNP
NAVAID		GNSS, DME/DME*
NAVPEC	Sensor	OBPMA
	Performance	0.3≤ TSE ≤ 2 NM
	Leg type	IF-CF-DF-TF-RF-CA-FA-VA-FM-VM-VI-HM
	Functionalities	Data base (LOA) – Parallel offset- RNP holding-FB turn
Surveillance		Radar or not
Communication		Voice (SIDs/STARs)
Route spacing		Doc. 4444 – Annex 11
Publication		-

Relationship between the PBN components

Terminal applications (SIDs and STARs)

PBN APPLICATION		RNAV 2	RNAV 1	RNP 1
NAVAID				GNSS
NAVPEC	Sensor			OBPMA
	Performance	See previous		TSE ≤ 1 NM
	Leg type			IF CF CA DF TF VA VM VI
	Functionalities			Data base – FB turn
Surveillance				Non radar
Communication				Voice
Route spacing				Doc 4444
Publication				RNP 1

Relationship between the PBN components

Approach applications

PBN APPLICATION		RNP APCH down to LNAV & LNAV/VNAV minima	RNP APCH down to LP & LPV minima
NAVAID		GNSS, DME/DME, DME/DME-INS*	SBAS
NAVPEC	Sensor	OBPMA	GNSS SBAS
	Performance	Final 0.3 NM	
	Leg type	CF-CA-TF-IF-DF	DF
	Functionalities	Data base, (LOA) FB turn	Data base, LOA
Surveillance		Radar or not	Radar or not
Communication		Voice	Voice
Separation minima		Doc 4444	Doc 4444
Publication		~~RNAV (GNSS) or~~ RNP RWY XY	RNP RWY XY (…)**

Relationship between the PBN components

Approach applications

PBN APPLICATION		RNP AR APCH and RNP AR DP
NAVAID		GNSS
NAVPEC	Sensor	OBPMA
	Performance	From 0.3 to 0.1
	Leg type	IF-CF-TF-DF-CA-RF (Optional VM)
	Functionalities	Data base (LOA*) FB turn VNAV
Surveillance		Radar or not
Communication		-
Route spacing		-
Publication		RNP RWY XY (AR)

Review of the PBN concept

PBN BENEFITS

Conventional Routes

RNAV

RNP

Current Ground Navaids

Waypoints

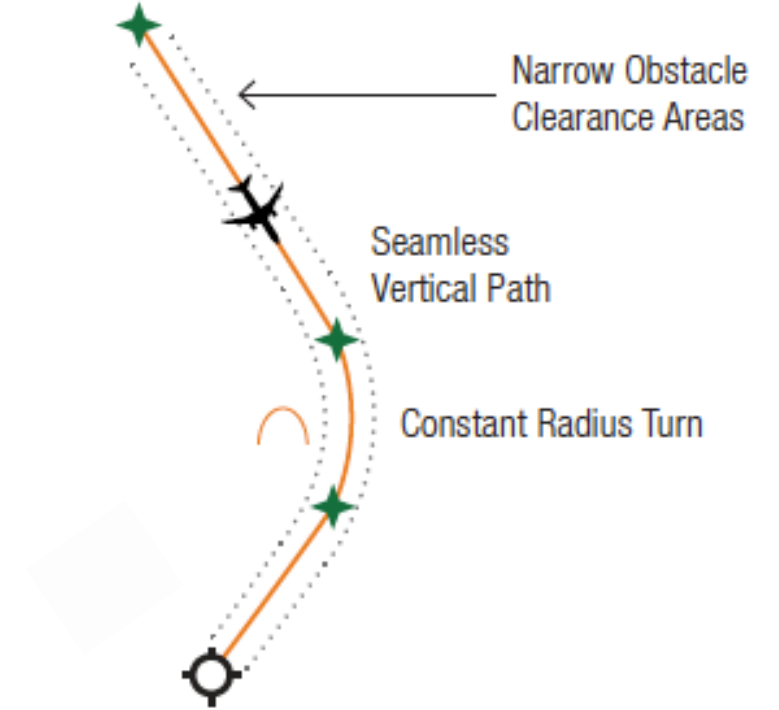Narrow Obstacle Clearance Areas

Seamless Vertical Path

Constant Radius Turn
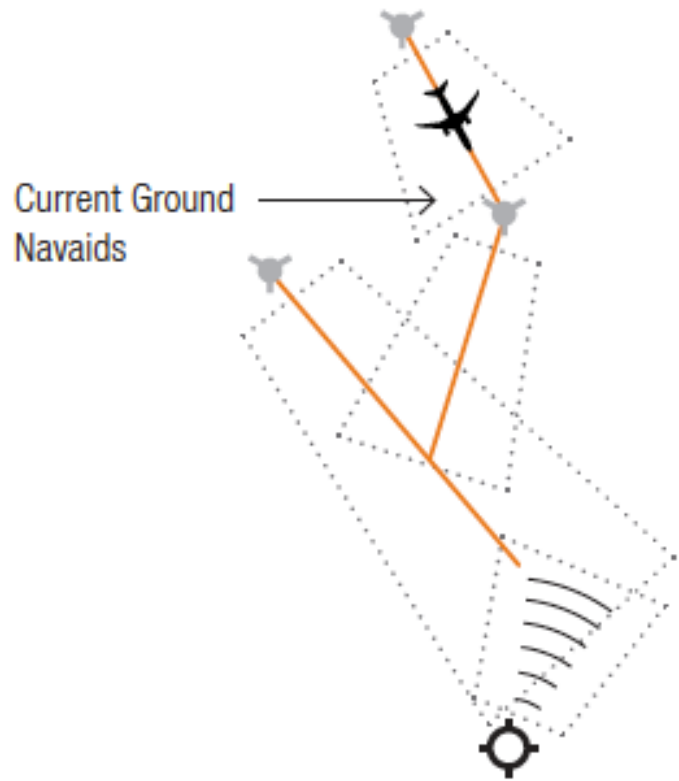
Limited Design Flexibility
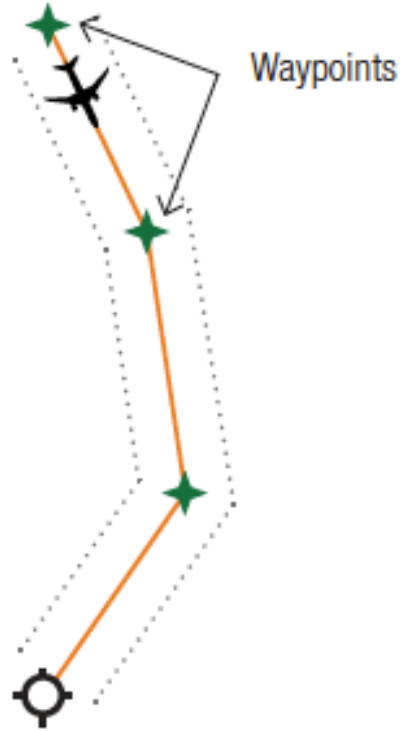
Increased Airspace Efficiency

Optimized Use of Airspace

CONVENTIONAL ROUTES COMPARED TO PBN-BASED ROUTES

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PBN benefits

❑ **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 and aircrew benefits:

☞ Safety culture;

☞ Greater predictability;

☞ Airspace containment;

☞ Fewer go-arounds;

☞ Less transit occupancy time;
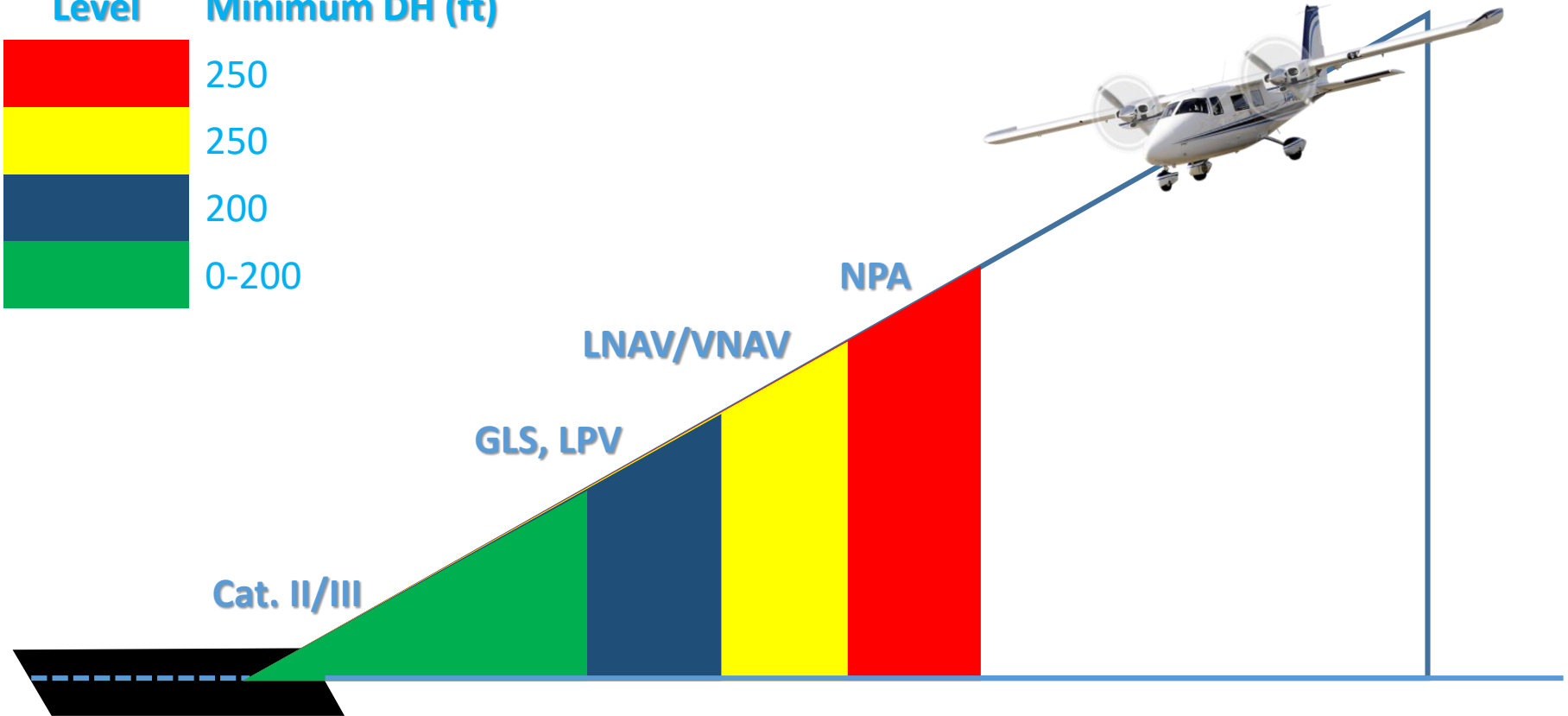
☞ Best practices involving stakeholders in design.

PBN benefits

OCA levels

Navaids or system	Level	Minimum DH (ft)
GNSS	🟥	250
GNSS+Baro or SBAS	🟨	250
Gbas or SBAS	🟦	200
ILS	🟩	0-200

NPA

LNAV/VNAV

GLS, LPV

Cat. II/III

Radar / Conventional vs. PBN flight paths
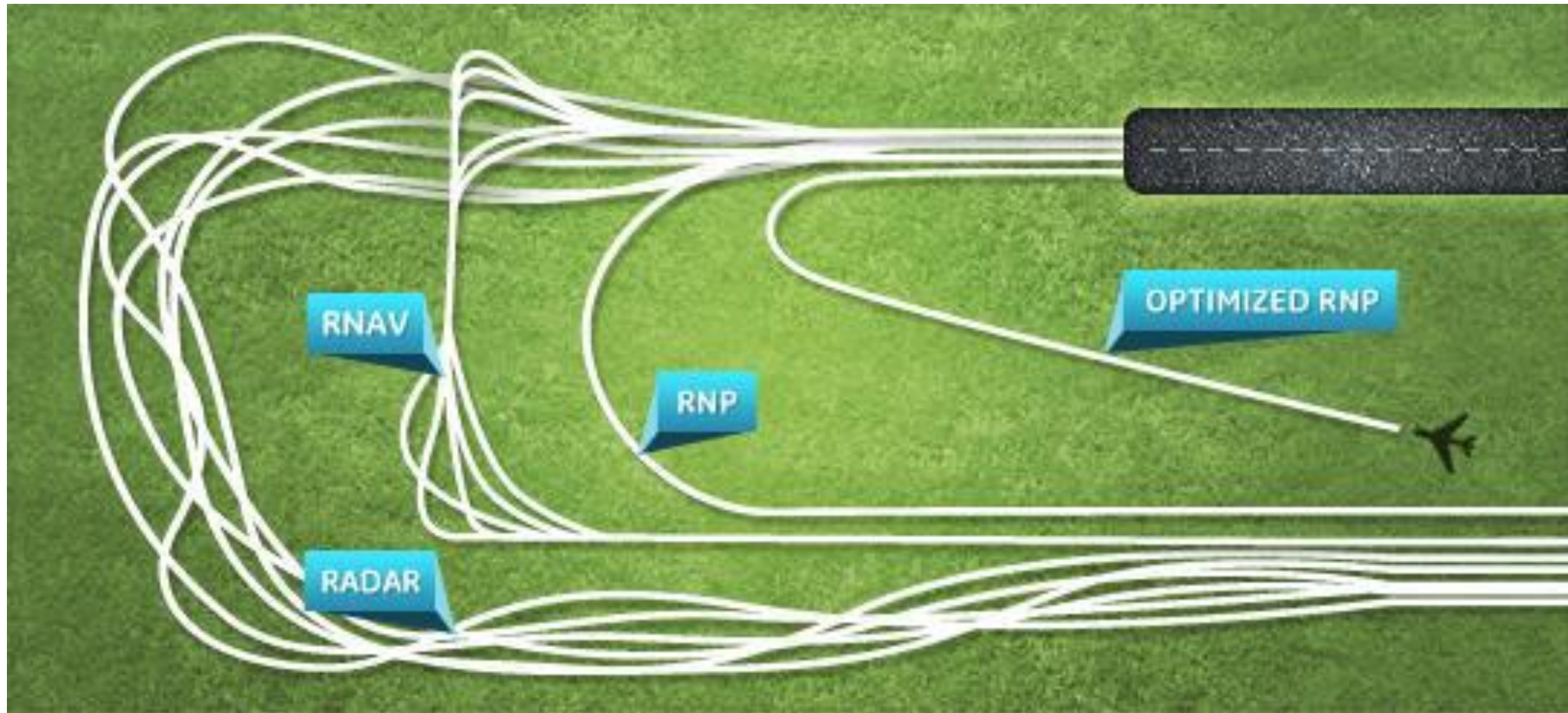
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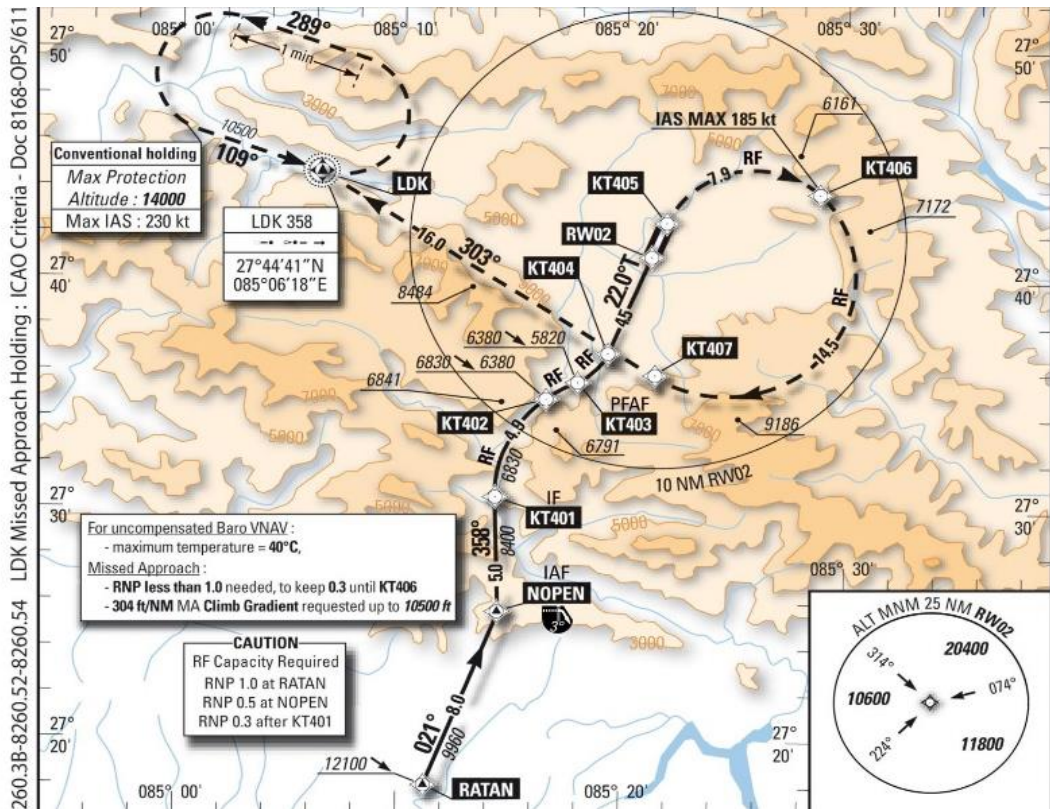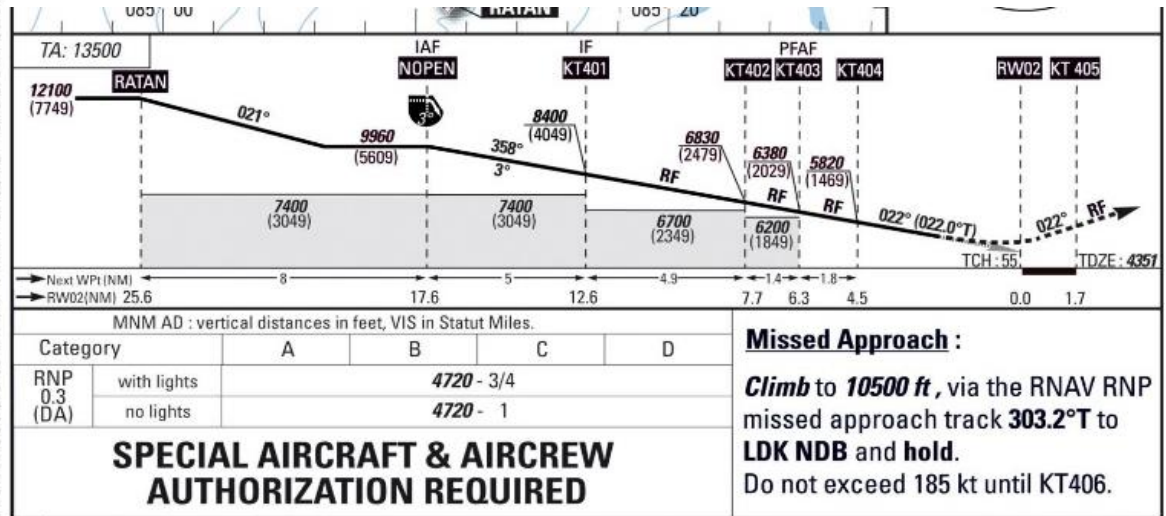
Review of the PBN concept

THE AFI PBN ROADMAP

African Flight Procedure Programme (AFPP)

Near-term strategy (2008-2012)

Application	Preferred Navspecs	As required Navspecs
Oceanic and Remote	RNAV 10	RNP 4
En-route continental	RNAV 5	RNAV 2, RNAV 1
Terminal Area	RNAV 1 with surveillance	
	RNP 1 in non-surveillance environment	
Approach	RNP APCH with baro-VNAV	RNP AR APCH
	RNP APCH with LNAV only*	

Note:
- *Where altimeter setting does not exist or aircraft of maximum certificated take-off mass of 5 700 kg or more, using an aerodrome are not suitably equipped for APV.*

African Flight Procedure Programme (AFPP)

Near-term implementation targets

Navspecs	Milestones	Application
RNP APCH with baro-VNAV	30% of the instruments RWYs by 2010	Airports with operational benefits
	50% of the instruments RWYs by 2012	Airports with operational benefits
RNAV 1*	30% for international airports by 2010	SIDs/STARs (Terminal)
	50% for international airports by 2012	SIDs/STARs (Terminal)
Transition to RNAV 5 or to RNAV 2/1	-	where operationally required

Mid-term strategy (2013-2016)

Application	Preferred Navspecs	As required Navspecs
Oceanic and Remote	RNAV 10	RNP 4
En-route continental	RNAV 5, RNAV 2	RNAV 1
Terminal Area	Expand RNAV 1 or RNP 1 applications	
	Mandate RNAV 1 or RNP 1 in high-density TMAs	
Approach	Expand RNP APCH with (Baro-VNAV or Augmented GNSS), supplemented with LNAV* only procedures	RNP AR APCH

Note:

- *Where altimeter setting does not exist or aircraft of maximum certificated take-off mass of 5 700 kg or more, using an aerodrome are not suitably equipped for APV.*

AFI Region PBN roadmap

Mid-term implementation targets

Navspecs	Milestones	Target	Application
RNP APCH with baro-VNAV or augmented GNSS	100% of the instrument RWYs	2016	Where practical
RNP APCH LNAV only	100% of instrument runway	2016	Approach
RNAV 1 or RNP 1	100%	2016	International airports
RNAV 1 or RNP 1	100%	2016	Domestic airports with operational benefits
RNP 10, RNAV 5/1/2	As required	-	Oceanic, remote, en-route continental

Long strategy (2023 and beyond):

☞ GNSS augmentation expected to be a primary navigation infrastructure; States encouraged to:

- Cooperate for implementation of seamless and inter-operable systems;
- Consider segregating traffic according to navigation capability.
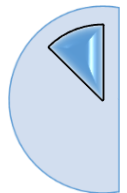
☞ Navpecs and target to be defined in due course.

Review of the PBN concept

PBN IMPLEMENTATION PROCESS

PBN implementation process

PLAN

Activity 1: Agree on operational requirements

Activity 2: Create an airspace design team

Activity 3: Agree on objectives, scope and timelines.

Activity 4: Analyse reference scenario.

Activity 5: Select safety criteria, safety policy and performance criteria.

Activity 6: Agree on ATM/CNS assumptions, enablers and constraints.

DESIGN

Activity 7: Design airspace, routes and holds.

Activity 8: Design initial procedure.

Activity 9: Design airspace volumes and sectors.

Activity 10: Confirm ICAO navigation specification.

VALIDATE

Activity 11: Validate airspace concept.

Activity 12: Finalize procedure design.

Activity 13: Validate procedure.

IMPLEMENT:

Activity 14: Integrate ATC system.

Activity 15: Develop awareness and training material.

Activity 16: Implement.

Activity 17: Conduct post-implementation review.

Summary

- ## What is PBN about?

  - Area Navigation, Globally Harmonized, Implementing Nav Specs

- ## Navspecs and Application / Airspace Concept

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

- ## PBN Terminology

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

- ## PBN defines aircraft RNP or RNAV performance in terms of?

  - Accuracy, Integrity, Continuity and functionality

- ## Difference between RNAV and RNP

  - RNP requires on-board performance monitoring and alerting

North American
Central American
and Caribbean
(NACC) Office
MexicoCity

South American
(SAM) Office
Lima

ICAO
Headquarters
Montreal

Western and
Central African
(WACAF) Office
Dakar

European and
North Atlantic
(EUR/NAT) Office
Paris

Middle East
(MID) Office
Cairo

Eastern and
Southern African
(ESAF) Office
Nairobi

Asia and Pacific
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