ICAO PBN Workshop
Tanzania

Introduction to PBN

AGENDA

- ICAO PBN MANUAL
- FOCUS ON OBPMA
- PBN BENEFITS

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AGENDA

- ICAO PBN MANUAL
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PLAN PBN France _ ICAO resolution A37-11

The ICAO Resolution A37-11 “Performance-based navigation global goals” was adopted by the Assembly of the ICAO at its 37th meeting (October 2010):

“The Assembly:

1 *Urges all States to implement RNAV and RNP air traffic services (ATS) routes and approach procedures in accordance with the ICAO PBN concept laid down in the Performance-based Navigation (PBN) Manual (Doc 9613);*

2 *Resolves that: states complete a PBN implementation plan as a matter of urgency to achieve:*

1} *implementation of RNAV and RNP operations (where required) for en route and terminal areas according to established timelines and intermediate milestones;* ***and***

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PLAN PBN France _ ICAO resolution A37-11

2} *implementation of approach procedures with vertical guidance (APV)*

(Baro VNAV and/or augmented GNSS), including LNAV-only minima, for all instrument runway ends, either as the primary approach or as a back-up for precision approaches by 2016 with intermediate milestones as follows: 30 per cent by 2010, 70 per cent by 2014; ***and***

3} *implementation of straight-in LNAV-only procedures, as an exception to* 2} *above, for instrument runways at aerodromes where there is no local altimeter setting available and where there are no aircraft suitably equipped for APV operations with a maximum certificated take-off mass of 5 700 kg or more;*

3 *Urges that States include in their PBN implementation plan provisions for implementation of approach procedures with vertical guidance (APV) to all runway ends serving aircraft with a maximum certificated take-off mass of 5 700 kg or more, according to established timelines and intermediate milestones;*

- ...”

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RNAV evolution towards Performance Based Navigation concept

- ICAO decided to create the PBN concept (behind the 11th Air Navigation Conference in 2004)
- PBN concept developed by a dedicated ICAO SG (The PBN SG)
- Performance-based navigation (PBN) is a revision of the required navigation performance (RNP) concept

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PBN concept

- Main PBN SG objectives are the:
  - Common understanding of the performance Based navigation concept and the relationship between RNP and RNAV functionality
  - Clarification of RNAV and RNP terminology
  - Update of ICAO doc 9613 (RNP manual) that is called now the ICAO Performance Based Navigation (PBN) manual

➢ Ultimately should prevent proliferation of navigation standard over the world with an harmonization between States

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PBN concept

PBN offers a number of advantages over the sensor-specific method of developing airspace and obstacle clearance criteria, i.e.:

a) reduces the need to maintain sensor-specific routes and procedures, and their associated costs;

b) avoids the need for developing sensor-specific operations with each new evolution of navigation systems, which would be cost-prohibitive;

c) allows for more efficient use of airspace (route placement, fuel efficiency and noise abatement);

d) clarifies how RNAV and RNP systems are used; and

e) facilitates the operational approval process for operators by providing a limited set of navigation specifications intended for global use.

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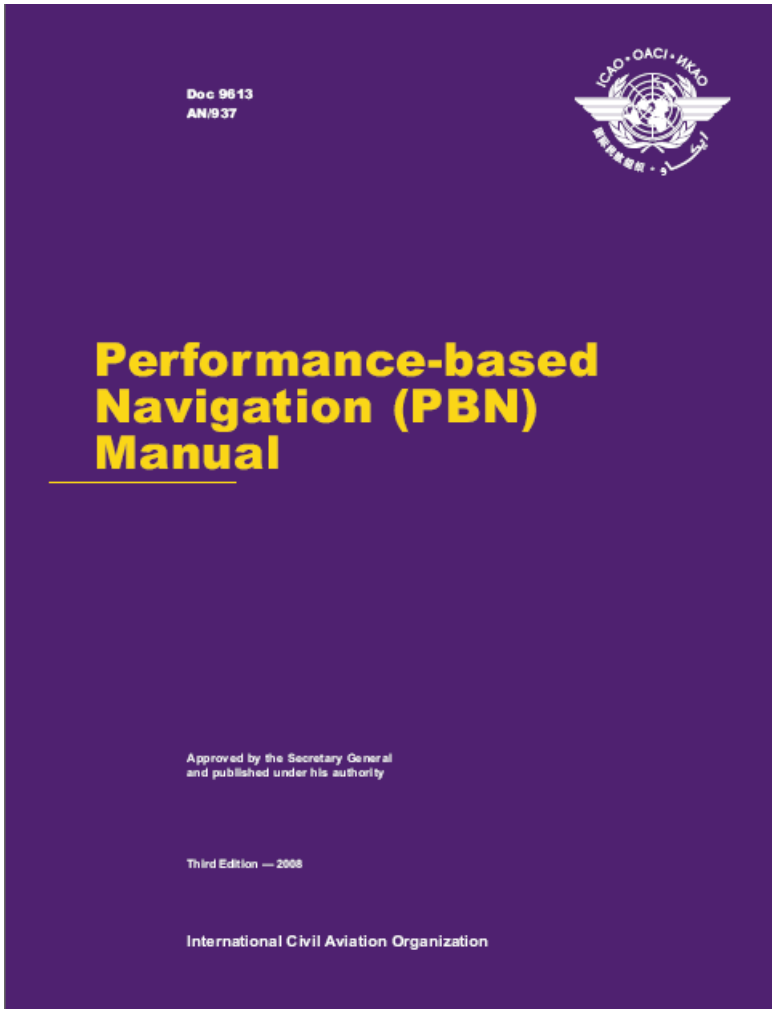
PBN concept – The PBN manual

ICAO PBN manual - doc 9613

1. defines the PBN concept (vol I)
2. Defines the navigation specifications to implement RNAV and RNP (vol II)



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ICAO Performance Based Manual Content

- VOLUME I: Concept and implementation guidance
  - Part A: Description of the airspace concept, scope and purpose, stakeholders use of PBN
  - Part B: How to implement according to 3 processes:
    - Determining the requirement
    - Identifying the navigation specification
    - Planning and implementing

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ICAO Perfomance Based Manual Content

- VOL II: Implementing RNAV and RNP
  - Part A: General
  - Part B: RNAV specification
    - Implementing RNAV10, RNAV5, RNAV1 and 2
  - Part C: RNP specification
    - Implementing RNP4, Basic RNP1, RNP APCH, RNP AR APCH

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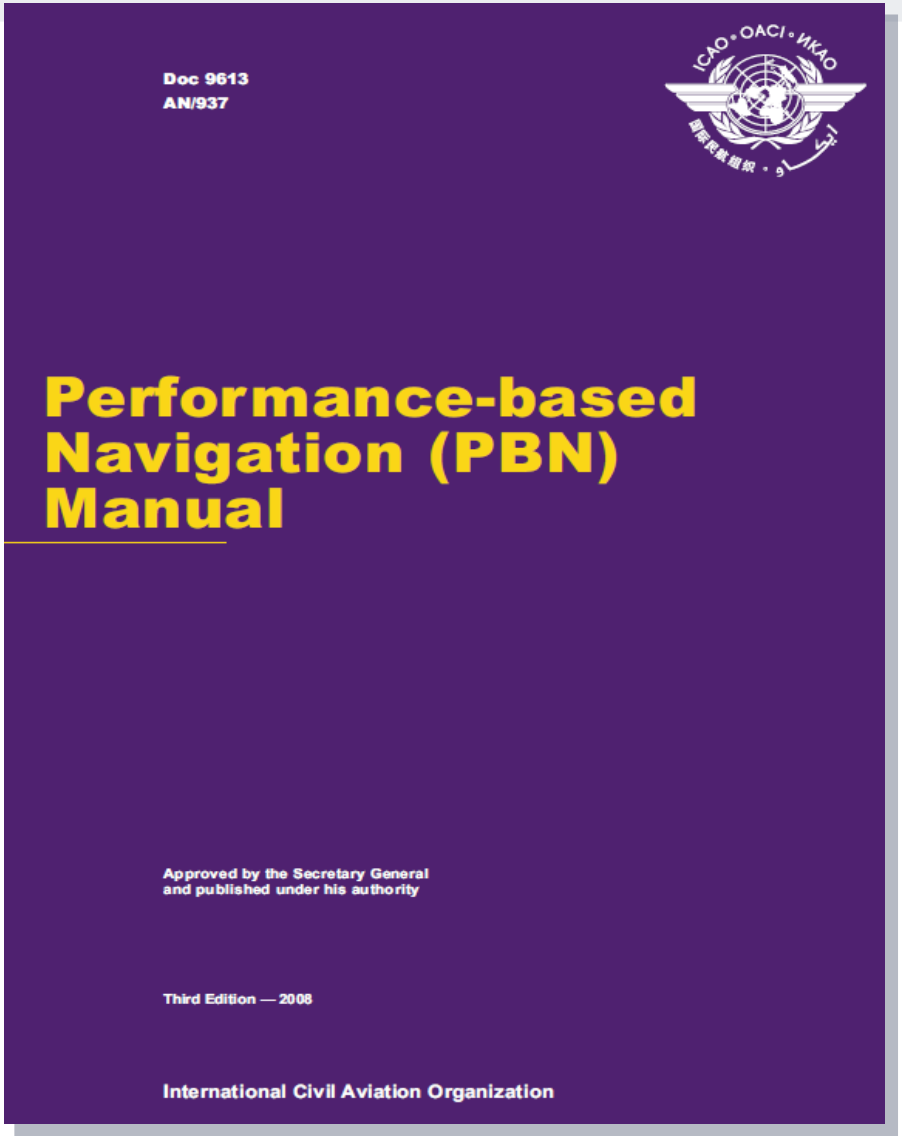
PBN Volume I



Concept

and

Implementation Guidance

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- Definition of PBN concept

- Use of PBN concept at different levels by

Strategic level

- Airspace manager
- Procedure designer
- Airworthiness and regulatory authorities

Tactical level

- Pilots
- Controllers

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Part B: Implementation Guidance

- Provides guidance for implementing RNAV or RNP applications in a given Region

- Provides a framework for using the ICAO Navigation Specifications published in Volume II of this manual

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Process Overview

- Three processes are provided. They are used in sequence.
  - Determine Requirements
  - Identifying ICAO Navigation Specification for Implementation
  - Planning and Implementation

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Implementation: Training

- EACH Navigation specification addresses Pilot and Controllers TRAINING

5.2.6. Controller Training

Air traffic controllers, who will provide control services at airports where RNP approaches have been implemented, should have completed training that covers the items listed below.

Core training

a) How area navigation systems work (in context of this navigation specification)

(i) Include functional capabilities and limitations of this navigation specification,

(ii) accuracy, integrity, availability and continuity including on-board performance monitoring and alerting;

(iii) GPS receiver, RAIM, FDE, and integrity alerts;

(iv) waypoint fly-by vs. fly-over concept (and different turn performance)

5.3.5. Pilot Knowledge and Training

The training program must provide sufficient training (for example, simulator, training device, or aircraft) on the aircraft's RNAV system to the extent that the pilots are not just task oriented.

a) The information in this chapter.

b) The meaning and proper use of RNP systems.

c) Procedure characteristics as determined from chart depiction and textual description.

Knowledge regarding depiction of waypoint types (fly-over and fly-by), required path terminators (IF, TF, DF) and any other types used by the operator as well as associated aircraft flight paths.

Training is essential !

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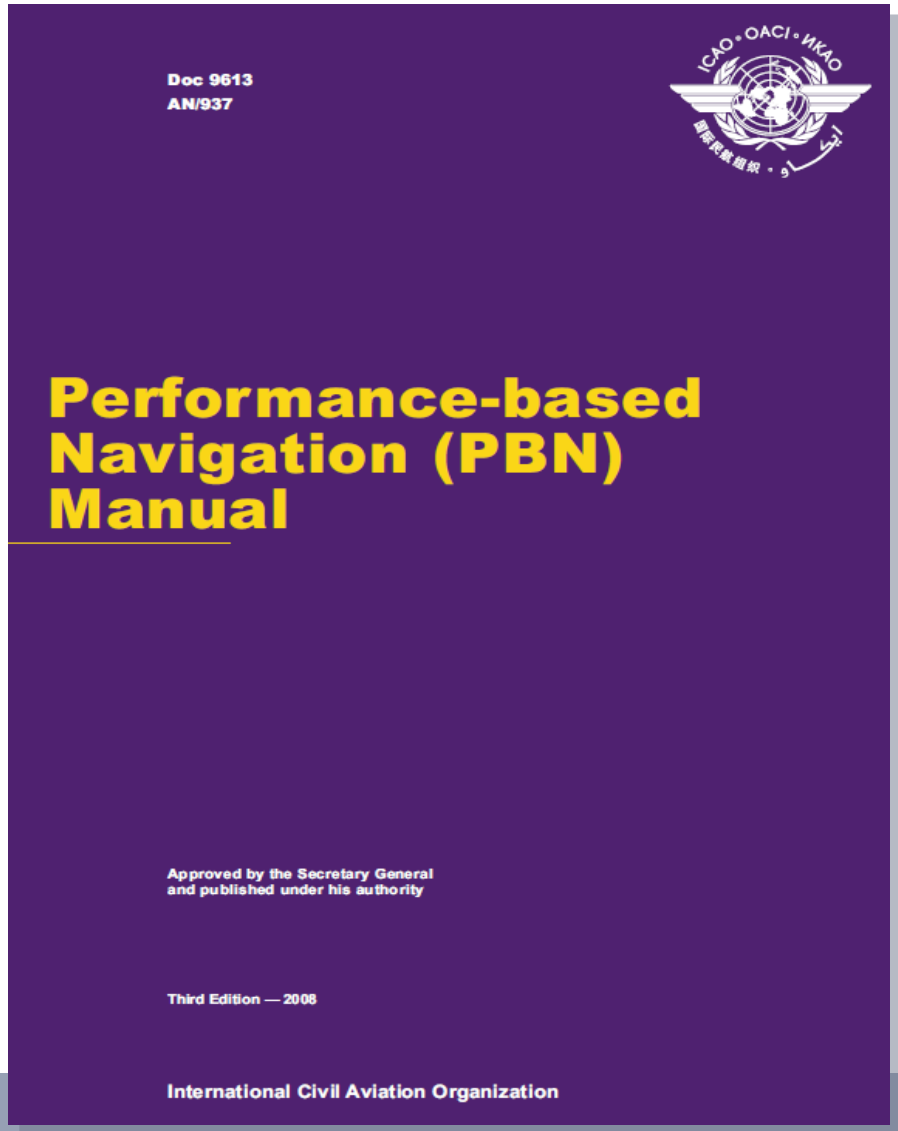
PBN Volume II



Implementing
RNAV and RNP

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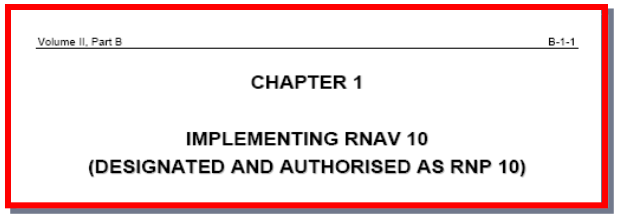
Implementation of RNAV and RNP applications

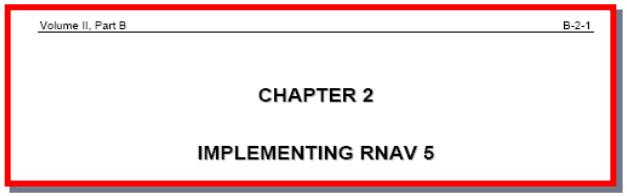
- For each RNAV or RNP application a same format is used to describe:
  - Area of operation and purpose
  - **ANSP** consideration
  - **Navigation specification**



Volume II, Part B B-1-1

CHAPTER 1

IMPLEMENTING RNAV 10
(DESIGNATED AND AUTHORISED AS RNP 10)



Volume II, Part B B-2-1

CHAPTER 2

IMPLEMENTING RNAV 5

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Navigation Specification

- Approval process
- A/C requirement
- Operating procedure
- Pilot training
- Navigation data base
- Oversight of operation

Same Format

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PBN Navigation Specifications

- A NAVIGATION SPECIFICATION defines :
  - What ***PERFORMANCE*** of RNAV system is required for aircraft operating on air traffic routes or instrument approach procedures, in a designated airspace
    - Defined in term of accuracy, integrity, continuity and availability
  - What ***FUNCTIONALITIES*** RNAV system must have to achieve performance
    - e.g. Display type, leg types….
  - What ***NAVIGATION SENSORS*** must be integrated in RNAV system to achieve performance
  - What ***REQUIREMENTS*** are placed on AIR CREW to achieve the required performance from the RNAV system

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PBN Concept

The performance of the navigation system are defined by :

- Accuracy: the difference between the estimated position and the actual position
- Integrity: a measure of the trust that can be placed in the correctness of the information supplied by the total system. It includes the ability of a system to provide timely and valid warnings to the user when the system must not be used for the intended operation.
- Continuity: the capability of the system to perform its function without unscheduled interruptions during the intended operation.

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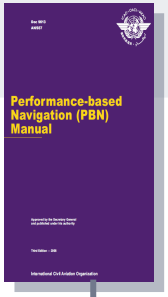
PBN Manual



3rd edition of PBN Manual

RNAV

On Board Perf. Monitoring and Alerting system not mandatory

- EN-ROUTE
  - RNAV 10
- TERMINAL
  - RNAV 5
  - RNAV 1
    RNAV 2

RNP

On Board Perf. Monitoring and Alerting system mandatory

- EN-ROUTE
  - RNP 4
- TERMINAL
  - Basic RNP1
- APPROACH
  - RNP APCH
  - RNP AR APCH

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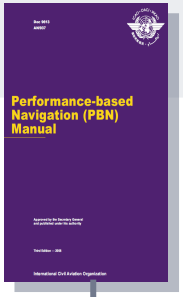
PBN Manual: 4th edition



New operations

RNAV
On Board Perf. Monitoring and Alerting system not mandatory

RNP
On Board Perf. Monitoring and Alerting system mandatory

RNAV: EN-ROUTE
- RNAV 10

RNAV: TERMINAL
- RNAV 5
- RNAV 1
- RNAV 2

RNP: EN-ROUTE
- RNP 4
- RNP 2

RNP: TERMINAL
- RNP1

RNP: APPROACH
- RNP APCH
- RNP AR APCH

ADVANCED RNP (Advanced features: RF, FRT, …)

RNP 0.3
for helicopter

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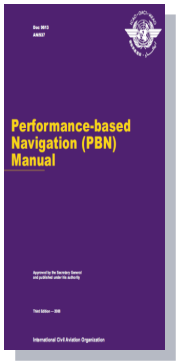
PBN Manual and Aircraft documentation



Not a regulatory guidance

Approval of operations by local authorities

PBN OPERATIONS equivalent to EXISTING OPERATIONS (from FAA or EASA regulations)

Operational documentation (AFM/FCOM) covers existing operations (EASA or FAA regulation)

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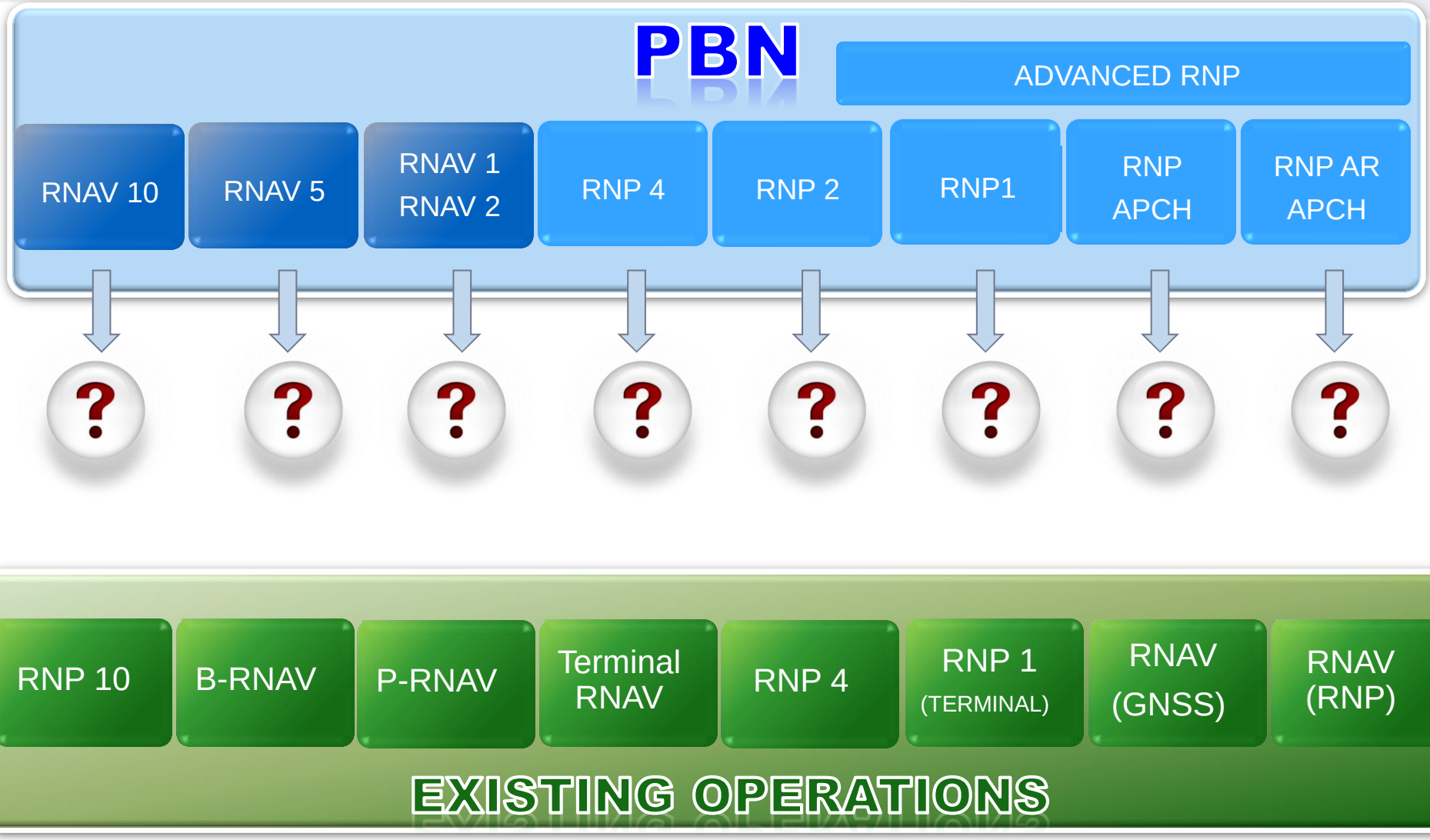
Link with existing operations



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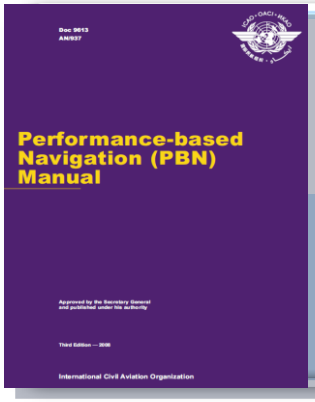
RNAV 10 operation



Chapter 1

IMPLEMENTING RNAV 10
(DESIGNATED AND AUTHORIZED AS RNP 10)

PBN

RNAV 10

Link with existing

RNP 10

Implementation of RNP 10 to support 50NM/50NM separation minima

RNAV 10 terminology in PBN for consistency

Related documents : FAA AC20-130A and FAA 8400.12A

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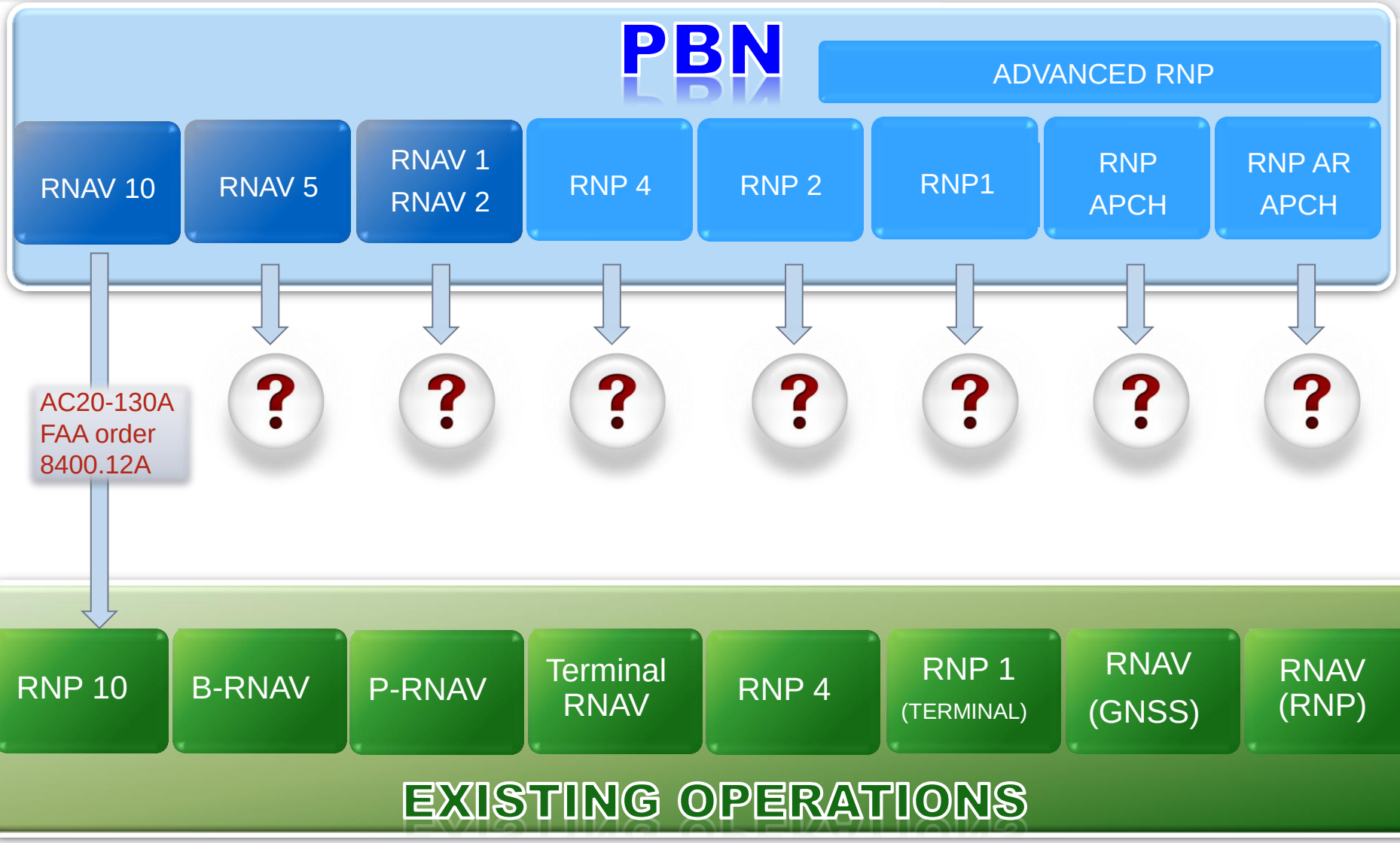
Link with existing operations



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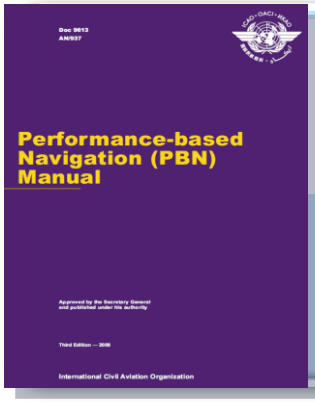
RNAV 5 operation



Chapter 2

IMPLEMENTING RNAV 5

PBN

RNAV 5

Link with existing

B-RNAV

Related documents:

EASA AMC 20-4 : Basic RNAV operations

FAA AC 90-96 : Approval of US operators for Basic RNAV

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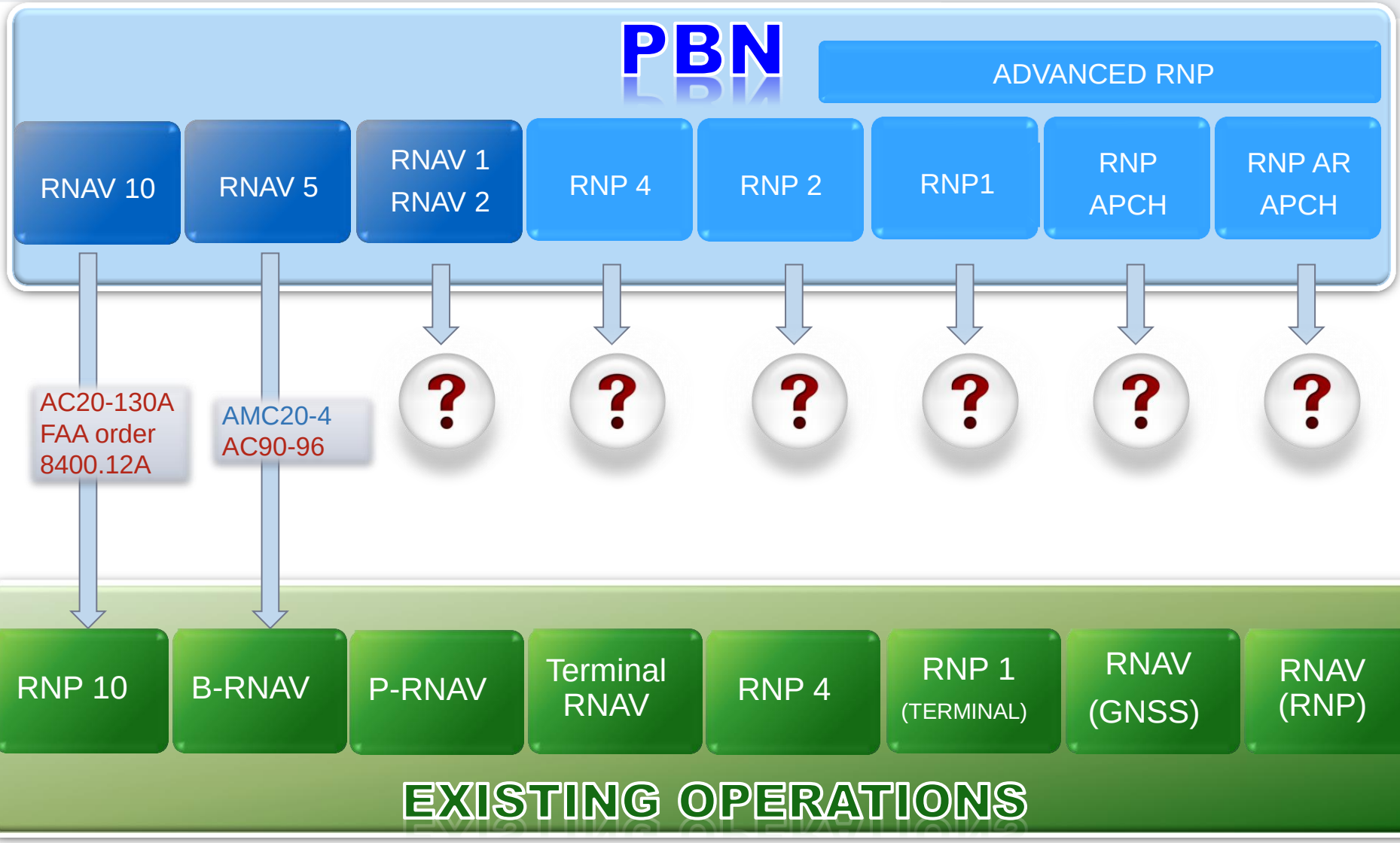
Link with existing operations



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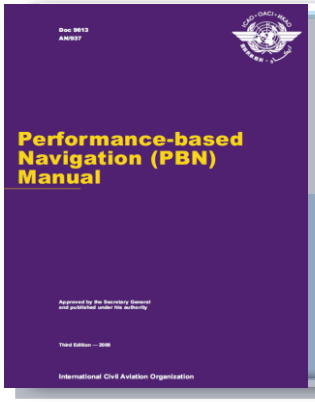
RNAV 1/2 operation



Chapter 3

IMPLEMENTING RNAV 1 AND RNAV 2

PBN

RNAV 1
RNAV 2

Link with existing

P-RNAV

Terminal RNAV

Related documents: EASA TGL 10 for PRNAV

FAA AC90-100 for Terminal and en-route RNAV operations

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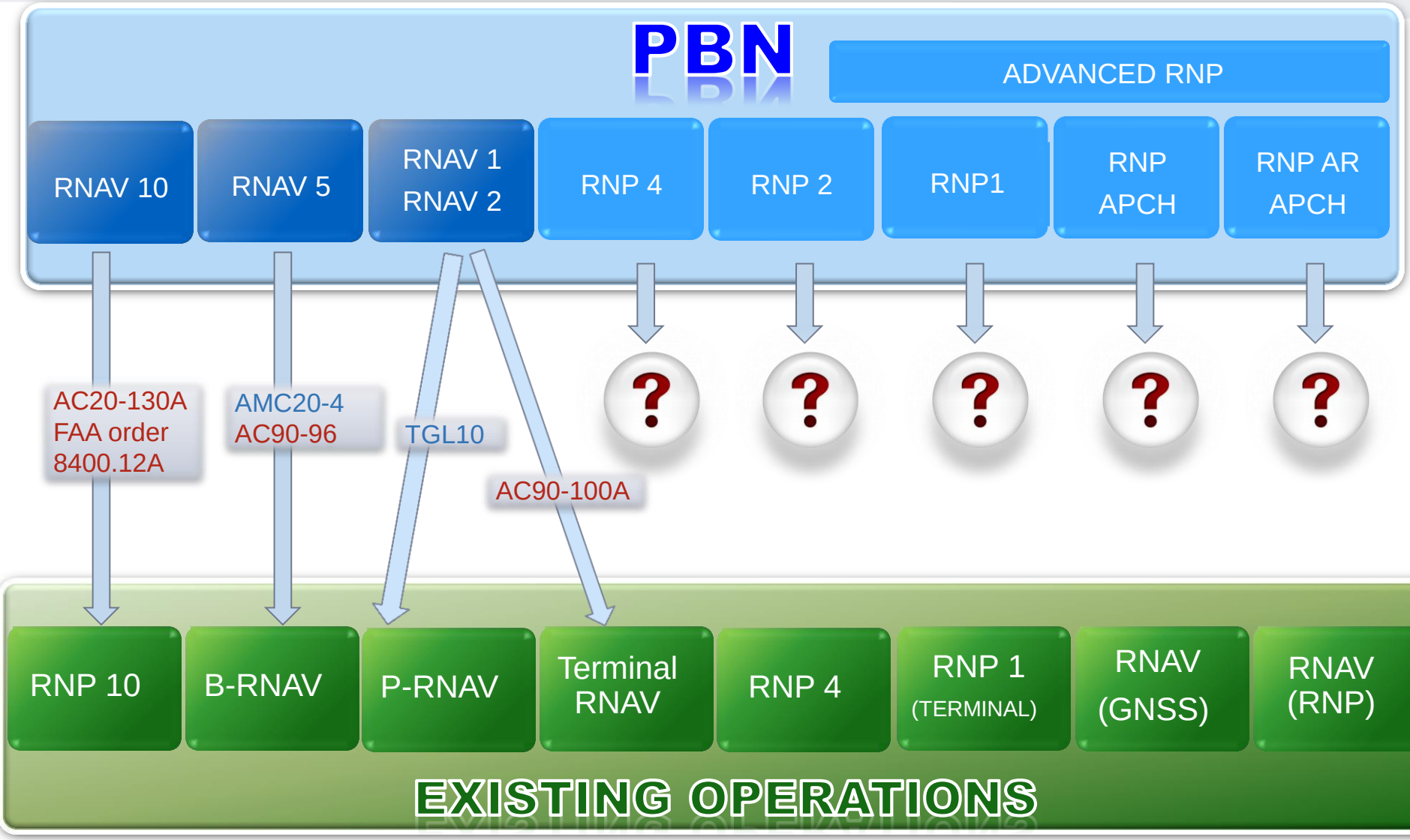
Link with existing operations



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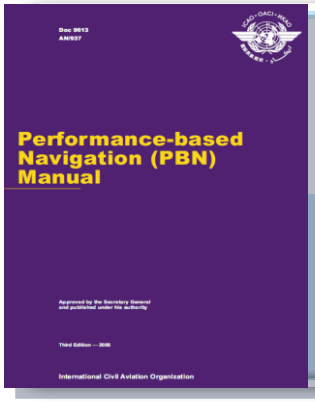
RNP 4 operation



Chapter 1

IMPLEMENTING RNP 4

PBN

RNP 4

Link with existing

RNP 4

Implementation of RNP 4 to support 30NM/30NM separation minima (ADS C requested)

Related document: FAA Order 8400.33: Approval of US operators for RNP 4

Will be introduced in AC90-105A (new issue planned)

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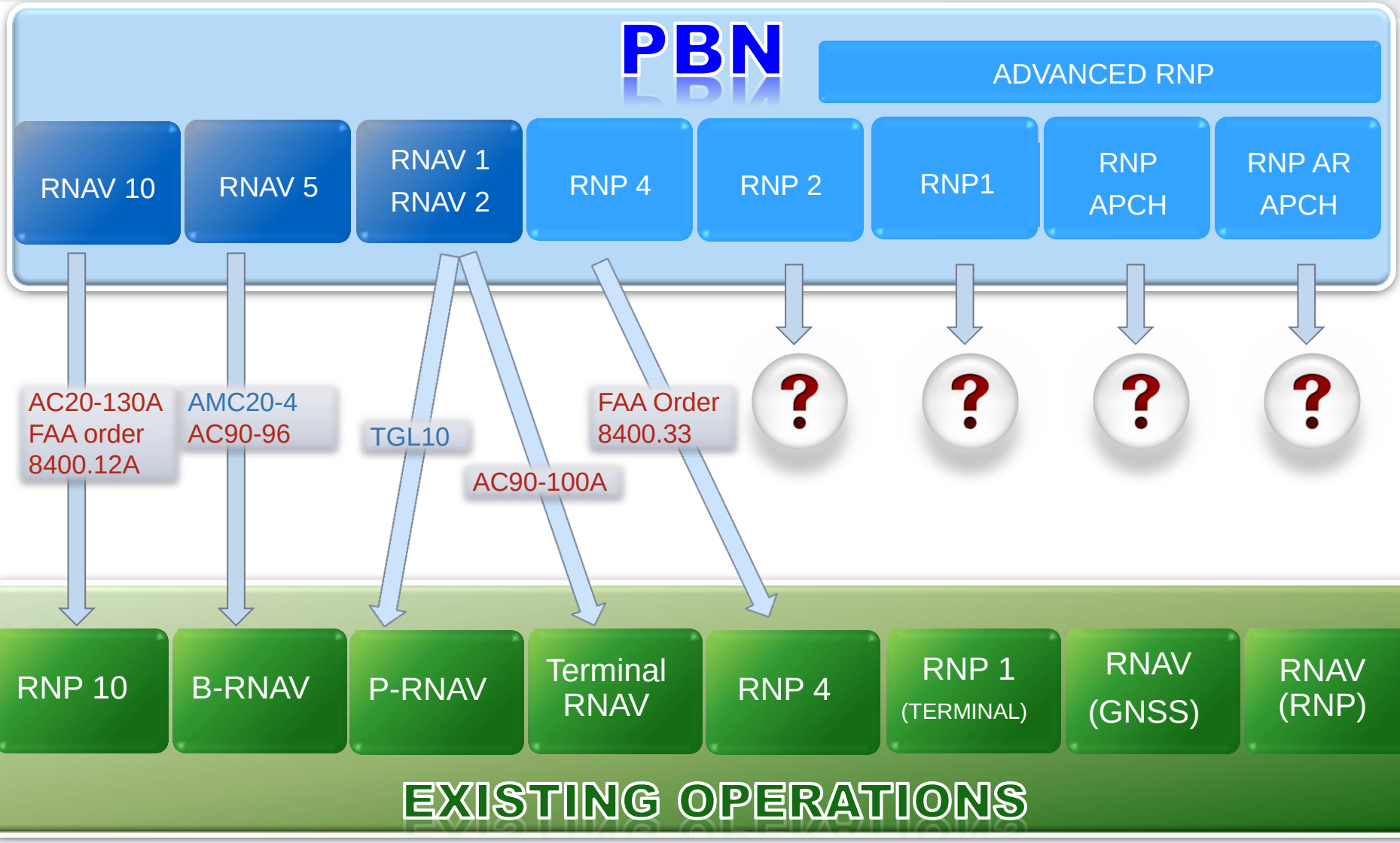
Link with existing operations



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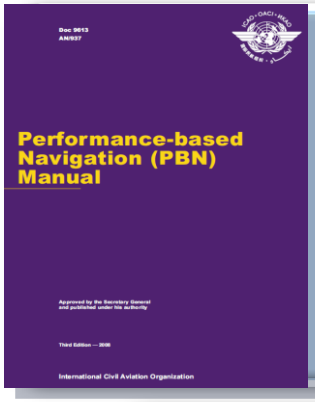
RNP 2 operation



PBN

RNP 2

To develop routes in areas with little or no ground-based navaid infrastructure in oceanic, continental, and in remote airspace

New operation not yet referenced in EASA or FAA regulation
Planned in future **FAA AC90-105A** and following new EASA regulation

→ Not mentioned in AFM or FCOM for the moment

Airbus aircraft compliance: No difficulty anticipated for FMS2 equipped A/C

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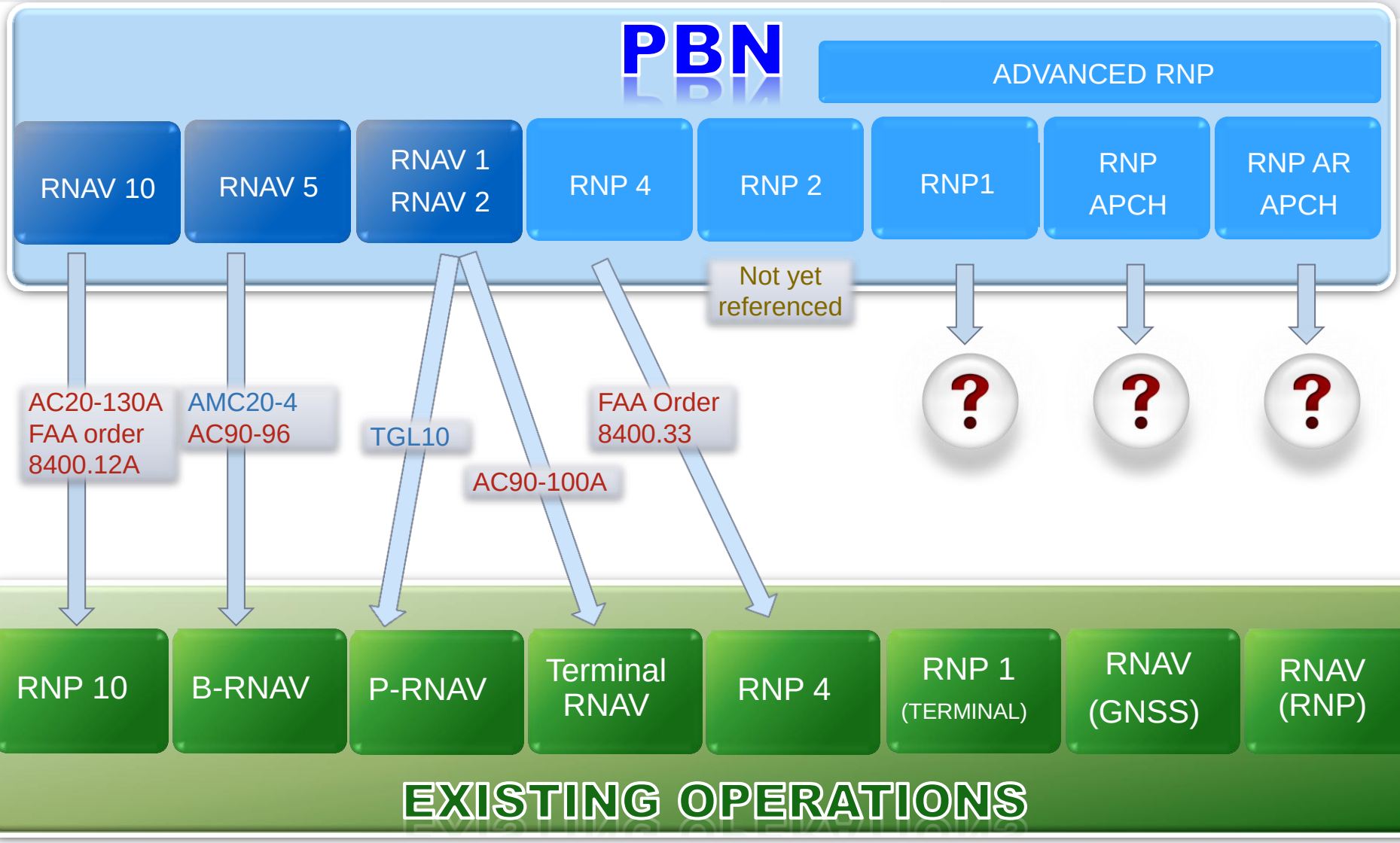
Link with existing operations



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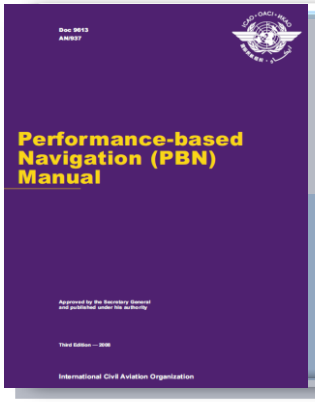
RNP 1 operation



Chapter 3

IMPLEMENTING BASIC-RNP 1

PBN

RNP 1

Link with existing

RNP 1
(TERMINAL)

To develop connectivity between en-route and terminal airspace

Related documents: FAA AC90-105 for RNP 1 (TERMINAL)

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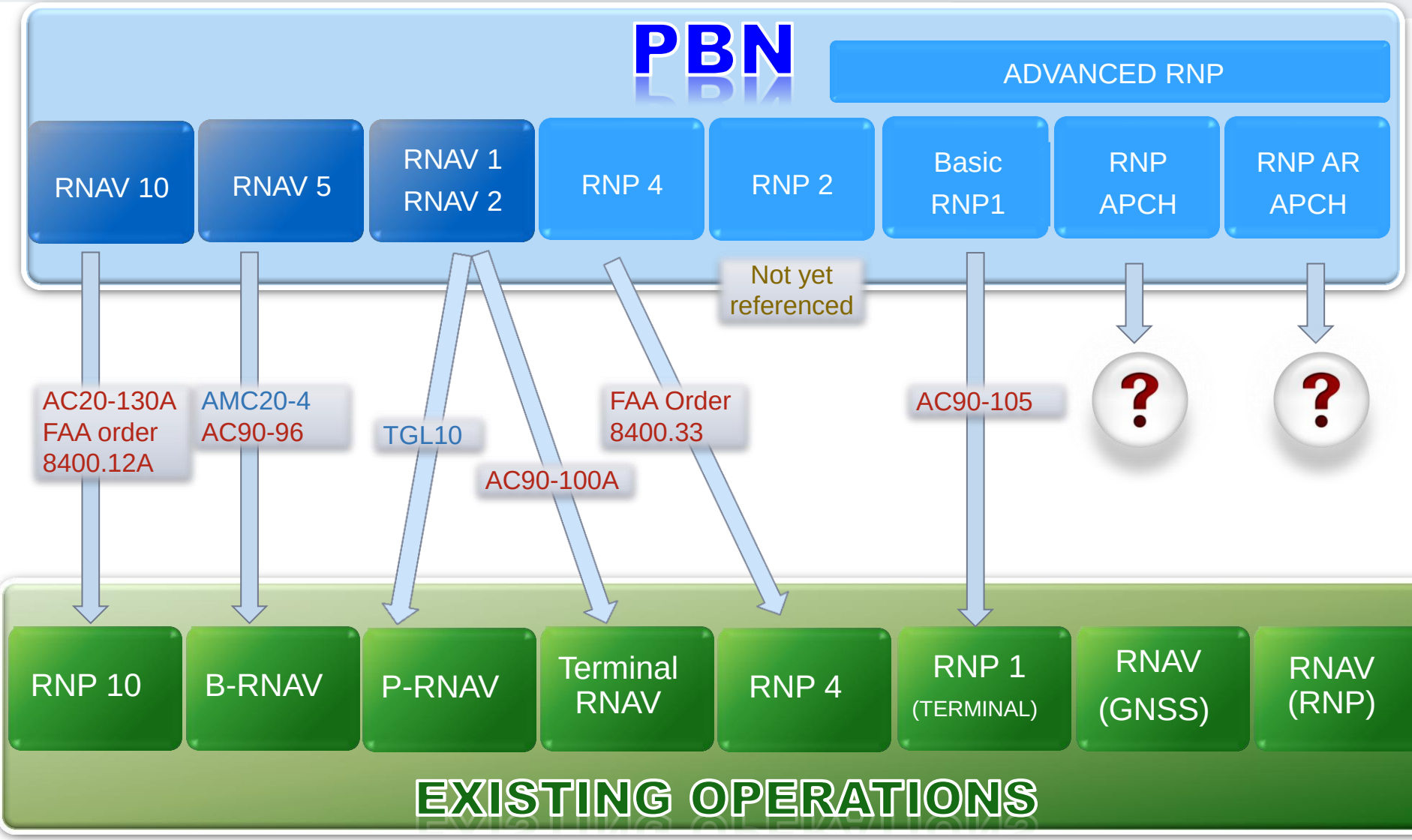
Link with existing operations



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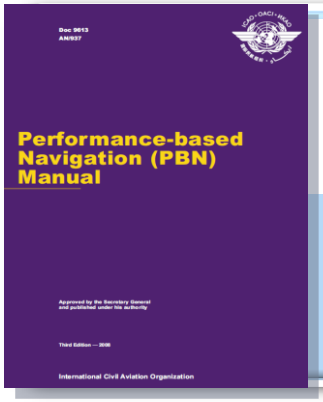
RNP APCH operation

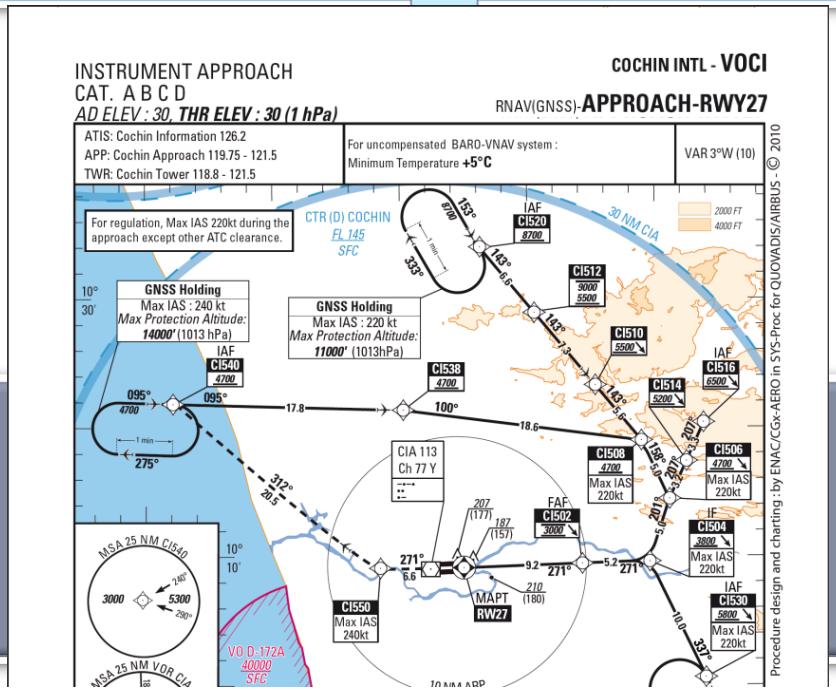


Chapter 5

IMPLEMENTING RNP APCH

PBN

RNP APCH



Related documents :

FAA AC90-105

EASA AMC 20-27

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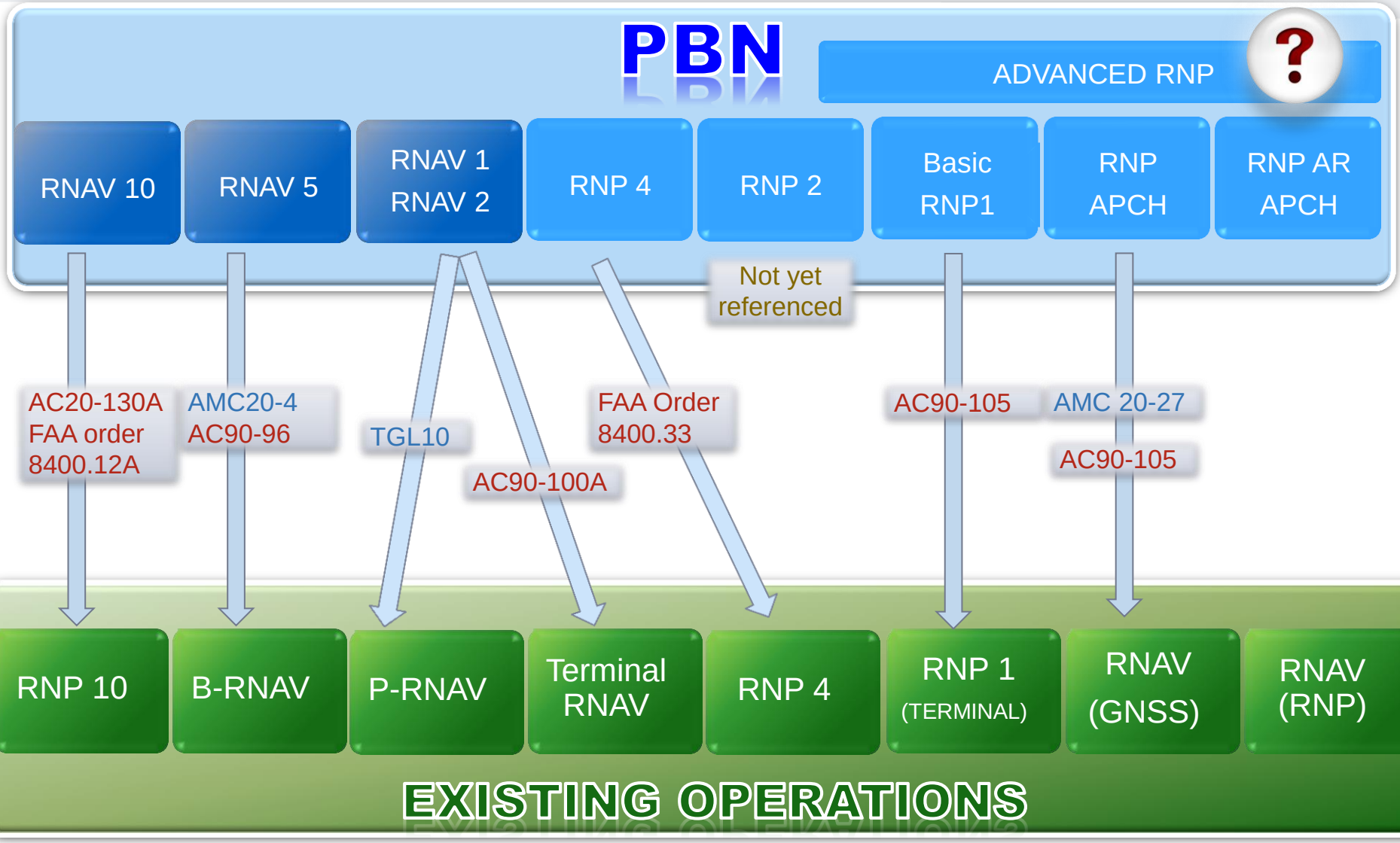

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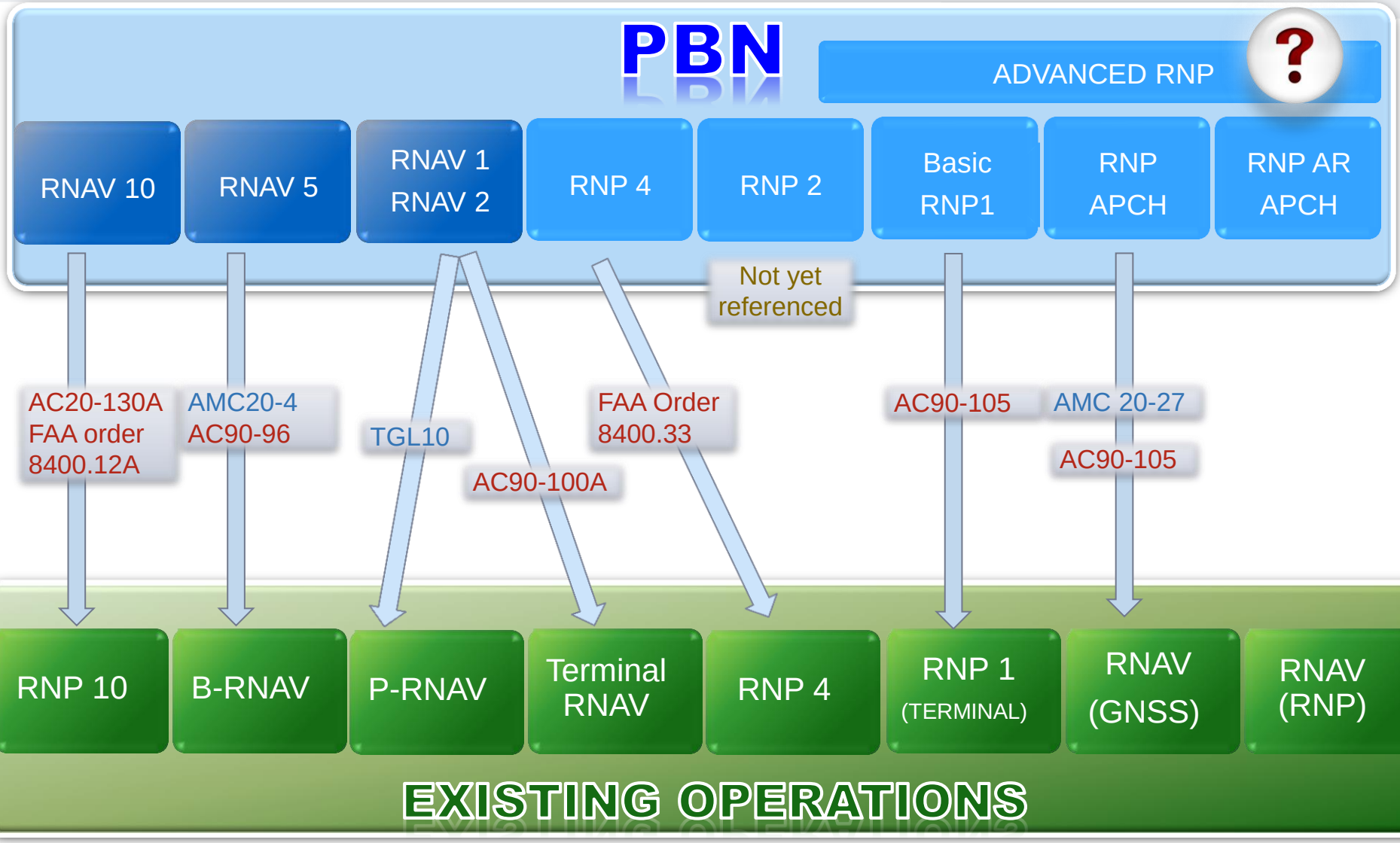

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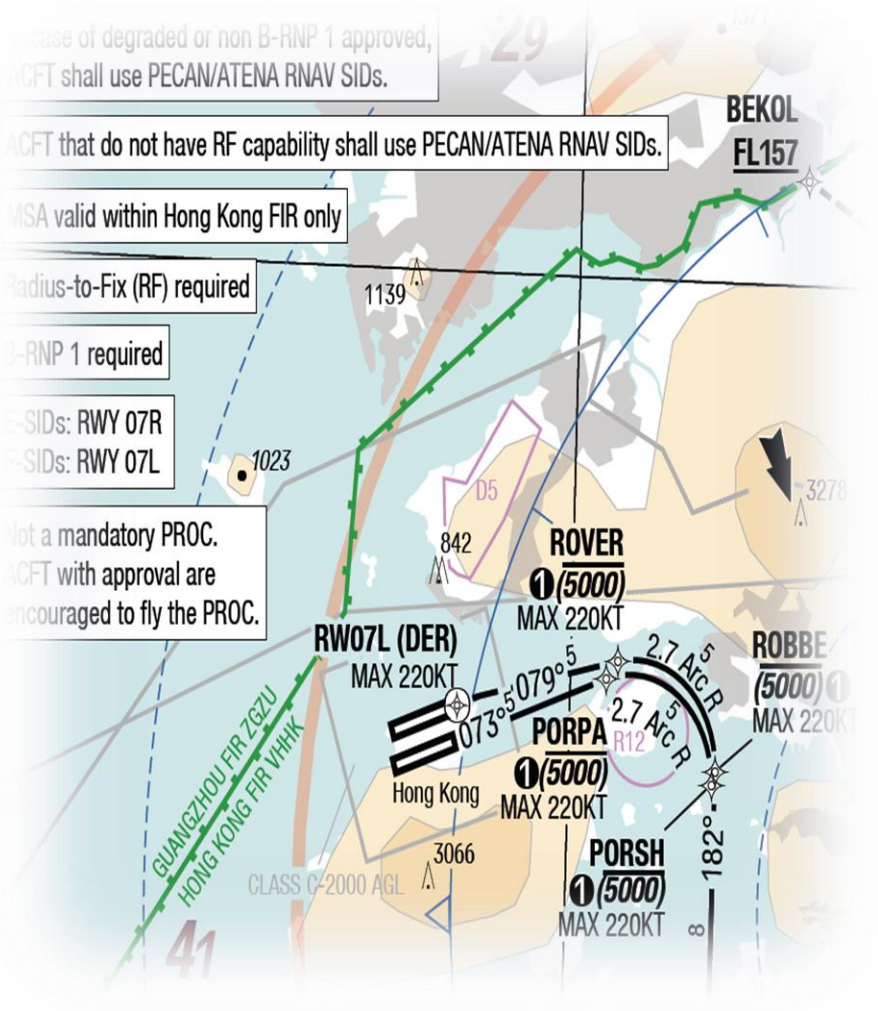
ADVANCED RNP

- Single assessment of A/C eligibility for
  - RNAV 5, 2 and 1
  - RNP 2, 1 and APCH
- Additional required or optional functionality
- No modification of existing operations: just add some functionalities

Related documents:

FAA AC 90-105 appendix 5

No EASA regulation for the moment



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ADVANCED RNP features

Function	Optional/required
RF legs	**Required**
Fixed Radius Transition (FRT)	Optional
RNP scalability	Optional
Higher continuity	Optional
Baro VNAV	Optional
Time Of Arrival Control (TOAC)	Optional (and not yet defined)

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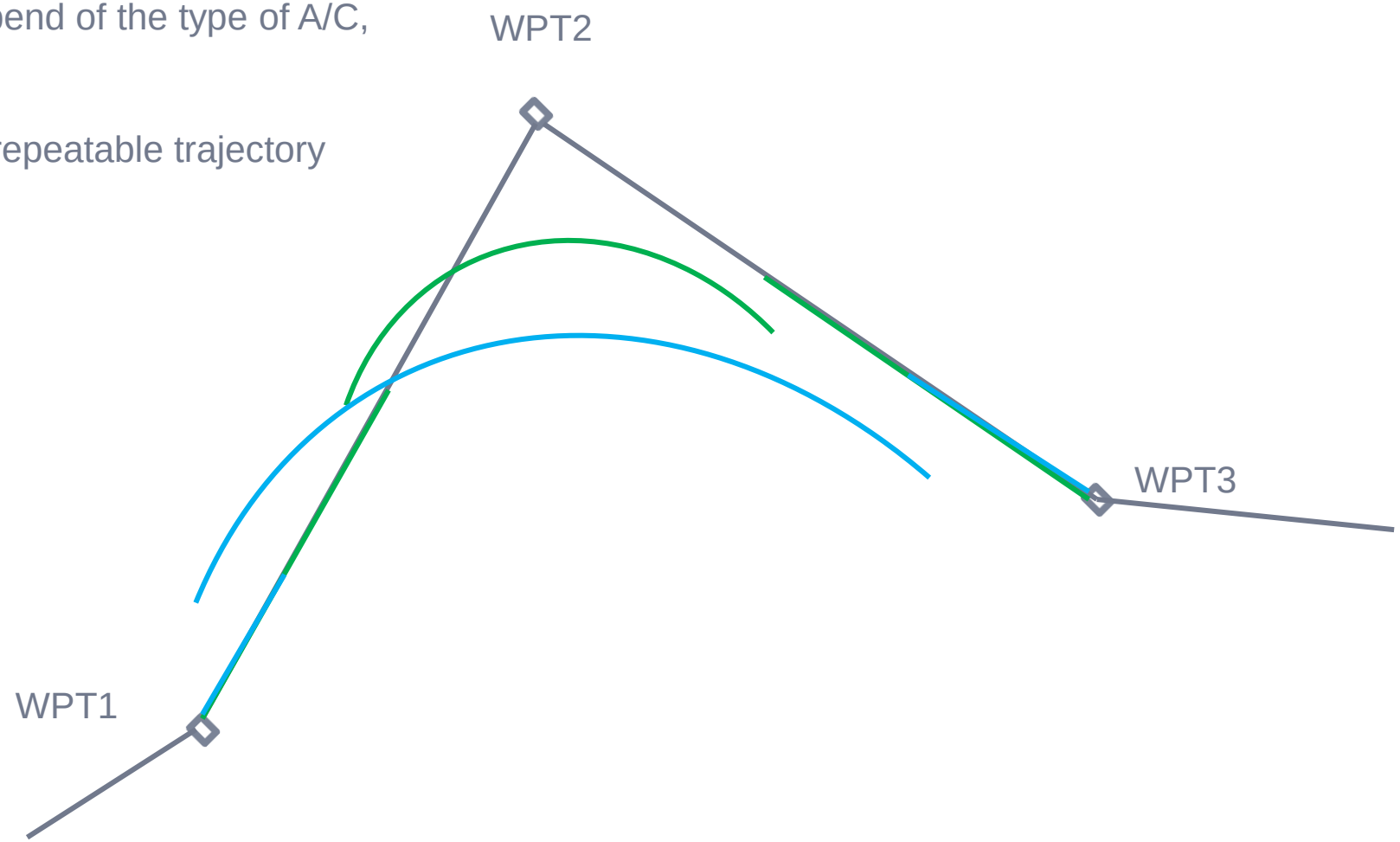
ADVANCED RNP: RF legs

Without RF legs: trajectory will depend of the type of A/C, FMS

→ not repeatable trajectory



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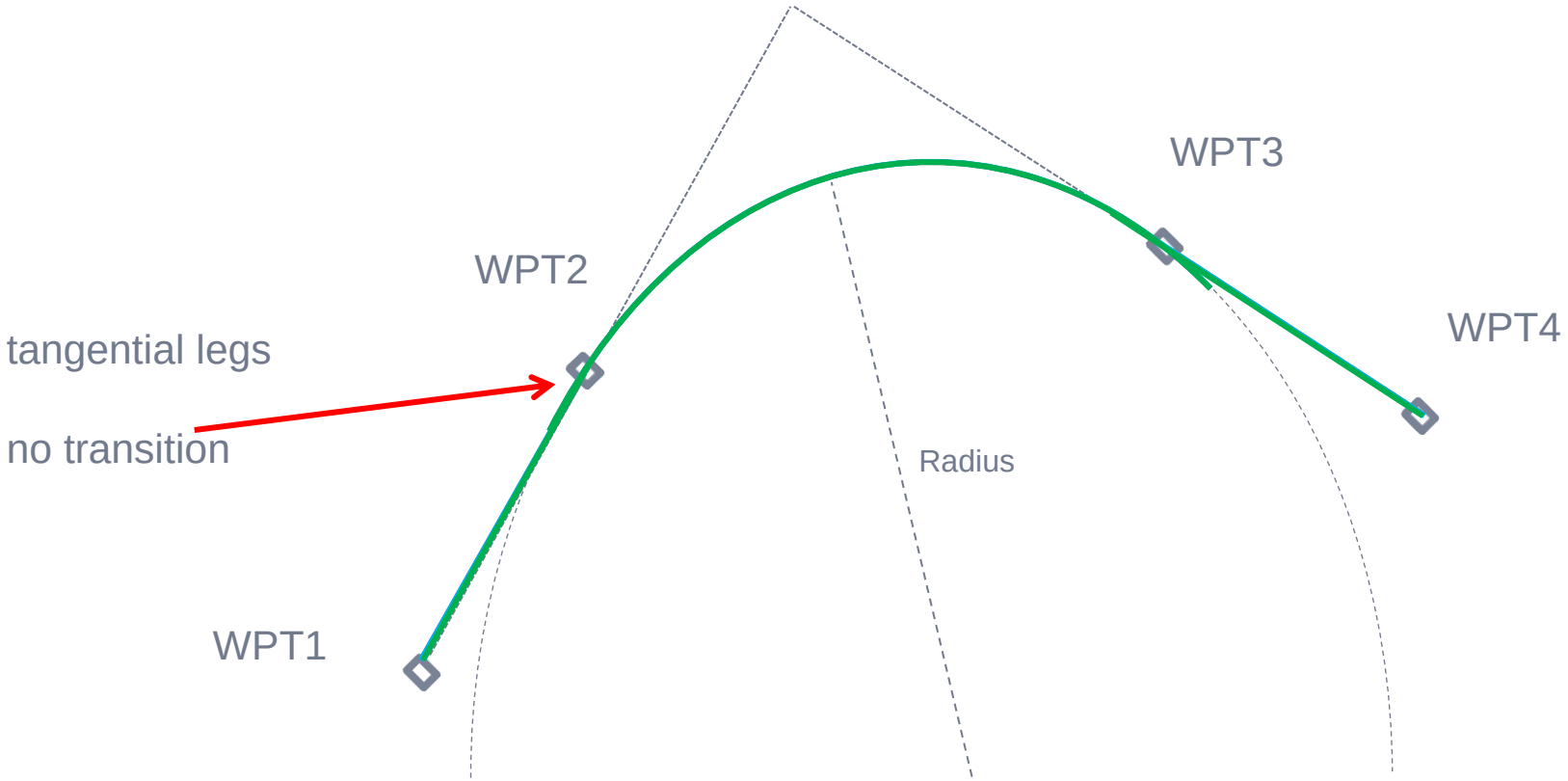
ADVANCED RNP: RF legs

With RF legs:
no transitions left to FMS



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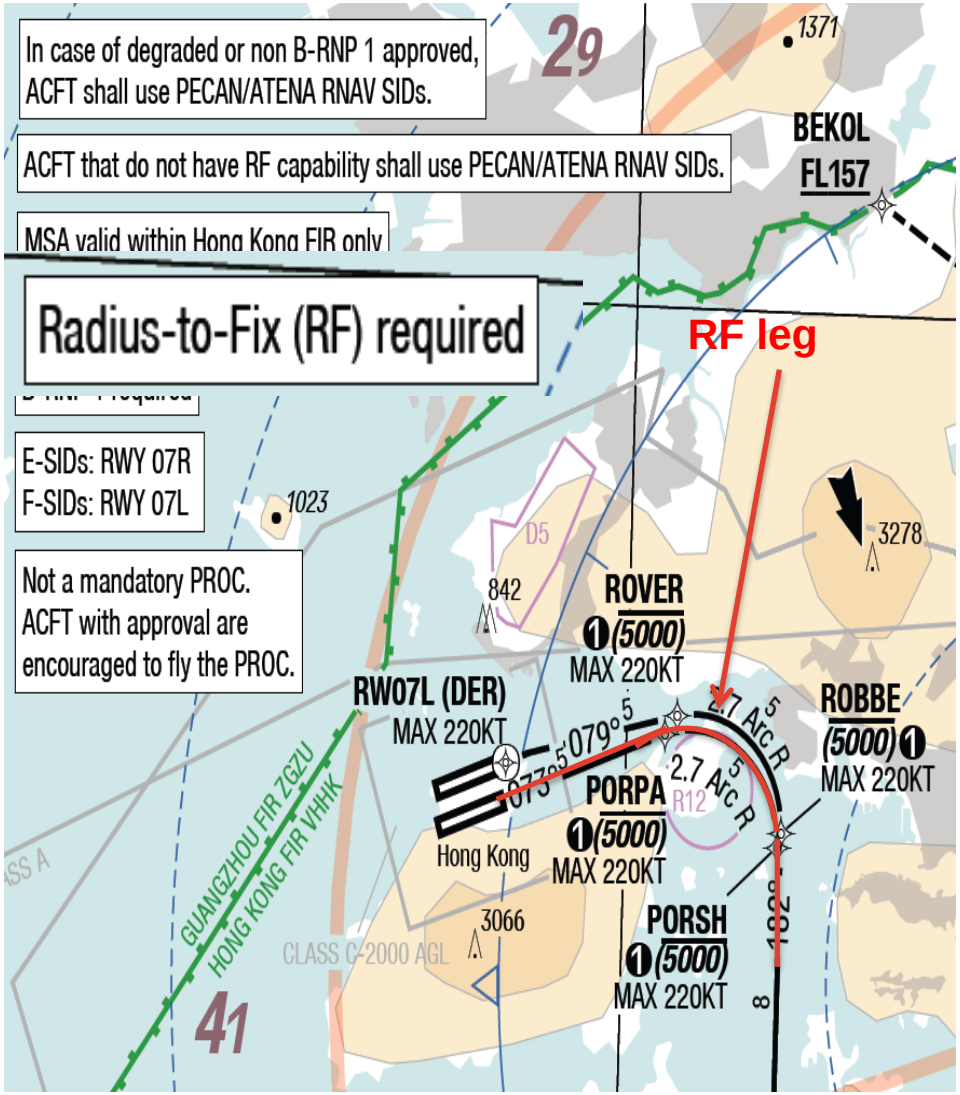
ADVANCED RNP: RNP 1

RF required indicated on chart



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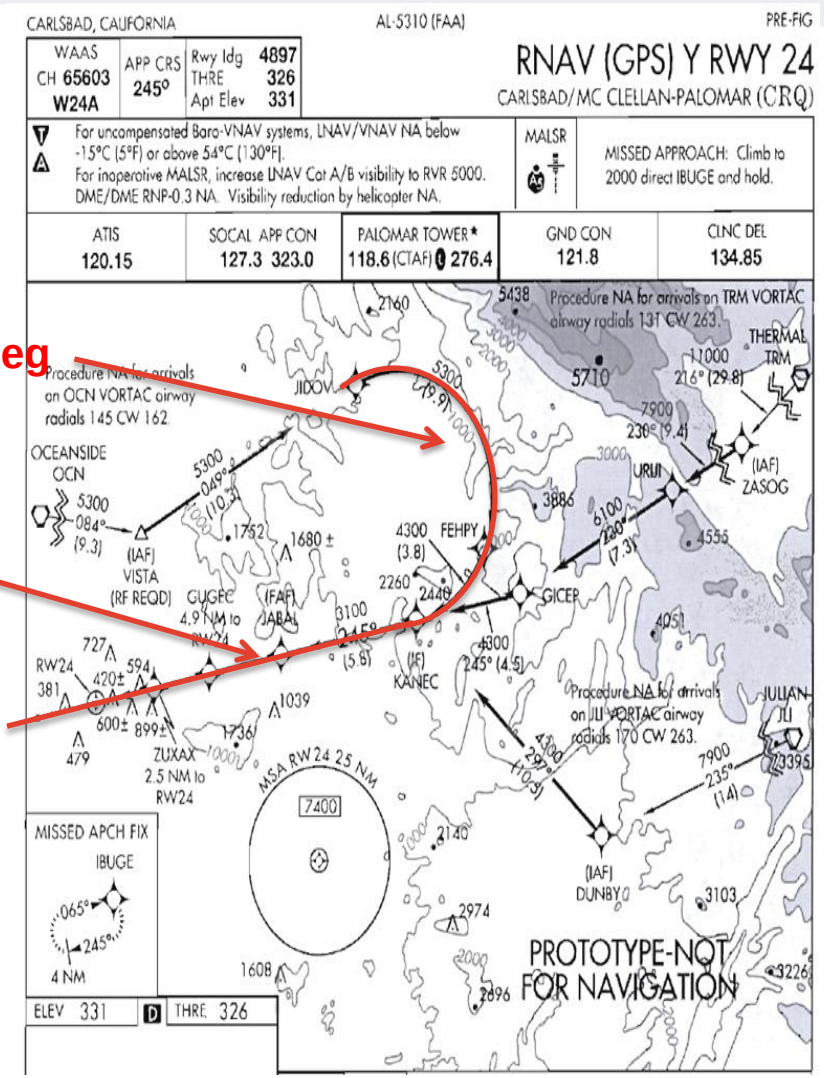
ADVANCED RNP: RNP APCH

- RF legs : allow turn without transition

But

- still buffer
- still no RF below FAF
- still Missed approach and intermediate with RNP 1

→ For more complex procedure:
RNP AR is needed



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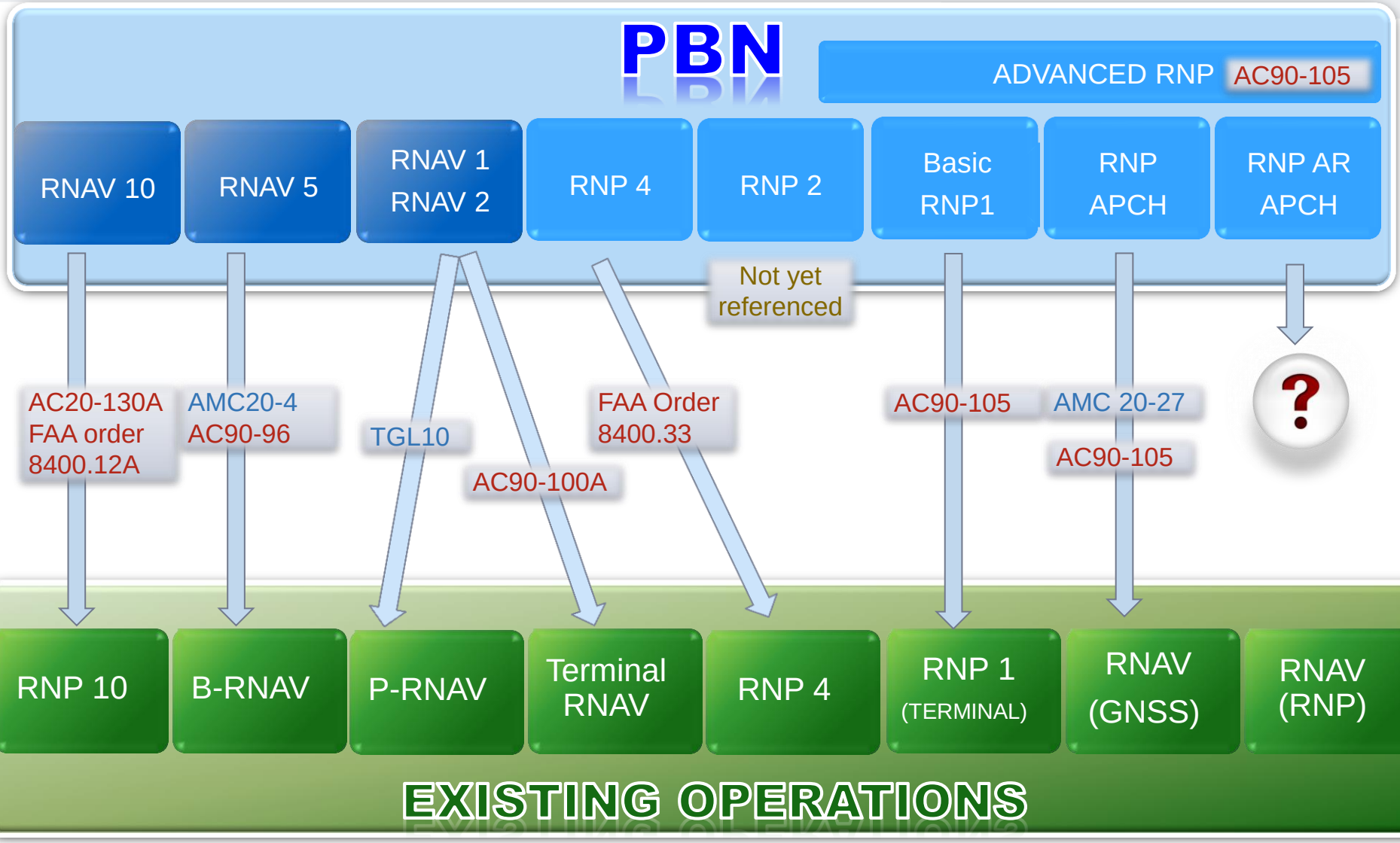
Link with existing operations



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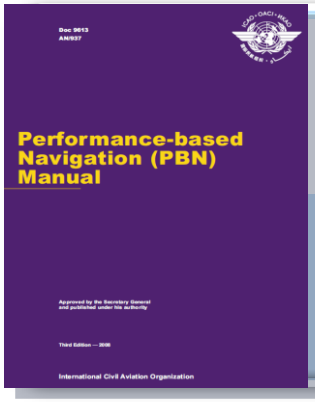
RNP AR operation



Chapter 6

IMPLEMENTING RNP AR APCH

PBN

RNP AR APCH

Link with existing

RNAV (RNP)

Related documents :

EASA AMC 20-26

FAA AC90-101 and now AC90-101A and AC20-138C

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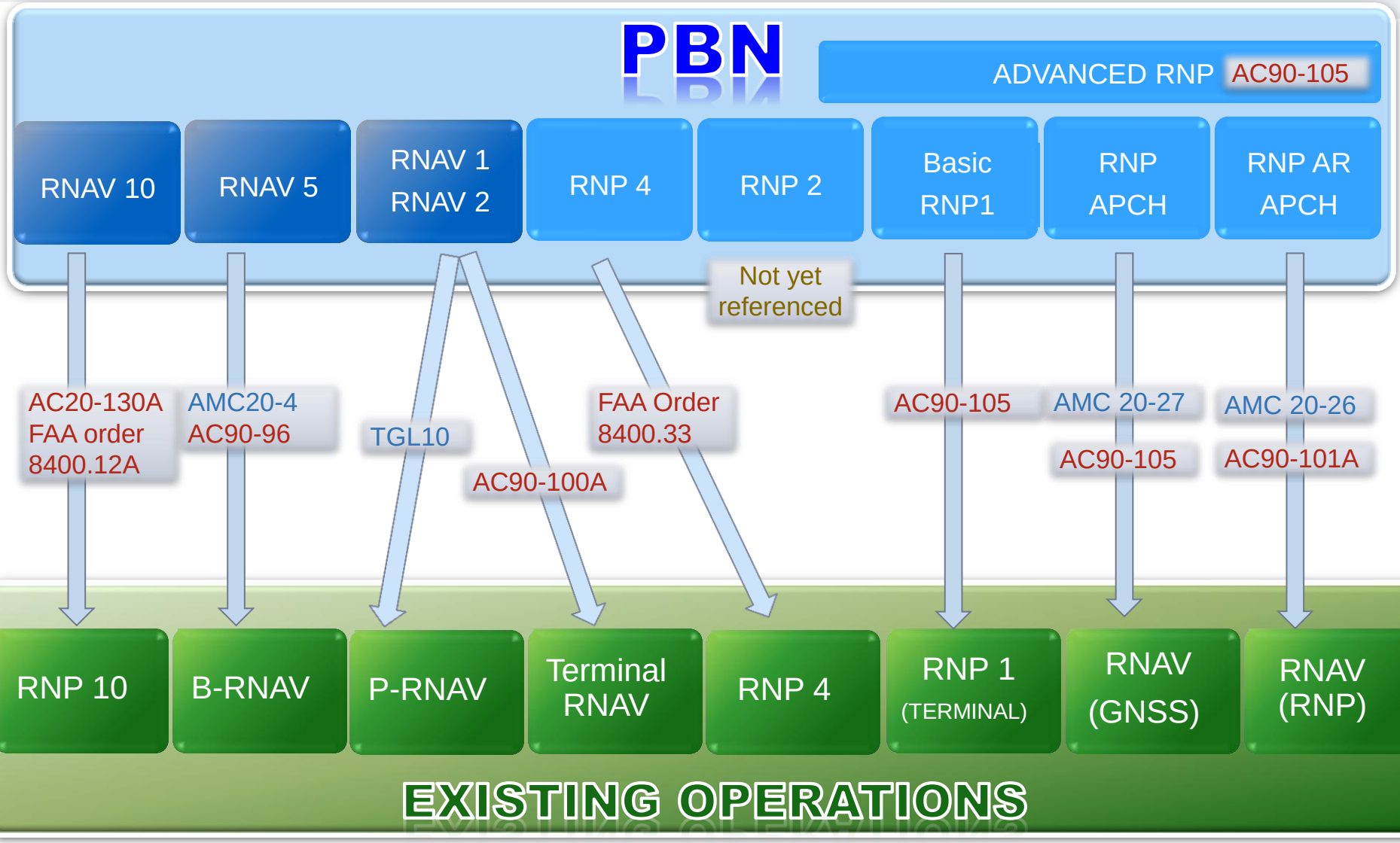
Link with existing operations



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AGENDA

- ICAO PBN MANUAL
- FOCUS ON OBPMA
- PBN BENEFITS

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PBN concept

RNAV 1

No ALERT on board

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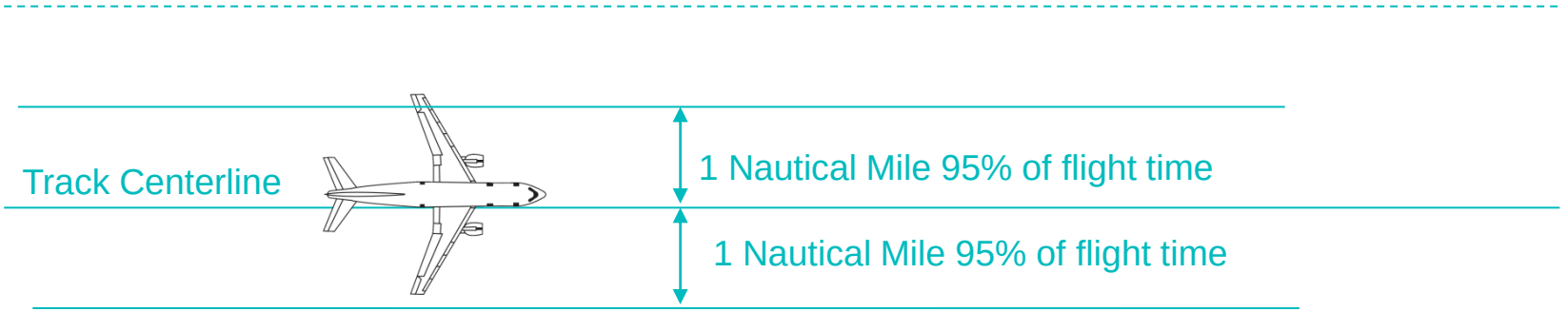
PBN concept

RNP 1

ALERT and Crew procedure



The Key difference

On-board performance Monitoring and alerting function

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On-Board performance monitoring and alerting function

What is an On-board performance monitoring and alerting function ?

- A function on board the aircraft detecting and informing the crew when the RNAV system is unable to satisfy the performance prescribed in the *navigation specification.*
- This function should monitor all type of errors which may affect the aircraft ability to follow the desired flight path.
- The required level of on board monitoring and alerting is stipulated in each RNP navigation specification.

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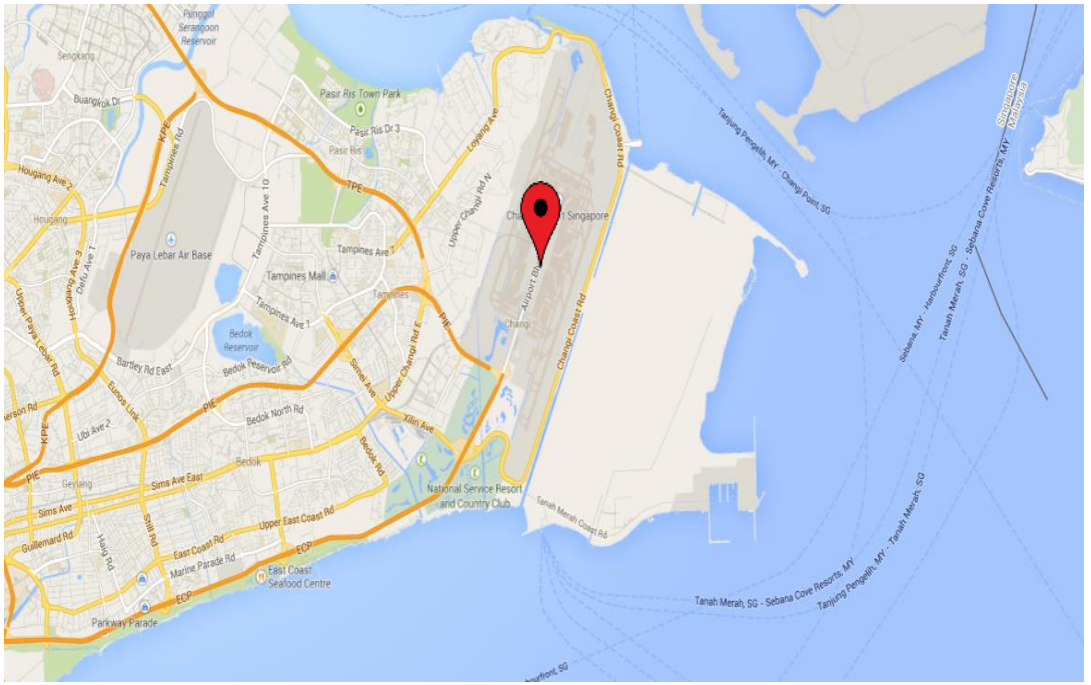
PBN Concept : Definitions

- **To NAVIGATE you need :**
  - **A MAP, to define your trajectory**

  →Waypoints in NDB
  - **To know where you are**

→ Position at A/C level thanks to IRS and GPS
  - **to be Guided along the trajectory**

→ Guidance by FMS/AP or FD order provide to the crew



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PBN Concept: Positioning

Position error from:

- Path Computation

+

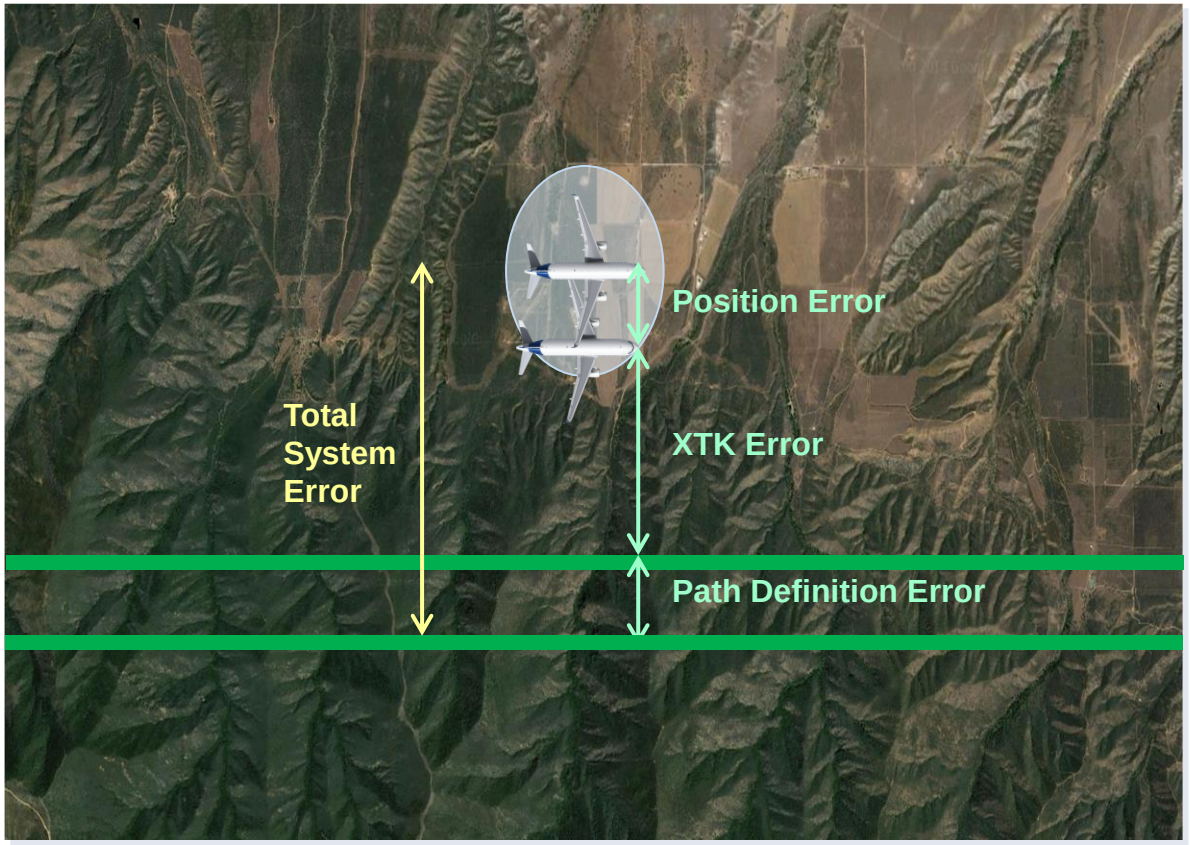
- Guidance : XTK error

+

- Position computation

=

Total System Error



XTK : Cross Track

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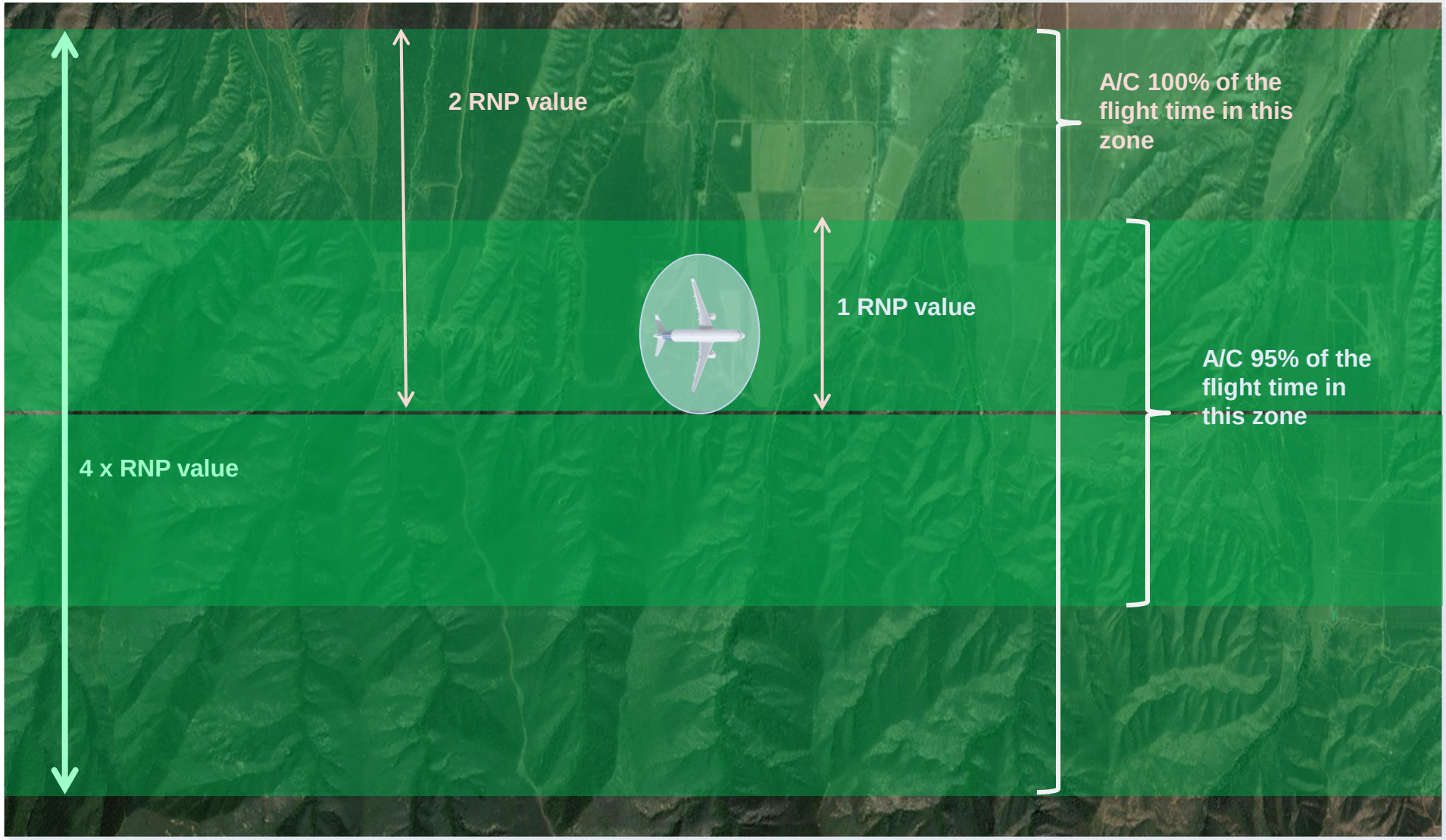
PBN Concept: Design of a RNP or RNAV procedure



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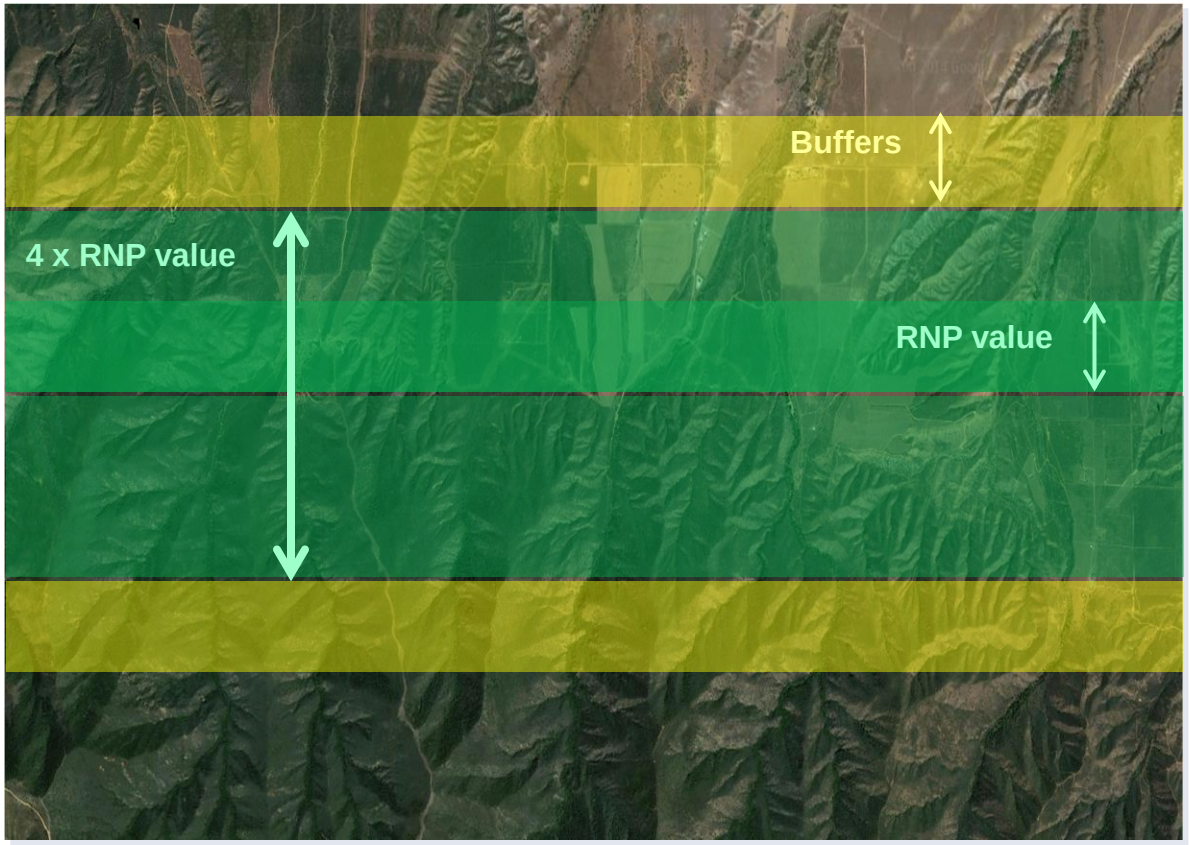
PBN Concept: Design of a RNP or RNAV procedure

- Corridor of 2 RNP each side of the A/C
- Buffers
- Outside this zone obstacle or other airspace are not taken into account



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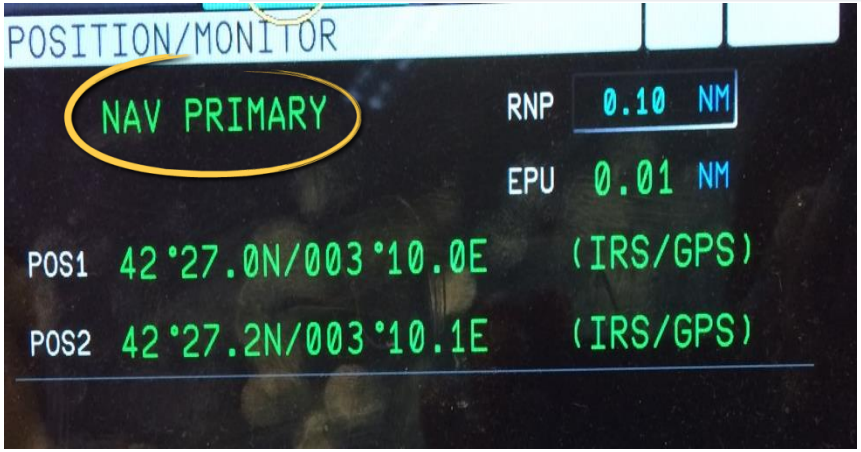
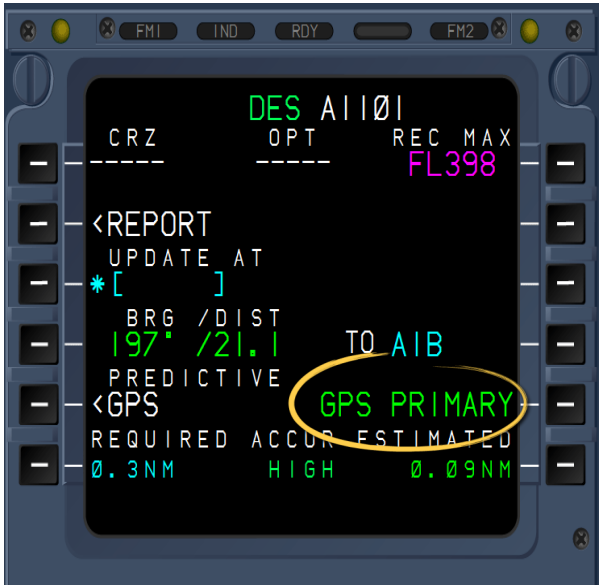
PBN Concept: RNP

- To be RNP capable, the FMS must monitors its navigation performance regarding the RNP value.
- It requests an On-Board Performance Monitoring and Alerting System.
- All Airbus A/C have an OBPMA





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Navigation System Error (NSE)

- Difference between the actual position and the calculated position
- Takes into account:
  - Transmitted Signal error
  - Position calculation error

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Flight Technical Error (FTE)

- Ability to follow the defined path
  - FTE in manual mode (Pilot follows the deviation from the CDI)
  - FTE with the FD
  - FTE of the Autopilot
- Error depends on the flight phase (sensibility of the deviation indicator, AP ….)

		Coupled	
Flight Phase	Manual (nm)	Flight Director (nm)	Autopilot (nm)
Oceanic	2.0	0.5	0.25
En Route	1.0	0.5	0.25
Terminal	1.0	0.5	0.25
Approach	0.5	0.25	0.125

FTE assumptions from RTCA DO 208 Appendix E

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Path Definition Error (PDE)

- Errors between the desired path and the defined path
- WPTs coordinates in WGS 84
- Possible Error Source:
  - Errors in the defined coordinates of the WPt
  - Mis interpretation of the source by the data base encoder
  - ….
- PDE is managed through a quality process and development methodology in data processing
  - DO 200A
  - LOA Type 1 and 2
  - ….

- The end user is the operator
  - He has to assess that adequate development methodology has been applied
  - Crew procedures to check that what is encoded is what is published.

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PBN Concept: Airbus A/C performances

- **PDE**: considered null (NDB well coded and verified)

- **XTK:** MONITOR BY THE CREW

upon AP less than 0.1NM most of the time

- **EPU:** MONITOR BY THE SYSTEM (OBPMA)

less than 0.08NM most of the time

4 RNP corridor to cover major critical failures

PDE : Path Definition Error
EPU : Estimated Position Uncertainty

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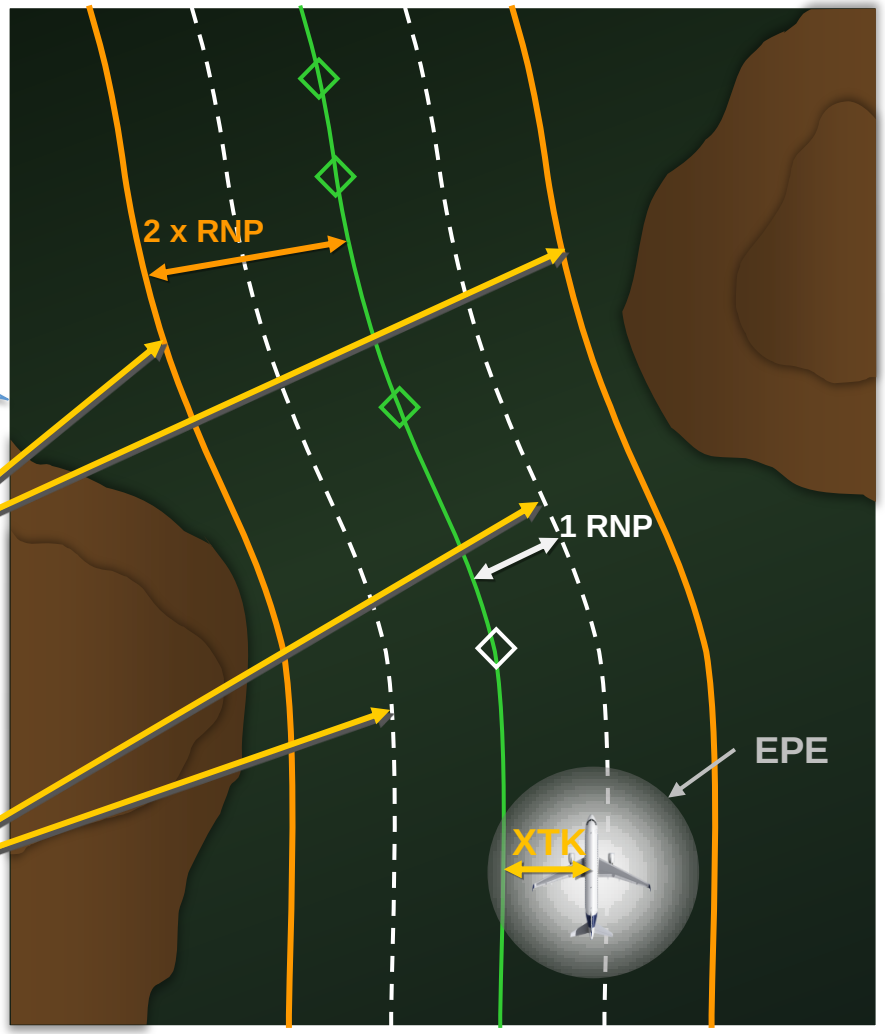
PBN – Flight Operations

PBN – Procedure Design

The new design criteria need adapted SOPs*

* Standard Operating Procedures



MINIMUM LATERAL OBSTACLE CLEARANCE LIMIT

A **2xRNP** corridor represents the **Containment limit** for escape, free of obstacles.

OPERATIONAL LIMIT

If LDEV or XTK reaches **1xRNP** (the **Operational limit) an approach will be interrupted.**

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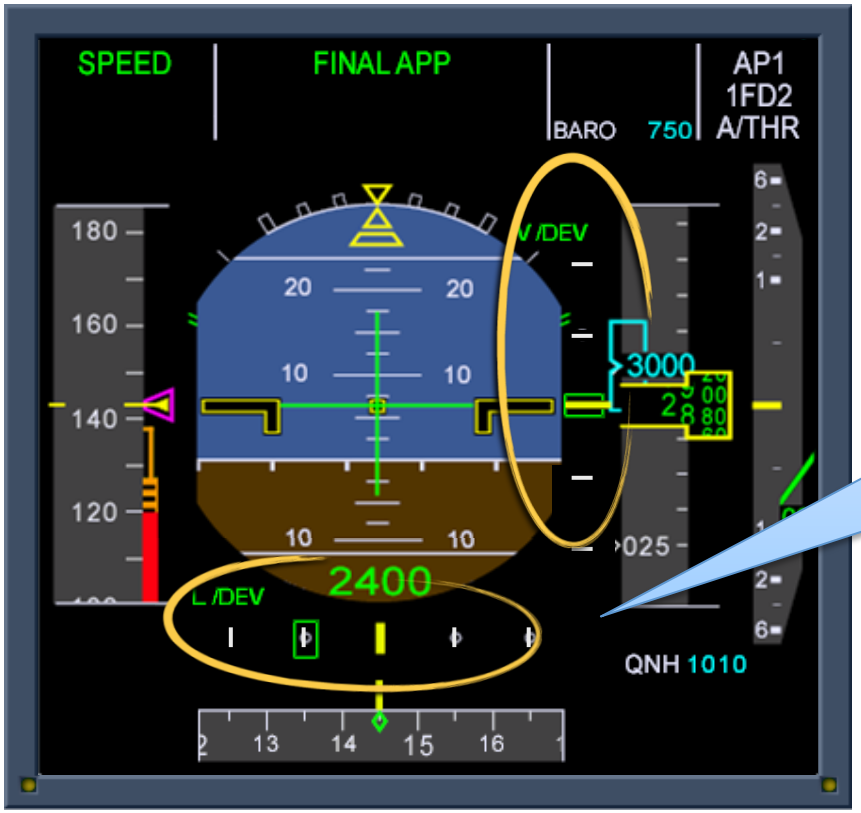
PBN Standard Operating Procedures

PBN – Trajectory Control

Main parameters controlled and monitored by the Flight Crew



It is the responsibility of the Crew to keep LDEV & VDEV inside the operational limits

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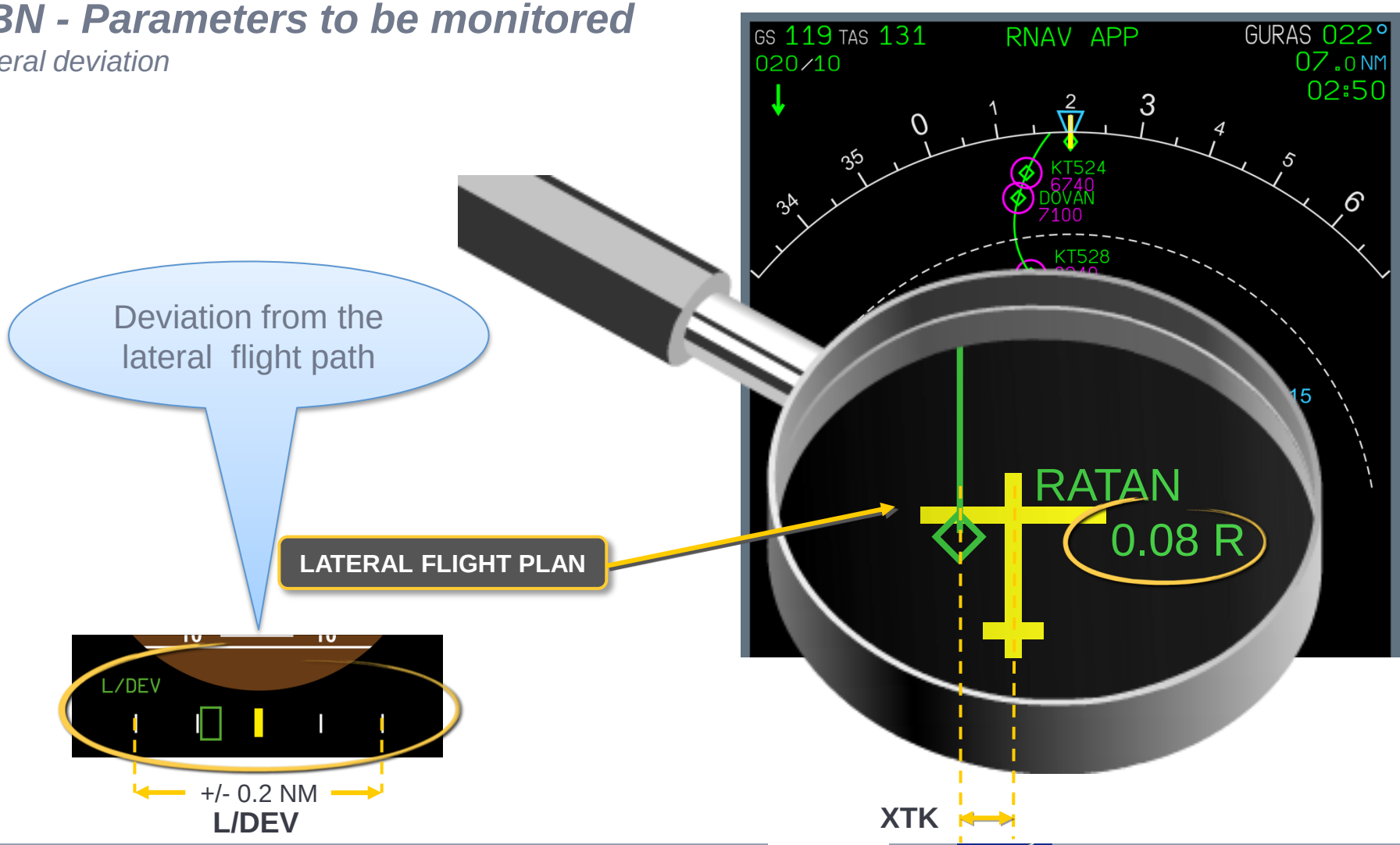
13/10/2014

PBN - Parameters to be monitored

PBN - Parameters to be monitored

Lateral deviation



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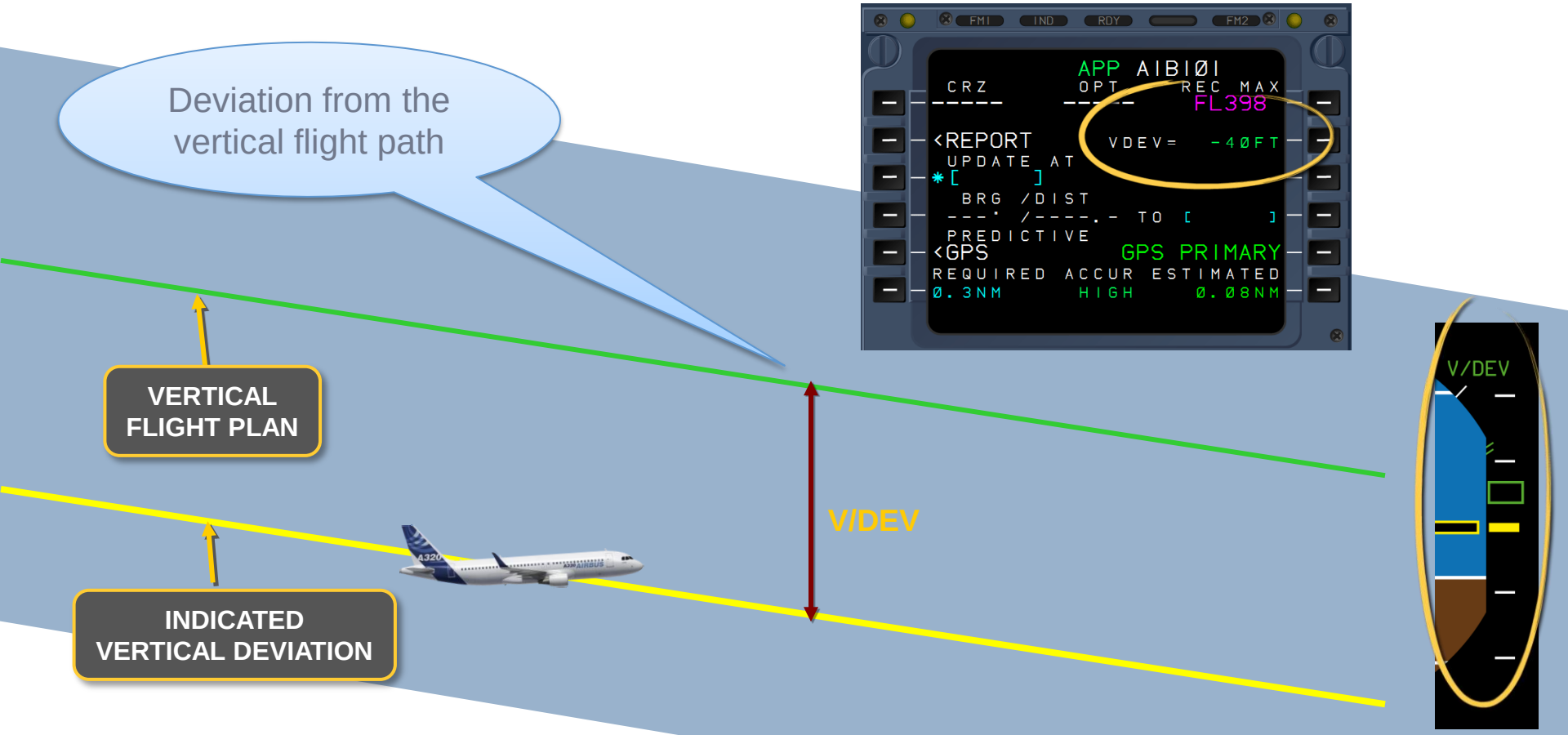
PBN - Parameters to be monitored

PBN - Parameters to be monitored

Vertical deviation



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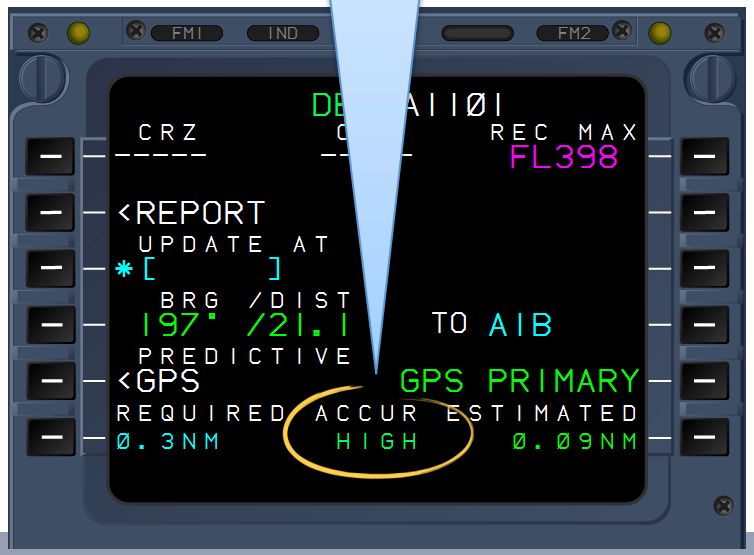
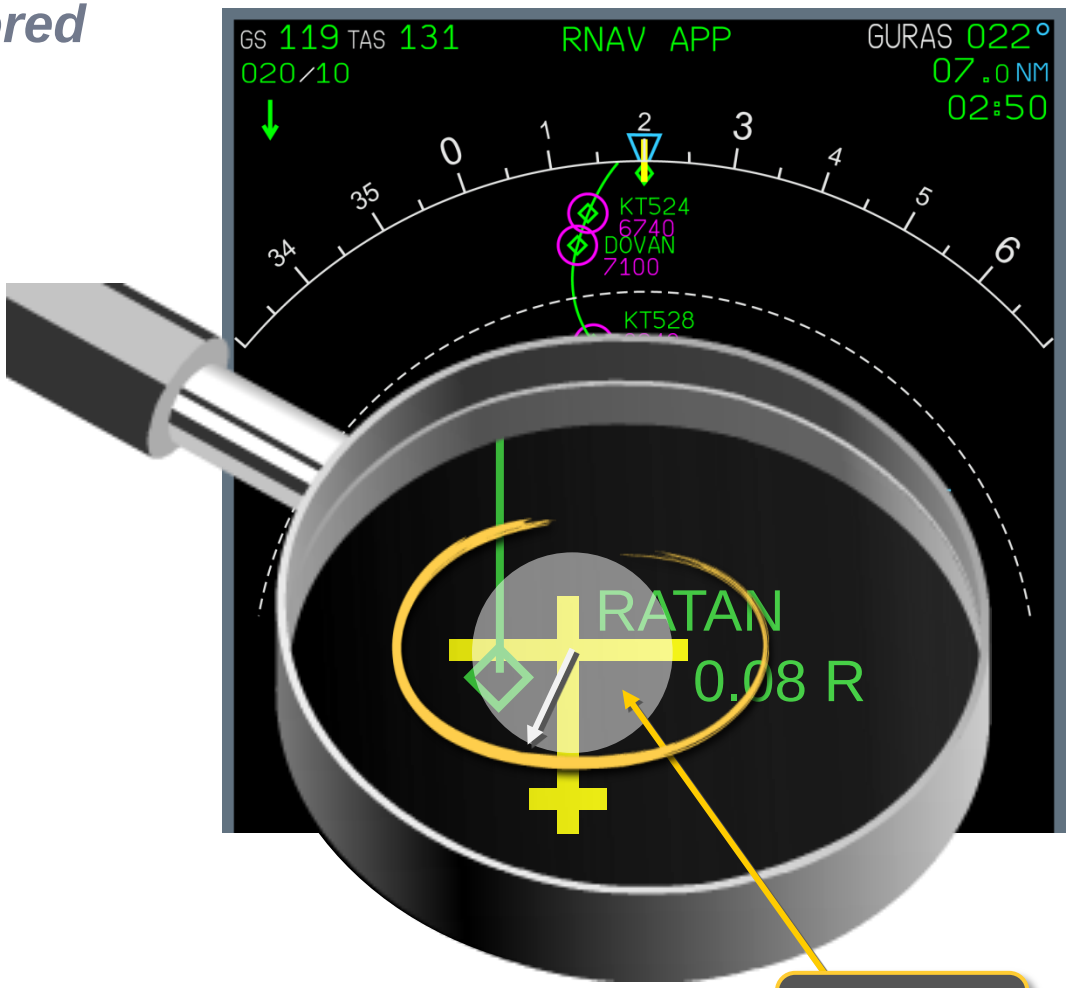
PBN - Parameters to be monitored

PBN - Parameters to be monitored

Navigation system

Accuracy level of the navigation system





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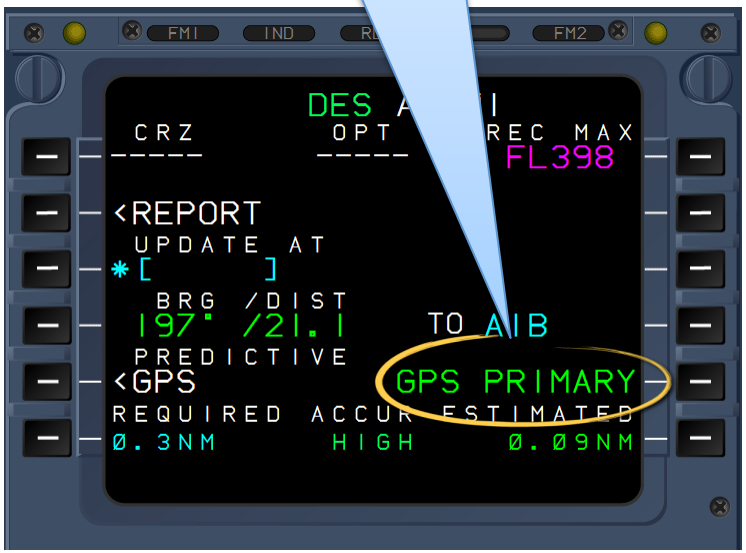
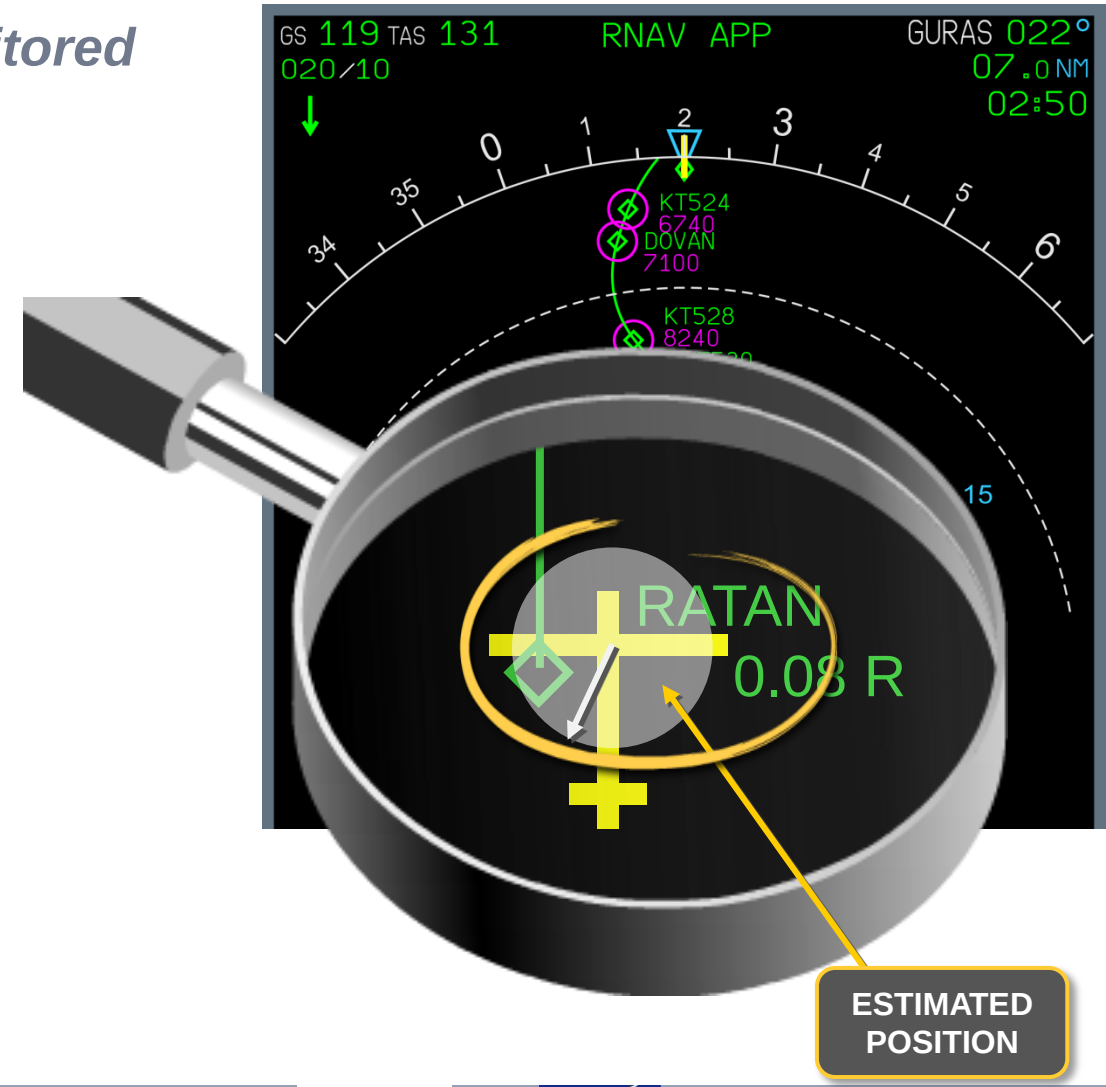
PBN - Parameters to be monitored

PBN - Parameters to be monitored

Navigation system

GPS PRIMARY:
No need for Navigation gross error checking by the crew





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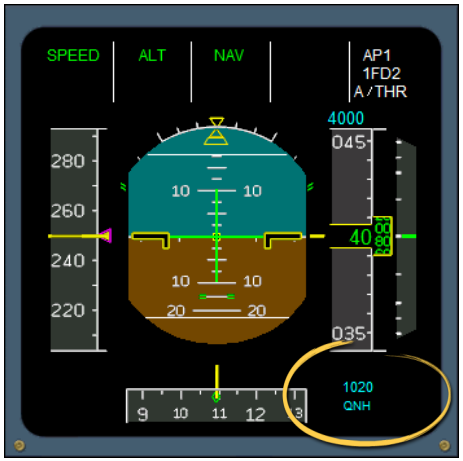
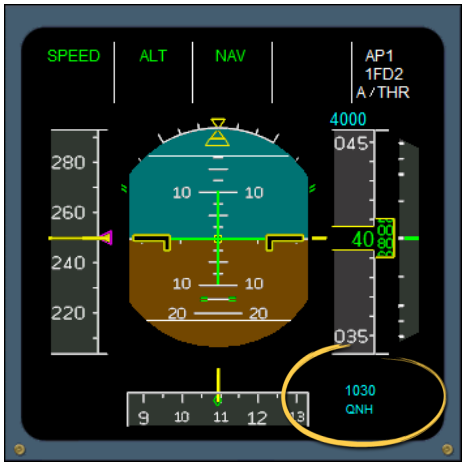
PBN - Parameters to be monitored

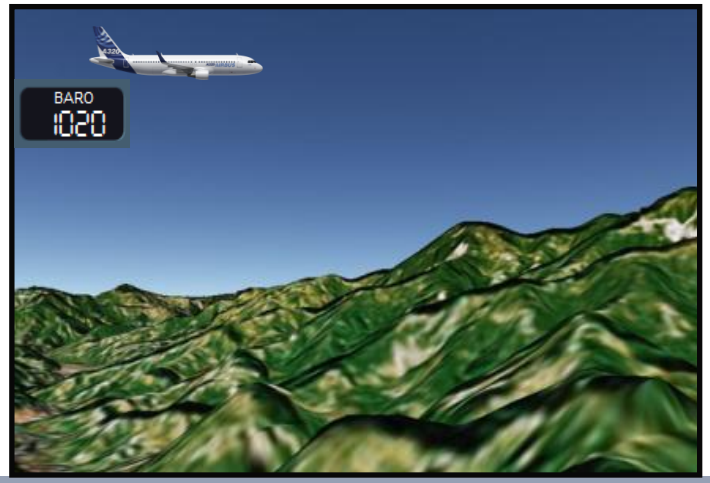
PBN - Parameters to be monitored

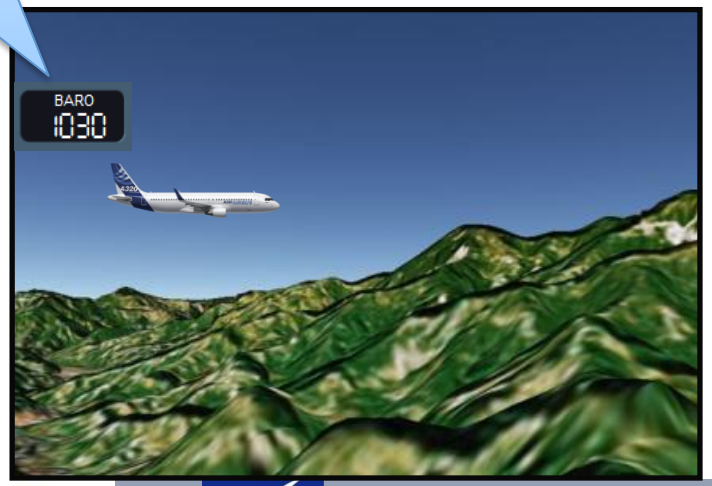
Altimeter setting



The correct Altimeter Setting is **ONLY** crew monitored







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PBN – Standard Operating Procedures

PBN – Standard Operating Procedures

Example: Call-outs for different situations

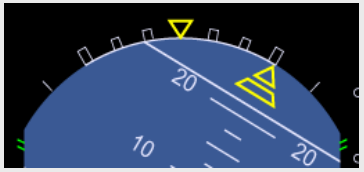
"CROSSTRACK"

When the lateral deviation reaches 1dot (0.1NM) or ½ RNP.

"V/DEV"

When the vertical deviation reaches half a dot (50ft)

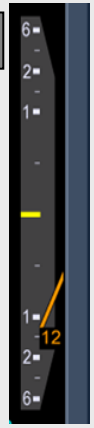
"BANK"



When the bank angle exceeds 30 º.

"SINK RATE"

When the vertical speed exceeds1200 fpm.



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AGENDA

- ICAO PBN MANUAL
- FOCUS ON OBPMA
- PBN BENEFITS

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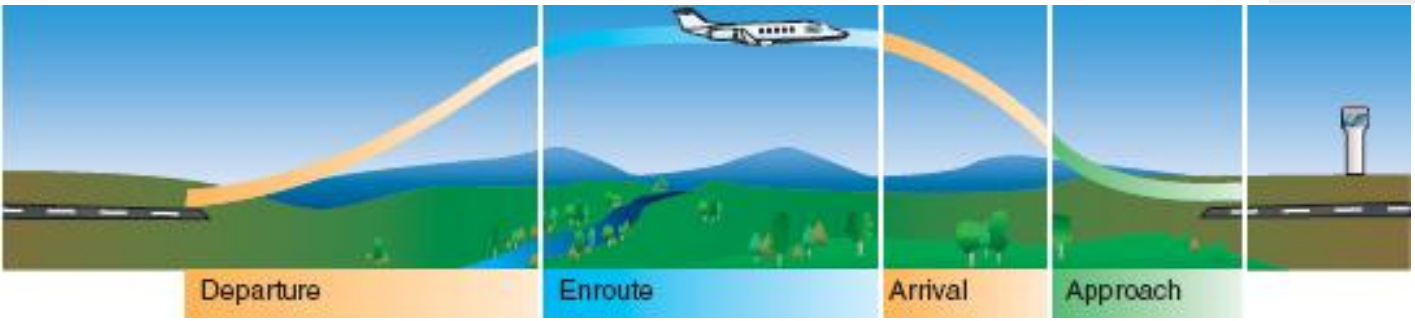
Required performance for the different phases of flight



- Required performance is driven by the the phase of flight.
- The criteria used to characterise an RNAV operation is generally the accuracy (Total System Error or TSE).
- Existing European and US navigation applications accuracy are in the following range for today's RNAV operation:
  - Oceanic and remote areas : from 12.6 Nm to 4 Nm
  - En Route continental : from 5 Nm to 2 Nm
  - Departure and Arrival : 1 Nm
  - Approaches : from 0.3 Nm to 0.1 Nm

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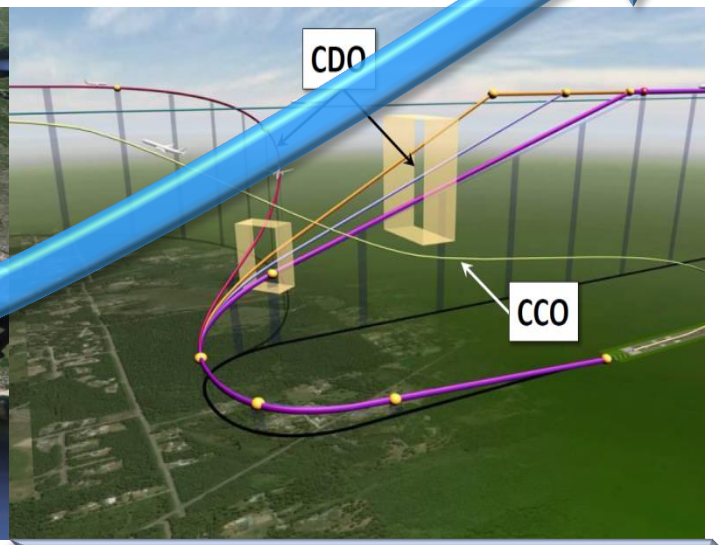
From a specific to a wide use of PBN

Increasing number of PBN applications

Specific: Few Airlines, few procedures	More and more users	Wide Use of RNP



90's
First RNP Approach

2014

The future 4D trajectory SESAR

Giving access to remote areas

Improving Airport capacity

Increasing efficiency fuel and time saving

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RNP common overview : obvious advantage

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RNP common overview

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PBN in terminal Area to face congested airspace

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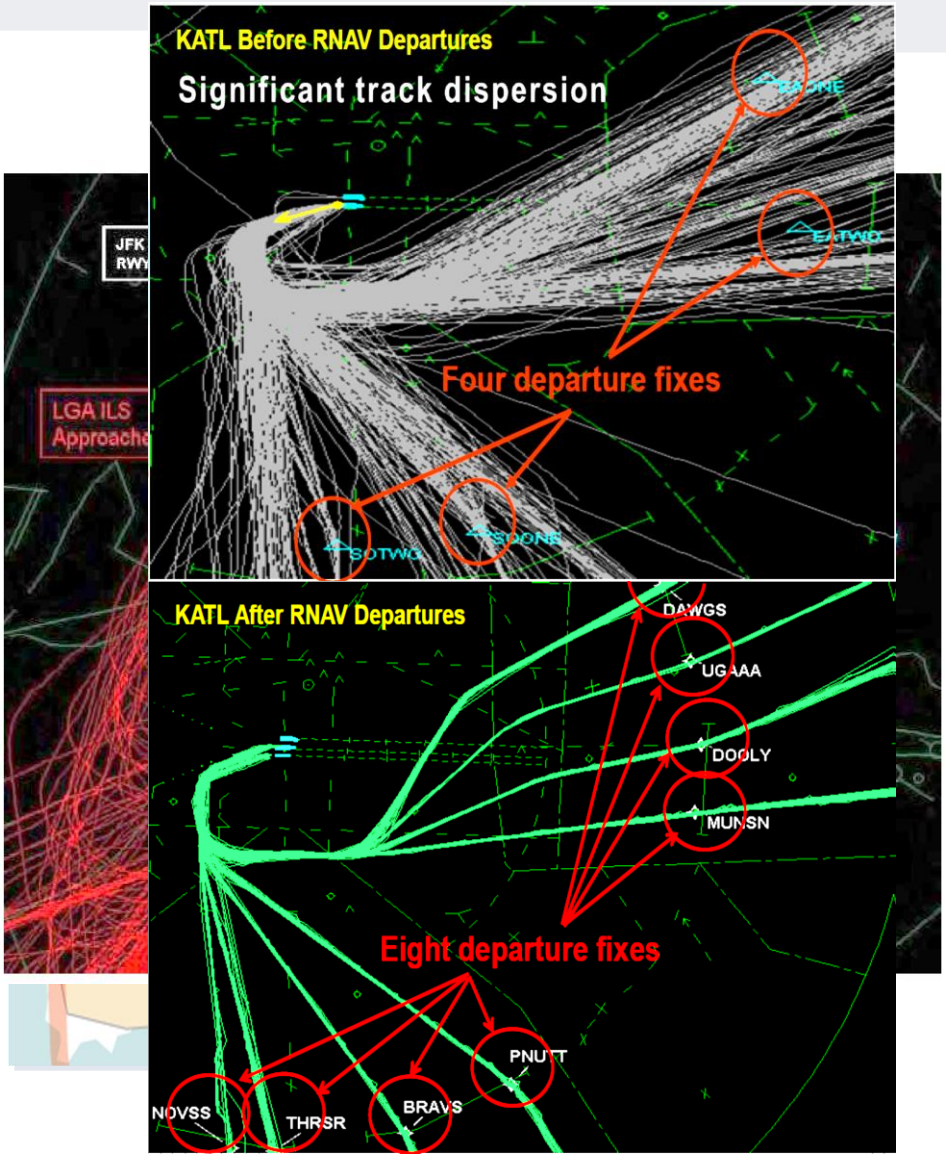
Advantages of PBN for ANSP

- Routes not based on ground navaids location
- Fully coded routes
- Lateral and vertical containment
  - Reduction of the separations
  - Solution for traffic segregations between 2 airports
  - Noise sensitive area avoidance



ANSP: Air Navigation Service Provider

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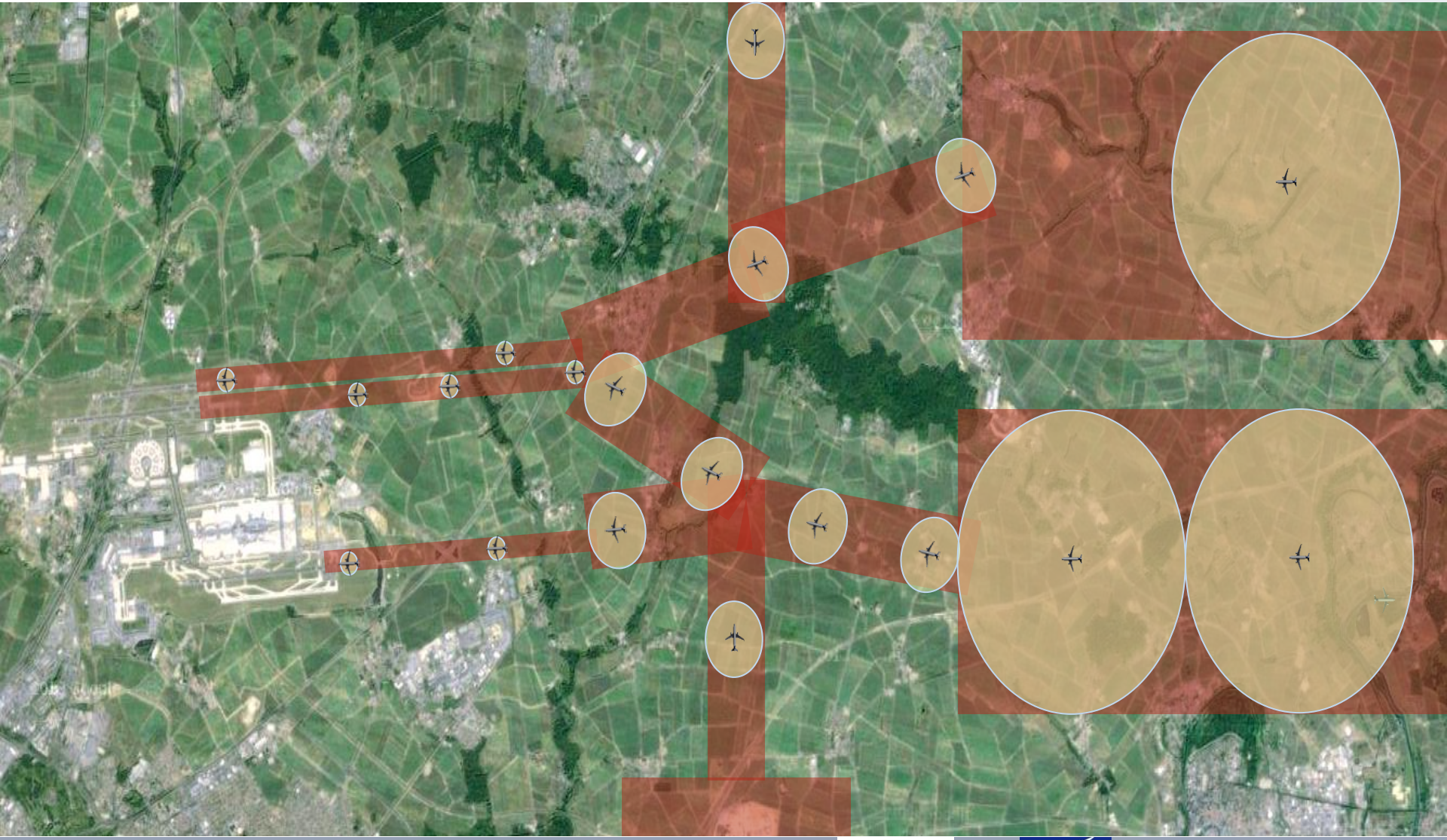
PBN used for traffic reasons



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