AFCAC/ICAO Joint Workshop on PBN Implementation

Performance Based Navigation (PBN) in Europe

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24th June 2014

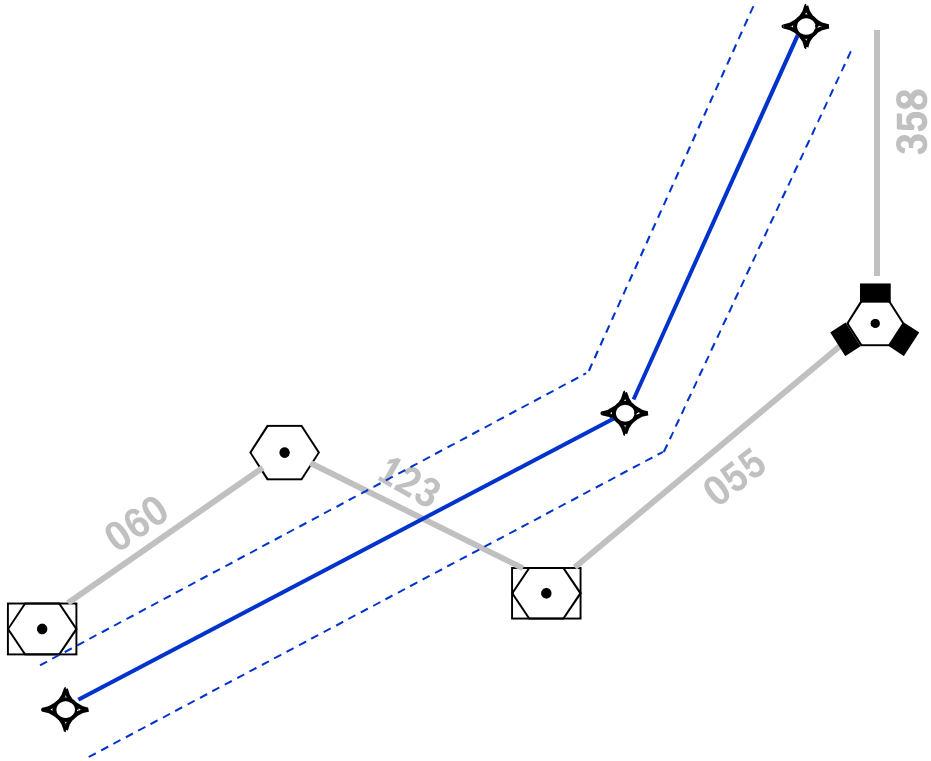
EUROCONTROL

Overview

- Area Navigation
- PBN Concept
- Linking PBN & the rest: Benefits
- European PBN developments
- Implementation Considerations
- Questions

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 systems, or
  - a combination of these capabilities



Blue line shows ATS route designed using area navigation techniques: without constraints of ground-based NAVAIDs

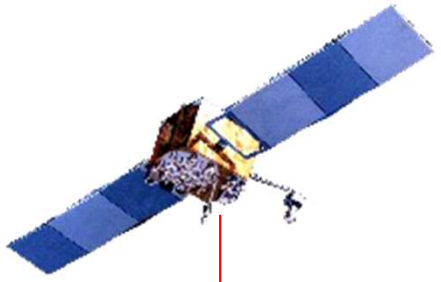
Area navigation is flown using a navigation computer

area navigation is the key enabler for PBN

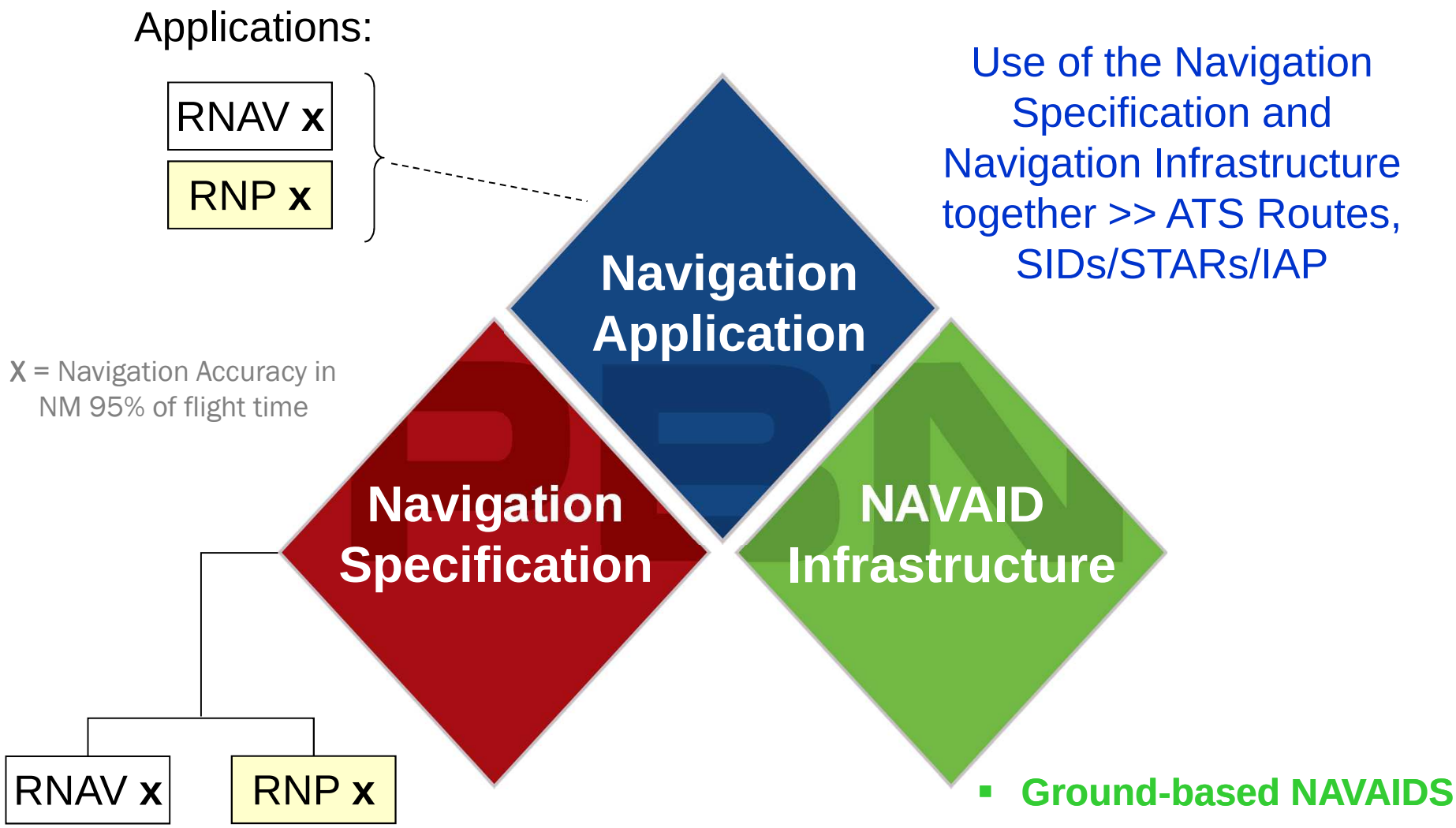
Area Navigation

How is Area Navigation Enabled?

- Through the use of a navigation computer
- Waypoints (co-ordinates) are input into computer
  - Manual entry permitted but limits capabilities
  - Automatically with an integrated database
- Pilot creates route (series of waypoints) i.a.w. flight plan
- Computer estimates position using navigation sensors fitted and compares estimation to defined route
- Deviation between the position and defined path will create guidance information



Components of PBN Concept



Use of the Navigation Specification and Navigation Infrastructure together >> ATS Routes, SIDs/STARs/IAP

- **Ground-based NAVAIDS**
- **Space-based NAVAIDS**

Components of PBN Concept

Accuracy
Integrity
Continuity

Aim is to limit number of Nav. Specs in global use

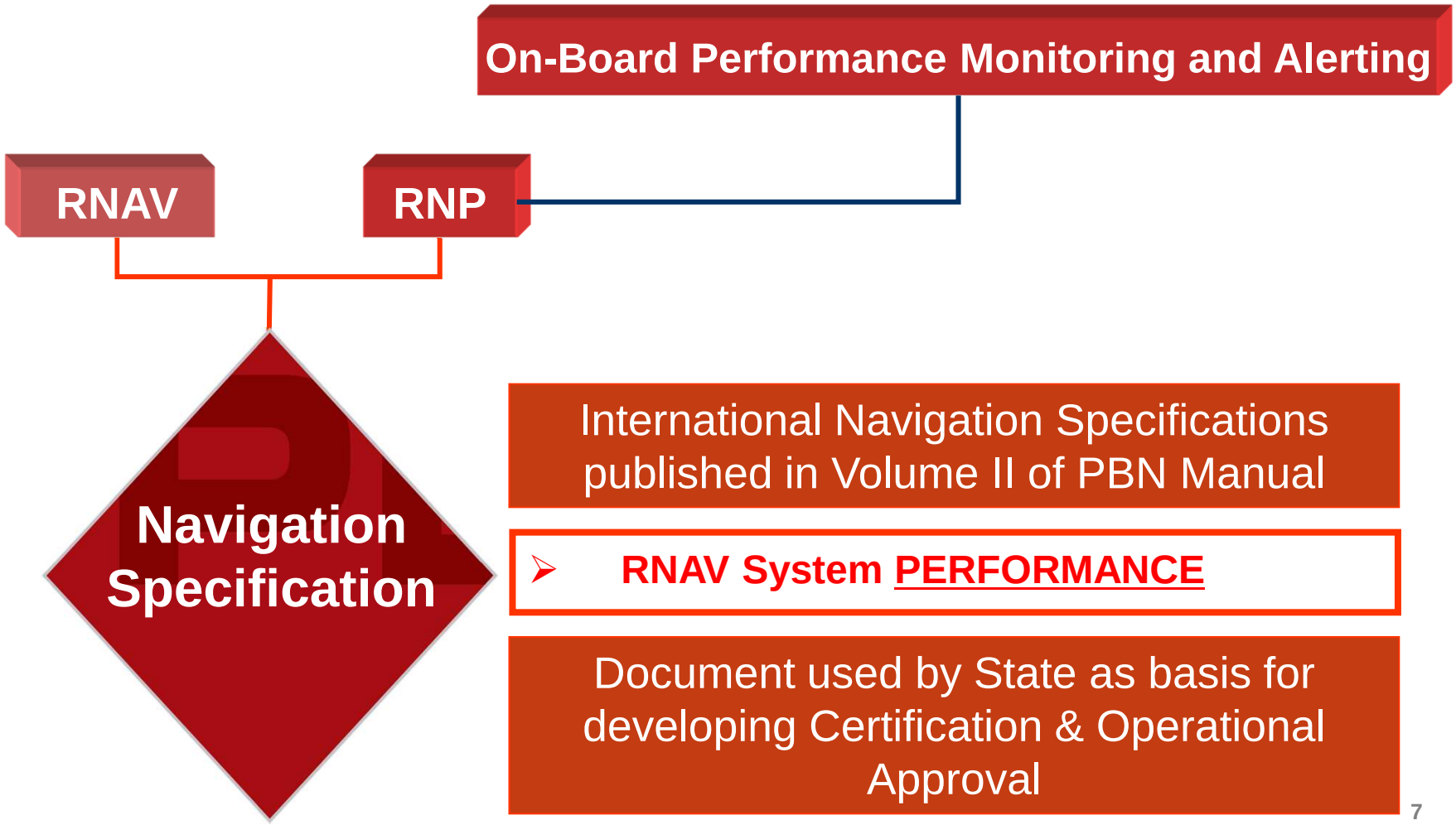
Navigation Specification

International Navigation Specifications published in Volume II of PBN Manual

- **What PERFORMANCE is required of the RNAV system?**
- **What Functionalities must RNAV system have to achieve *Performance***
- **What Navigation Sensors must be integrated in RNAV system to achieve *Performance***
- **What requirements are placed on the Air crew to achieve the required *Performance* from the RNAV system?**

Document used by State as basis for developing Certification & Operational Approval

Components of PBN Concept



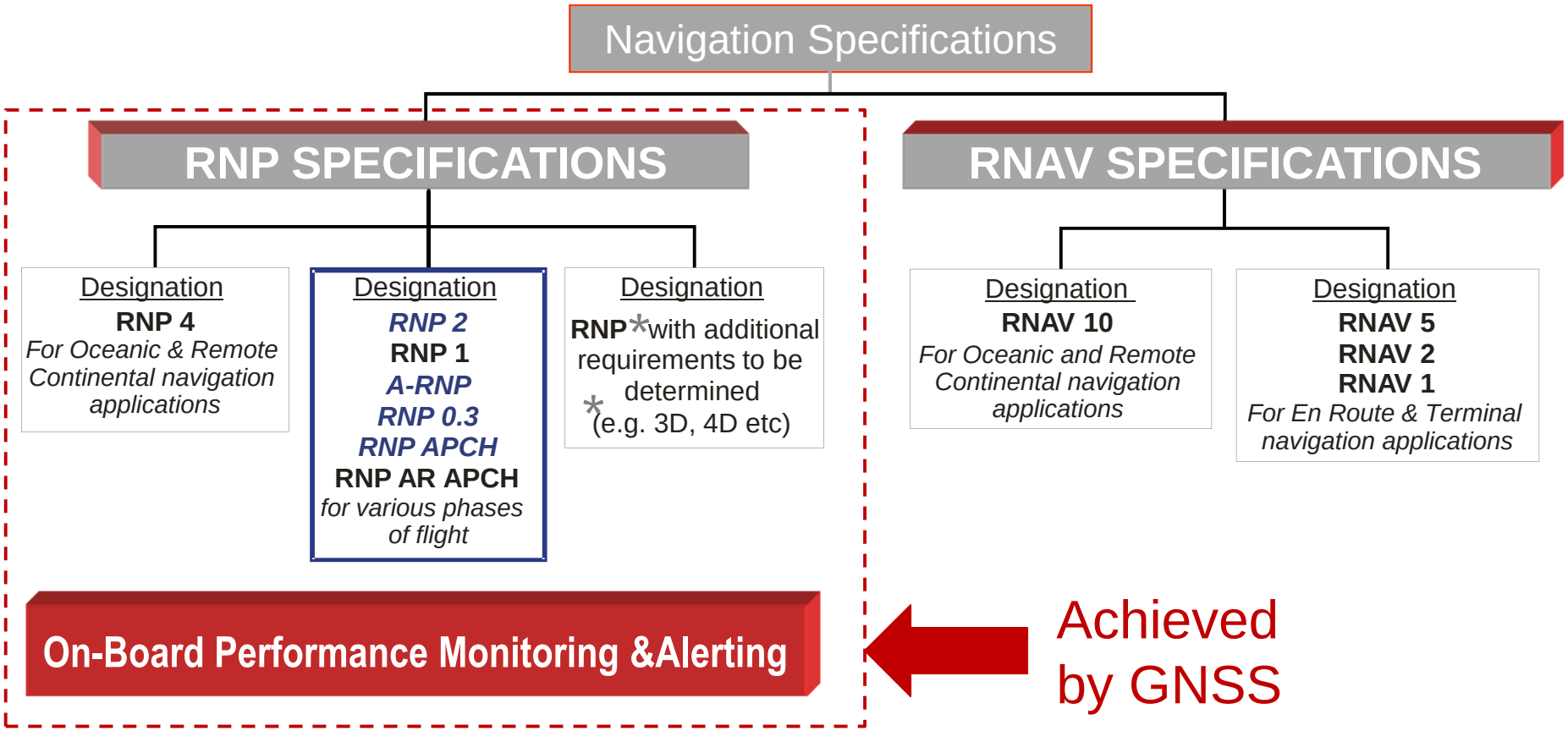
International Navigation Specifications published in Volume II of PBN Manual

➢ **RNAV System <u>PERFORMANCE</u>**

Document used by State as basis for developing Certification & Operational Approval

PBN Specifications

The name of RNAV or RNP specifications for en route and terminal mostly indicates the lateral accuracy requirements 95% of the flight time. E.g. RNAV 1 (1nm either side of track 95% flight time).



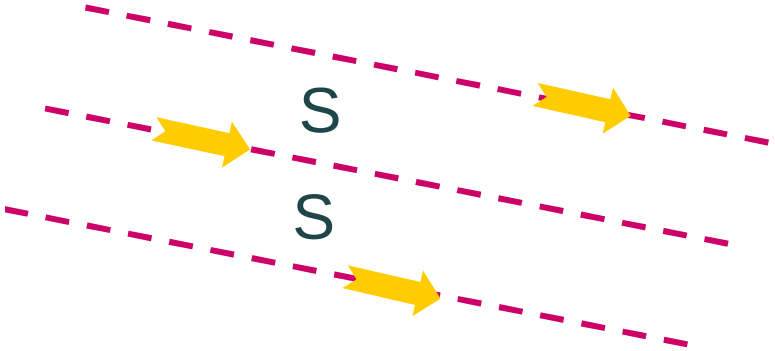
KEY MESSAGE!

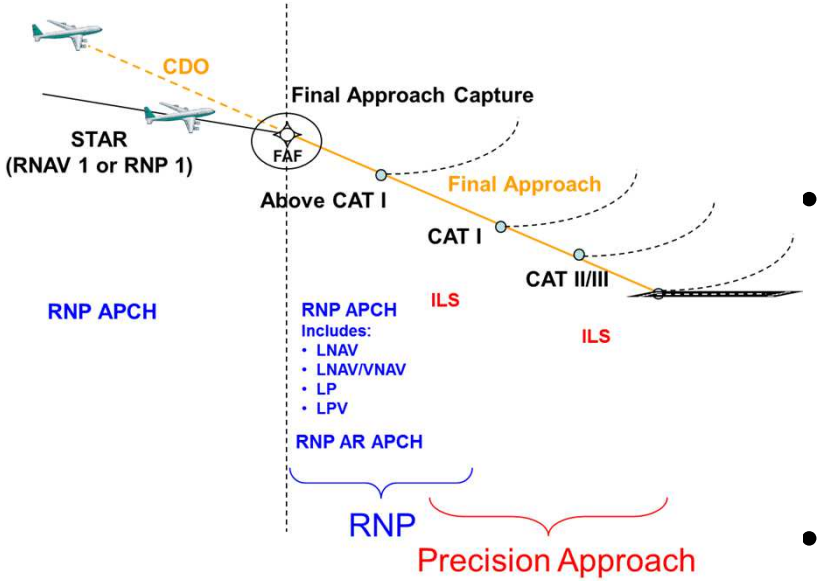
- PBN is a move from sensor to performance based navigation.

- Although PBN uses technology e.g. area navigation system, and navigation sensors e.g. GPS – the concept is **PERFORMANCE** based.

- PBN uses technology to achieve this **PERFORMANCE**.

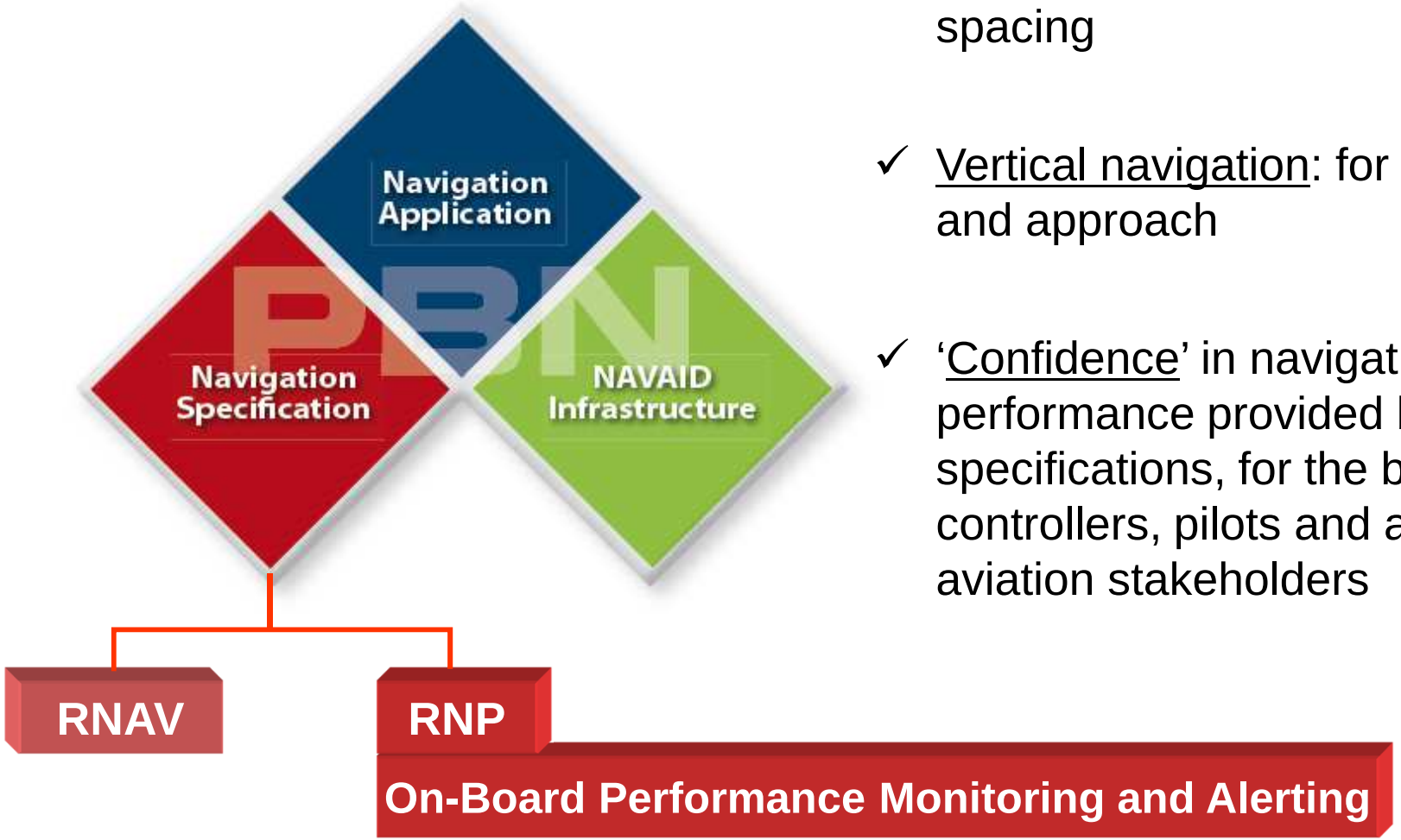
Linking PBN & the rest: Benefits





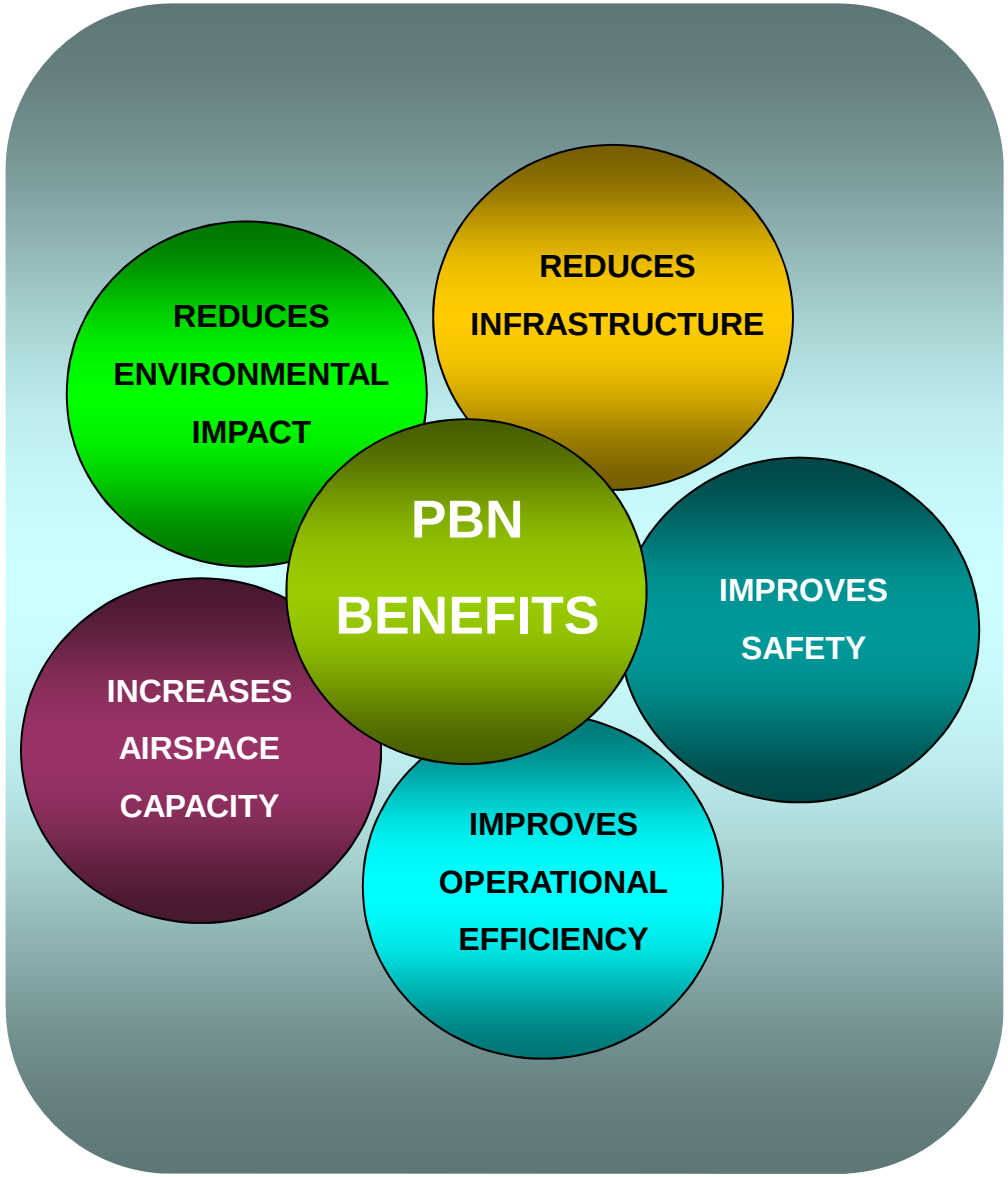
- Lateral: ATS routes (incl. SIDs/STARs) are backbone of the ATM System
  - For separation/spacing, ATC wants aircraft operating on the **route centreline**.
  - Needed: good **lateral** aircraft navigation performance. ⇨
- Vertical: navigation performance also improves ATM operations and airport access.
  - Needed: reliable **vertical** navigation performance ⇨
- *P – B – N*

Linking PBN & the rest: Benefits

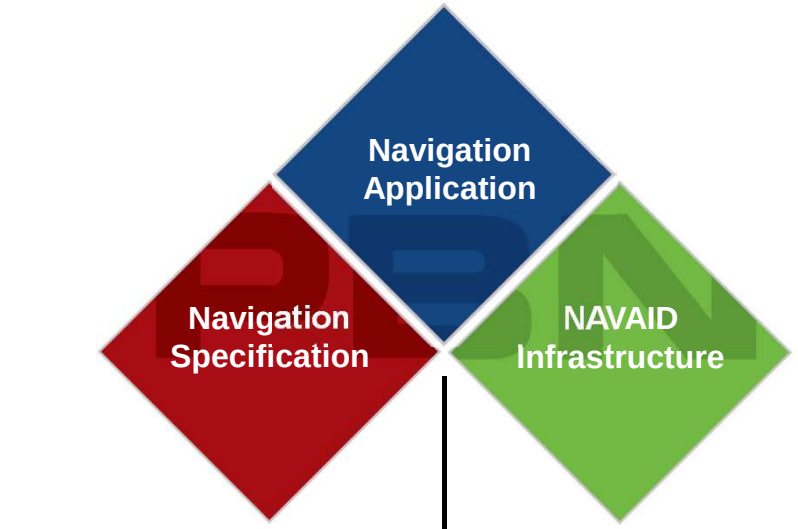


- ✓ Lateral navigation: benefit on ATS Routes for separation and spacing
- ✓ Vertical navigation: for landing and approach
- ✓ 'Confidence' in navigation performance provided by PBN specifications, for the benefit of controllers, pilots and all aviation stakeholders

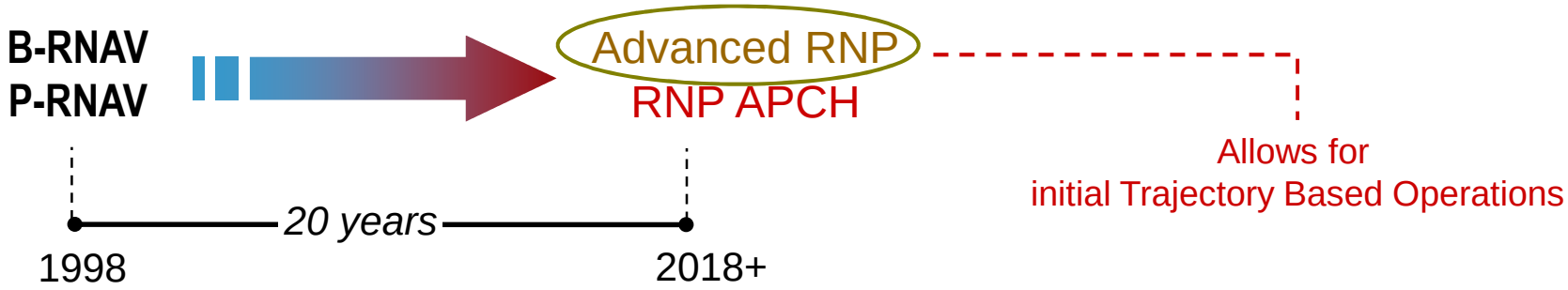
Overall PBN expected benefits



European developments



- ✓ *Improved ATS Route design*
- ✓ *Better SIDs/STARs design*
- ✓ *Free Route flexibility*
- ✓ *More capacity*



Current Airspace Concept

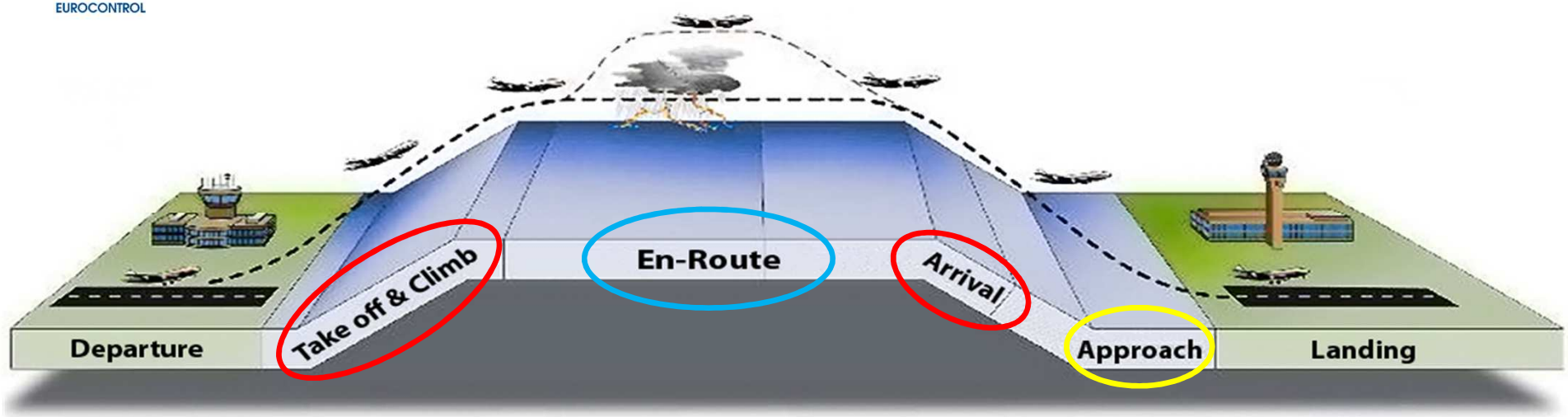
EUROPE'S HIGH-LEVEL AIRSPACE CONCEPT

At a very generic level, Europe's current airspace concept, which extends well beyond PBN, can be said to have the following characteristics:

- A parallel network of ATS routes, based on B-RNAV, across the continent;
- A system of feeder or link routes based mainly on B-RNAV which connect to P-RNAV or Conventional SIDs and STARs starting at the nominal TMA boundary
- An organised track system (OTS) in the North Atlantic based on MNPS (this is due to change to RNP 2 or RNAV 10).
- The use of Reduced Vertical Separation Minima (RVSM) between FLs 290 and 410.
- Airspace Classification Class C above FL195.
- Extensive use of the "Flexible Use of Airspace" concept;
- Some use of "Free Routes"
- Evolution from State managed upper airspace to Functional Airspace Blocks (FABs).

Europe's Airspace Concept is evolving to include the use of **Advanced RNP** in en-route and terminal operations, and **RNP APCH** on the Approach.

European PBN applications



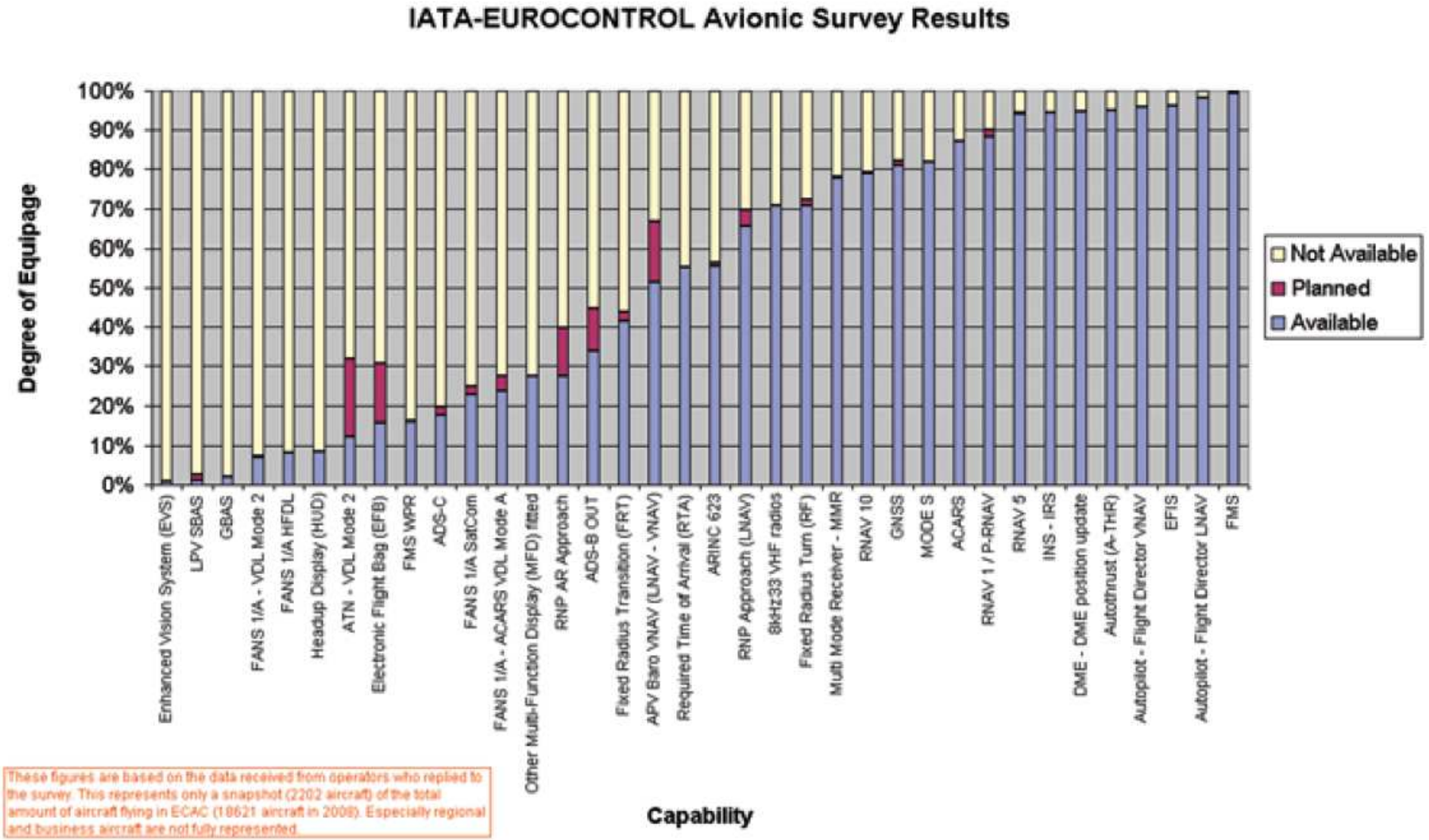
Flight Phase	Application	Target Date	Current Situation	Required Performance	Enabling Systems
En-Route	RNAV 5 (B-RNAV)	1998	Mandatory	+/- 5NM (95%)	VOR/DME/ GPS*/ INS*
Arrival/Departure	RNAV 1 (≈ P-RNAV)	2006+	Implementation	+/- 1NM (95%)	DME/GPS
Approach / Landing	RNP APCH (LNAV)	2006	Implementation	+/- 0.3NM (95%)	GPS
	APV Baro (LNAV/VNAV)	2008	Implementation	+/- 0.3NM (95%)	GPS/Baro VNAV
	APV SBAS (LP/LPV)	2010	Implementation	HAL +/- 40m (10^{-7}) VAL +/- 50m (10^{-7})	GPS + SBAS (EGNOS)
	RNP AR APCH (LNAV/VNAV)	Individual Implementation	Implementation	Depends on required accuracy <0.3NM (95%)	GPS

*** Not part of PBN**

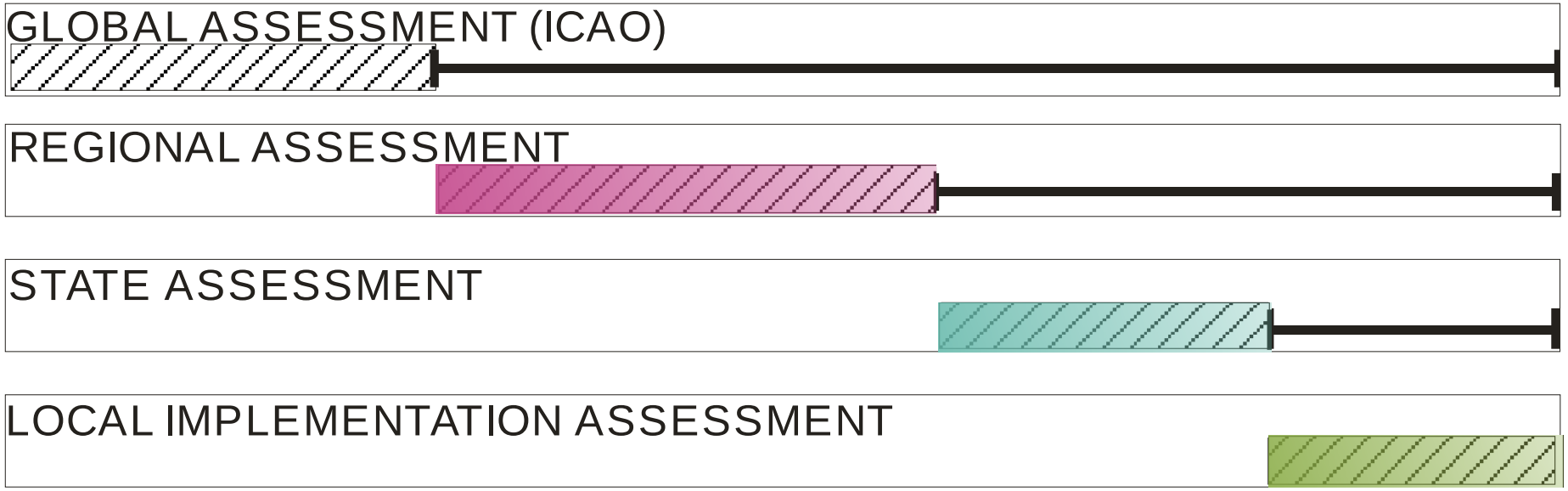
Implementing PBN

Airspace Design Activities

PLAN: e.g. Know your Fleet – ECAC 2010



Act. 5-17: Developing the Safety Case



Act. 11-13b: Validation

- Why doing it ?
- What to validate?
  - Validate Airspace concept and resulting Procedures
  - Assess if ATM objectives are achieved
  - Confirm flyability of Instrument Flight Procedures
  - Identify possible problems and develop mitigations
  - Provide evidence design is safe
  - Validation is an ongoing process

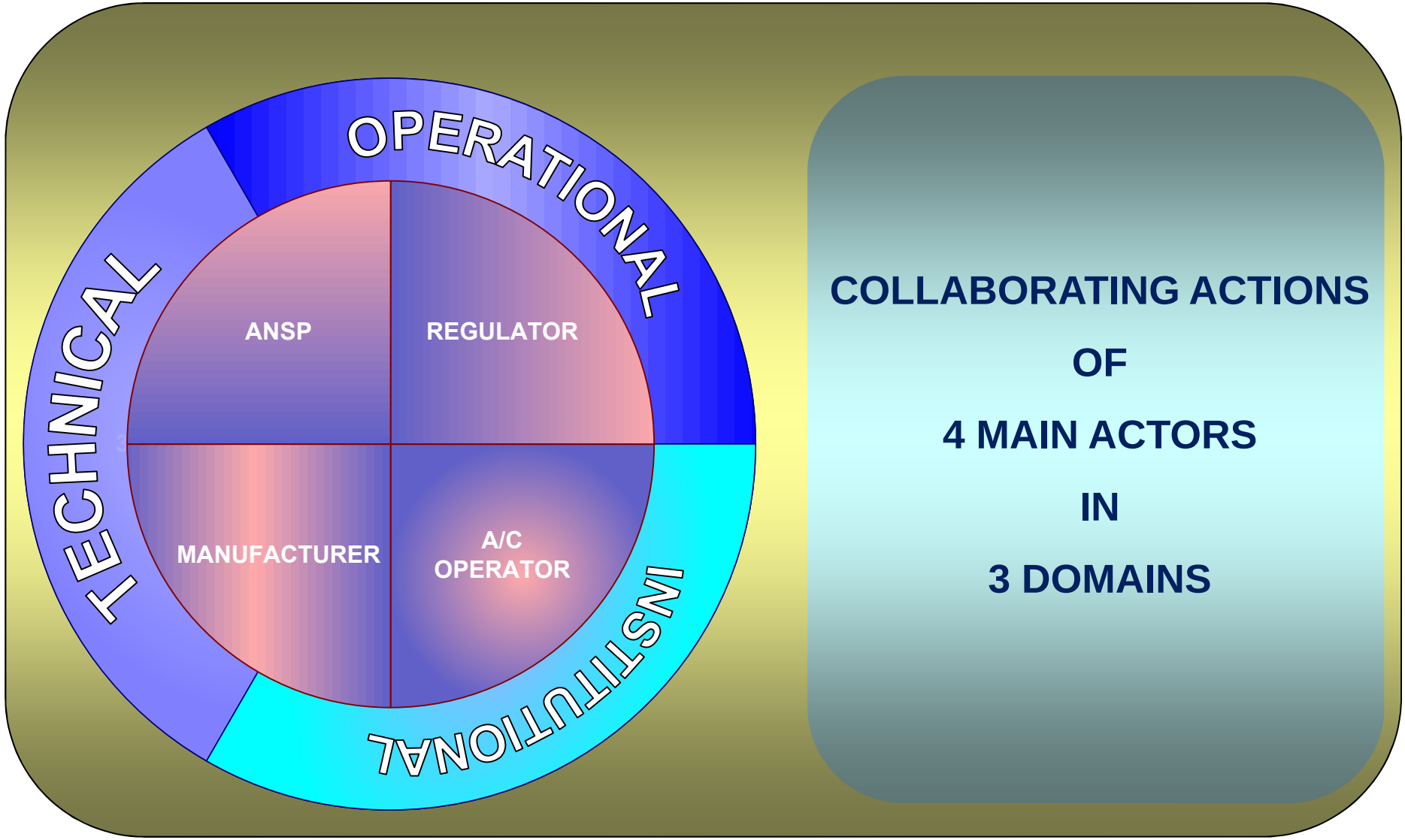
Act. 13a-13b: Procedure Validation

- Ground Validation
  - Obstacle clearance
  - Charting
  - Coding
  - Flyability
- Flight Validation
  - Obstacle verification (optional)
  - Flyability (workload, charting, manoeuvring)
  - Infrastructure
- Database Validation

Act. 15: Awareness and Training

- Success relies on good understanding
- Must address all involved stakeholders
- Nav Specs provide training requirements for:
  - Flight Crew
  - ATCos
- Must be timely but not rushed
- Use Implementation team as ‘champions’

Challenges for PBN implementation success



Challenges for PBN implementation success

INSTITUTIONAL

- ✈ regulation settlement
- ✈ costs
- ✈ consultation
- ✈ timeline
- ✈ coordination & overall monitoring
- ✈ human factors

TECHNICAL

- ✈ PBN enablers availability
- ✈ readiness for development and deployment
- ✈ synchronisation between actors (A/C operators / manufacturers / ANSPs / regulator)
- ✈ clear statements on conventional Navaids continuation / discontinuation
- ✈ technical solutions for all the community (GA / BA / Airlines / State Aircraft / RPAS ?)

OPERATIONAL

- ✈ procedures
- ✈ aircraft equipage
- ✈ training
- ✈ air space design
- ✈ anticipation

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EXTRA SLIDES

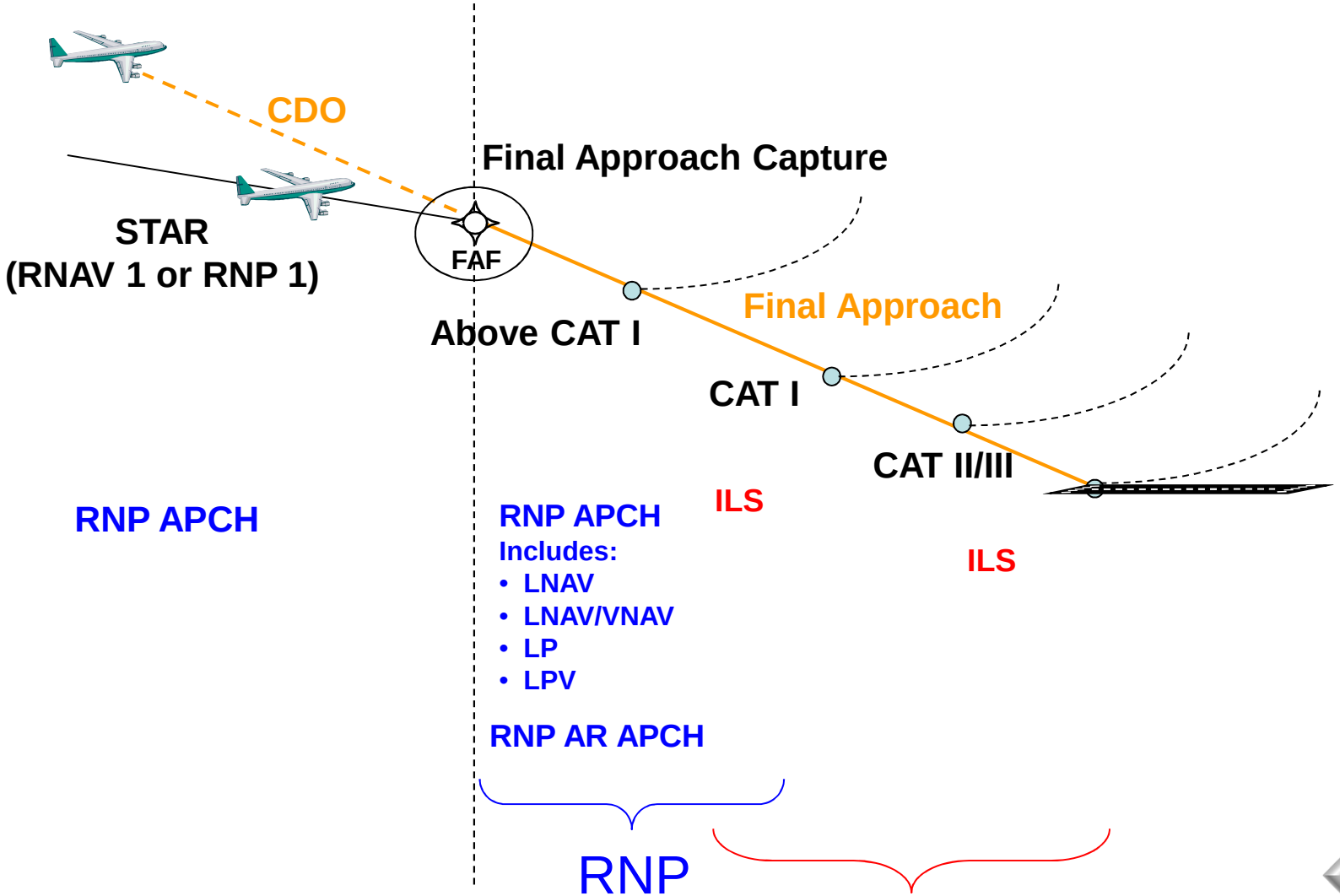
Potential capacity benefit of PBN

Parallel Routes / based on	Advanced RNP		P-RNAV		B-RNAV
	En-route	Terminal	En-route	Terminal	En-route
Same Direction	7 NM	7 NM	9 NM	8 NM	16.5 NM
Opposite Direction					18 NM
Other					10-15 NM with increased ATC intervention rates
Spacing on turning segments	As above using FRT en-route and RF for SIDs/STARs		Larger than above because no FRT		Much larger than above because no automatic leg change.

- How is the air traffic affected if there is an *area* outage of GPS?
  e.g. Unplanned outage due to jamming, space weather?

<< Sl. 10

‘Vertical’ PBN Benefits: lower minima



<< Sl. 10

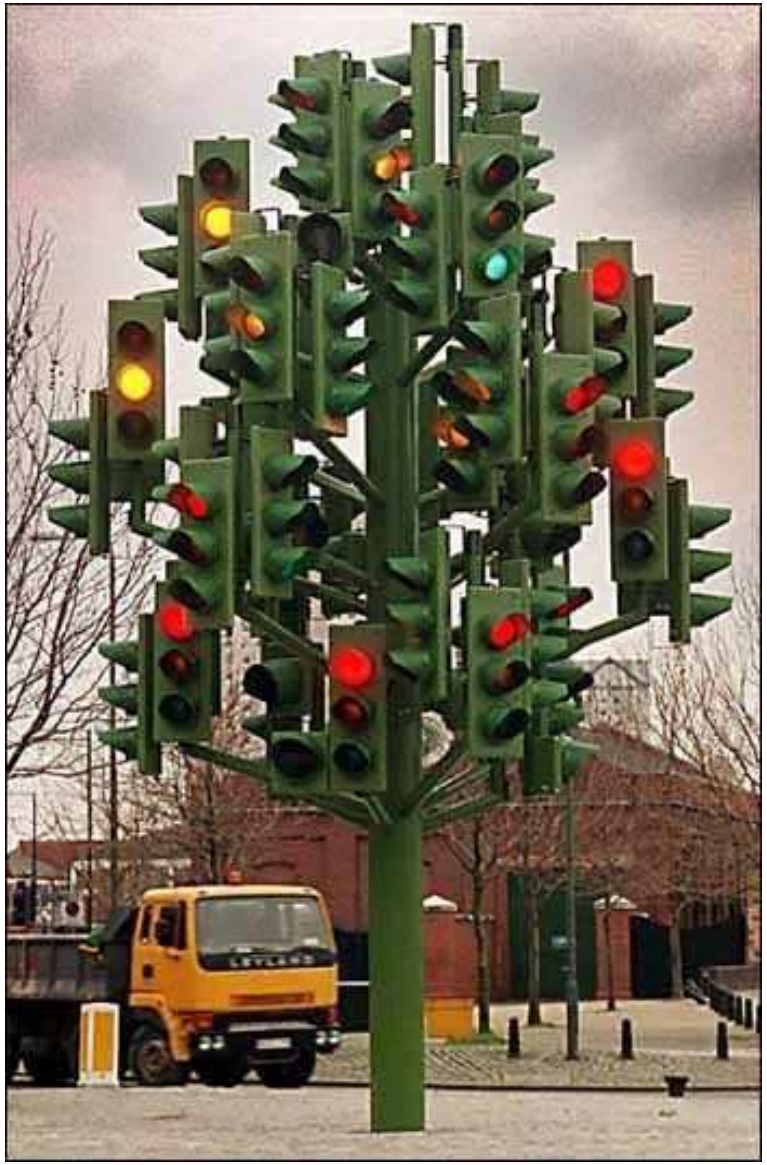
APV – APproaches with Vertical Guidance

- There are various ways to complete the final approach phase of flight ….
  - ILS
  - MLS
  - GLS (GBAS)
  - **RNP** ← **APV** is **here**
- Each kind of approach has different minima
  - How low can you go? …DH/MDH…
- In this phase of flight effort aims to ensure sufficient confidence in space/air/ground systems to improve safety and permit the *lowest* minima for the *worst* metconditions.

APV – APproaches with Vertical Guidance

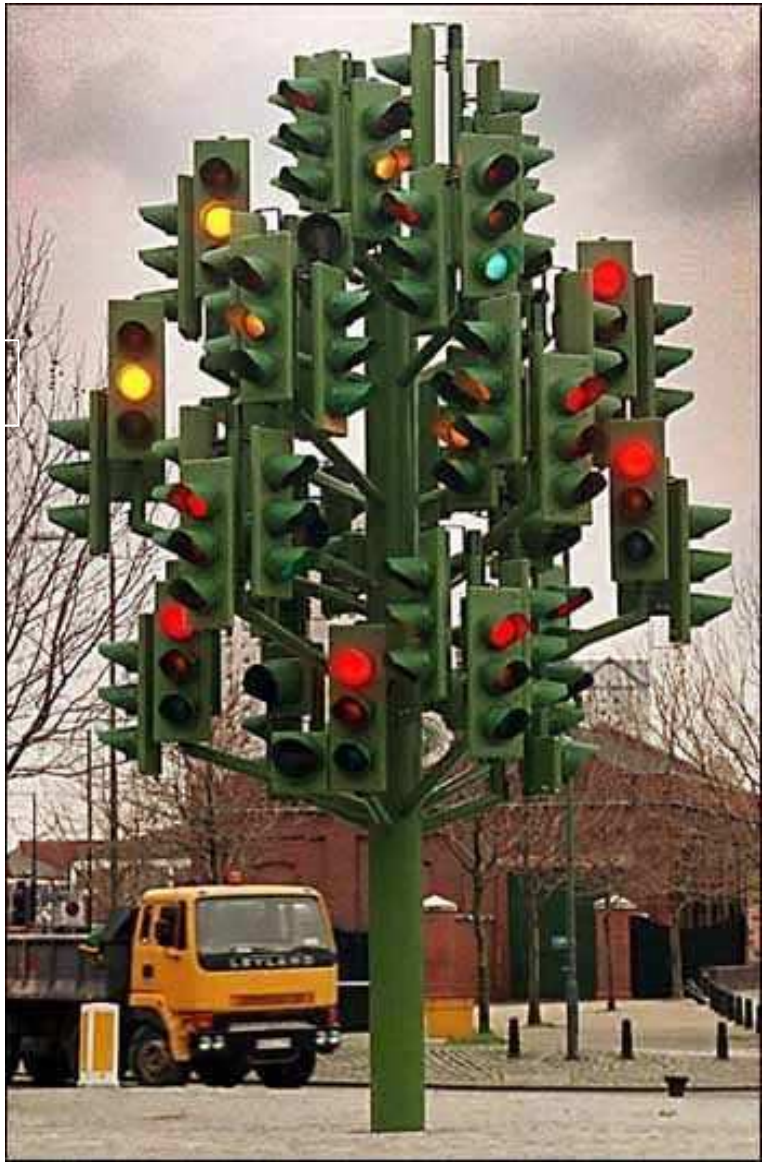
- RNP APCH
  - GPS
    - Lateral
    - Lateral + Vertical
  - SBAS
    - Lateral
    - Lateral + Vertical
- RNP AR

  Lateral + Vertical (+ curved)



APV – APproaches with Vertical Guidance

- RNP APCH
  - GPS
    - Lateral LNAV
    - Lateral Vertical LNAV/VNAV
  - SBAS
    - Lateral LP
    - Lateral Vertical LPV
- RNP AR (Required)
  - Lateral Vertical



APV – APproaches with Vertical Guidance

- RNP APCH ··· RNAV(GNSS) *(Chart)*

Modern Air Carriers

- Lateral — **NPA to LNAV *minima***
- Lateral Vertical — **APV Baro VNAV to LNAV/VNAV *minima***

GA

- Lateral — **NPA to LP *minima***
- Lateral Vertical — **APV SBAS to LPV *minima***

- RNP AR ··· *(Chart)* RNAV(RNP)
  - Lateral Vertical

High precision (lateral) RNP
Baro VNAV
Stringent Crew Procedures

RNAV Approaches and PBN