PBN concept and implementation overview

AFI Regional GNSS/SBAS Coordination Meeting
Virtual Meeting, 04–05 March 2021

Agenda Item 2: ICAO General Provisions

Outlines

1. The Performance-Based Navigation theory
2. Global Navigation Satellite System (GNSS) overview
3. PBN benefits
4. AFI PBN roadmap
5. SBAS benefits

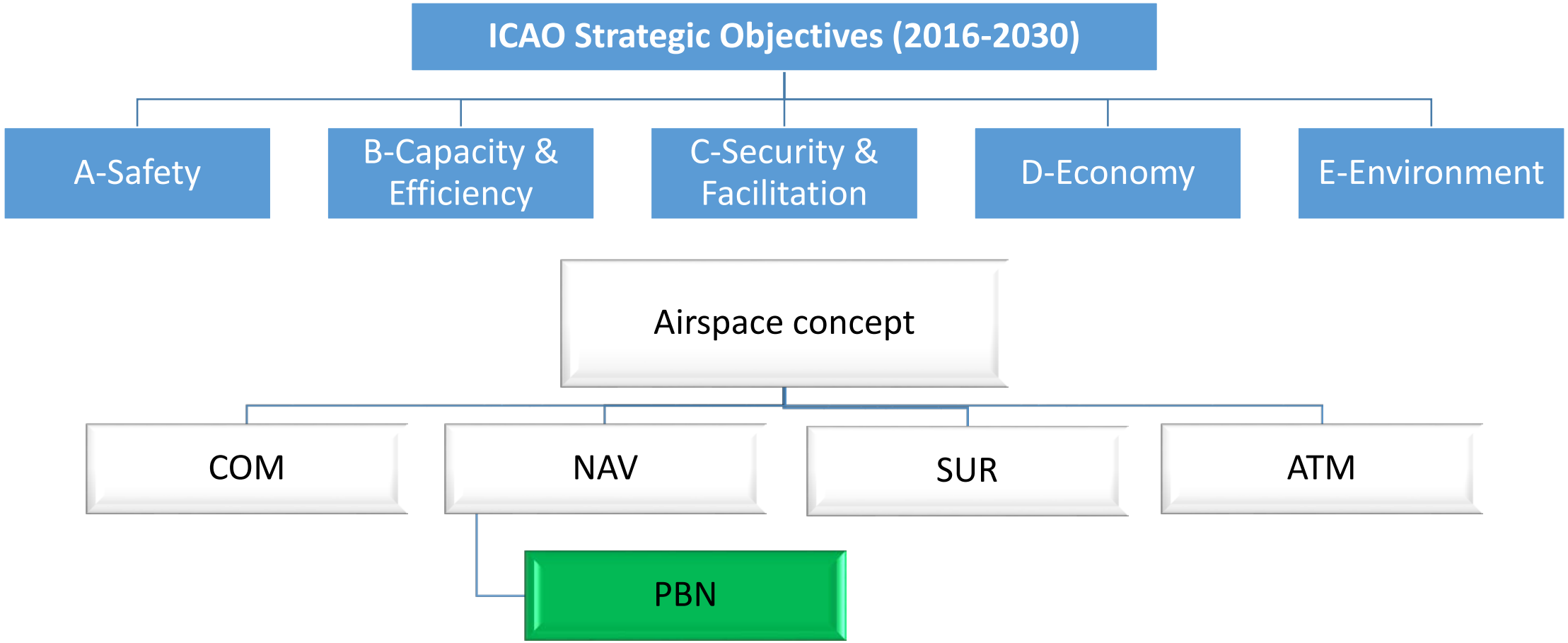
Area Navigation

- Transitioning to Performance-based Area Navigation from either:
  - ☞Conventional navigation, or
  - ☞Regional or Local area navigation.

Globally Harmonized

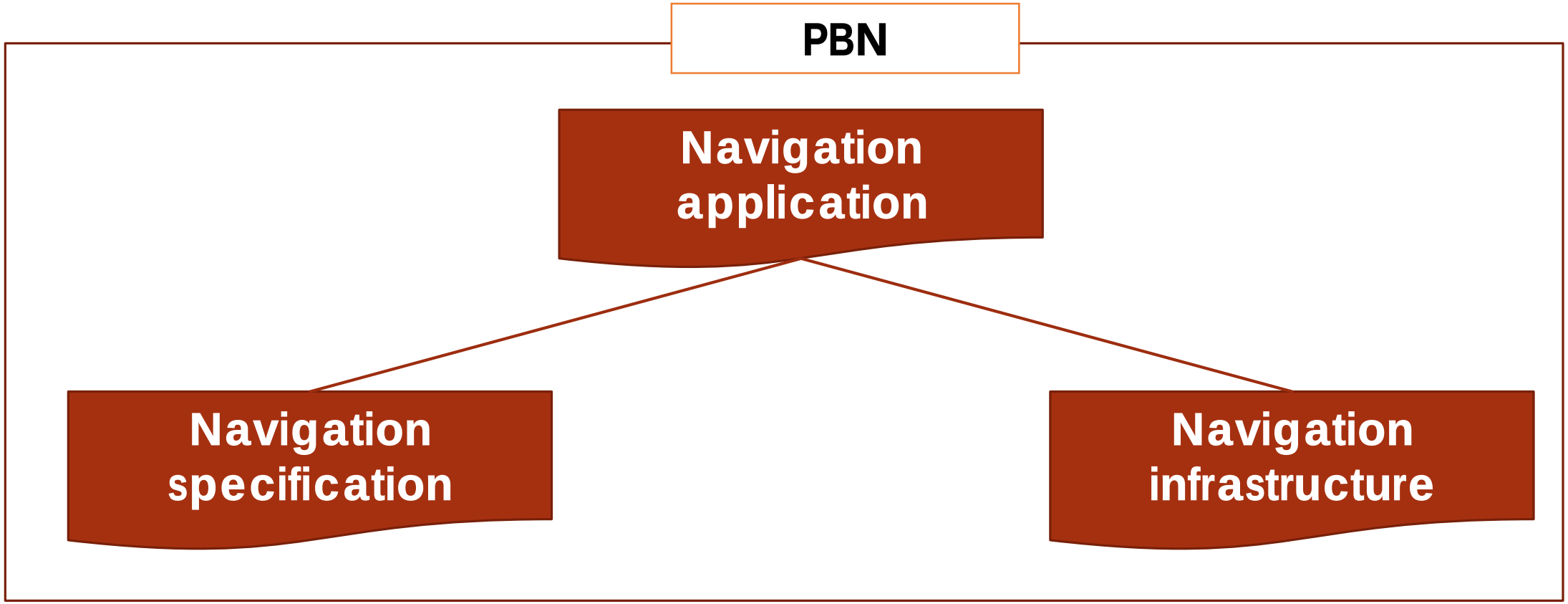
- PBN is being implemented according to Doc 9613 in the same manner all around the world;
- Same design criteria;
- Same pilot procedures;
- Same ATC separation;
- Same phraseology;
- Same airspace design principles… this course will address these, should be harmonized as well.

Performance-Based Navigation theory



Performance-Based Navigation theory

- PBN relies on the use of area navigation and comprises three components:



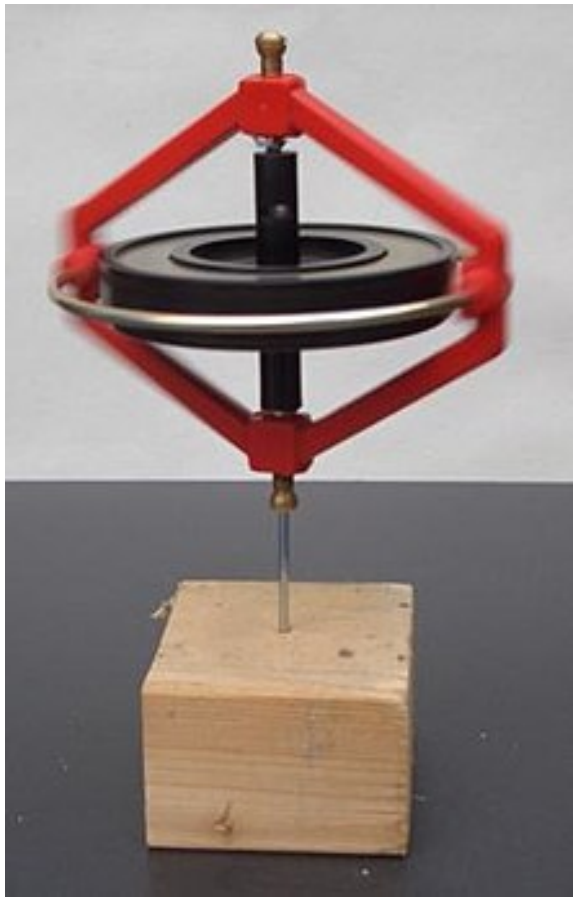
Performance-Based Navigation theory

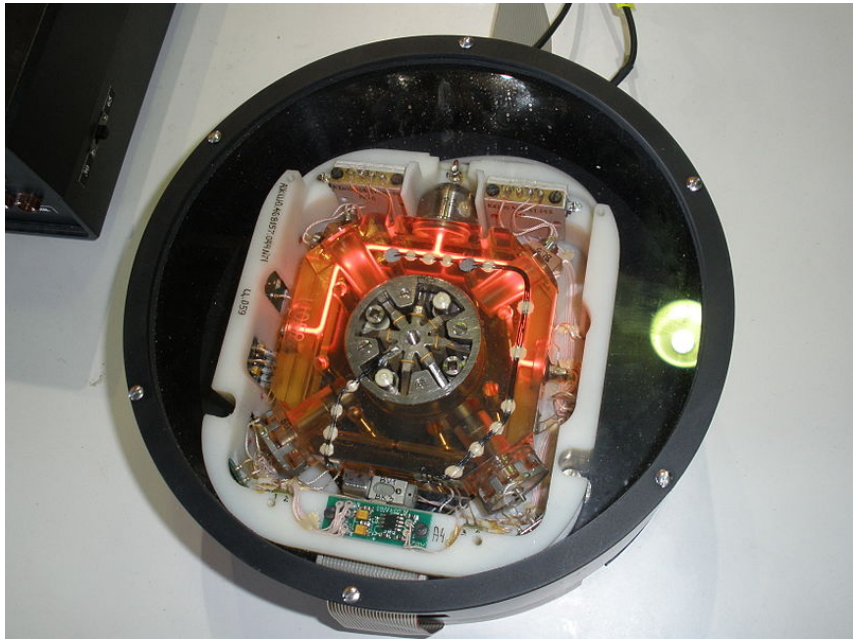
NAVIGATION INFRASTRUCTURE: Refers to ground–based navaids(VOR-DME, DME), space-based navaids (GNSS) and autonomous systems (INS, IRS).

- Example in Europe, RNAV 1 is used in terminal area with:
  - GNSS and,
  - DME/DME .
- In many countries in Africa, RNP 1 is used in terminal area with:
  - GNSS

NDB is not part of PBN

Performance-Based Navigation theory





Performance-Based Navigation theory

NAVIGATION SPECIFICATION: describe the operational approval process define for each **area of operation**:

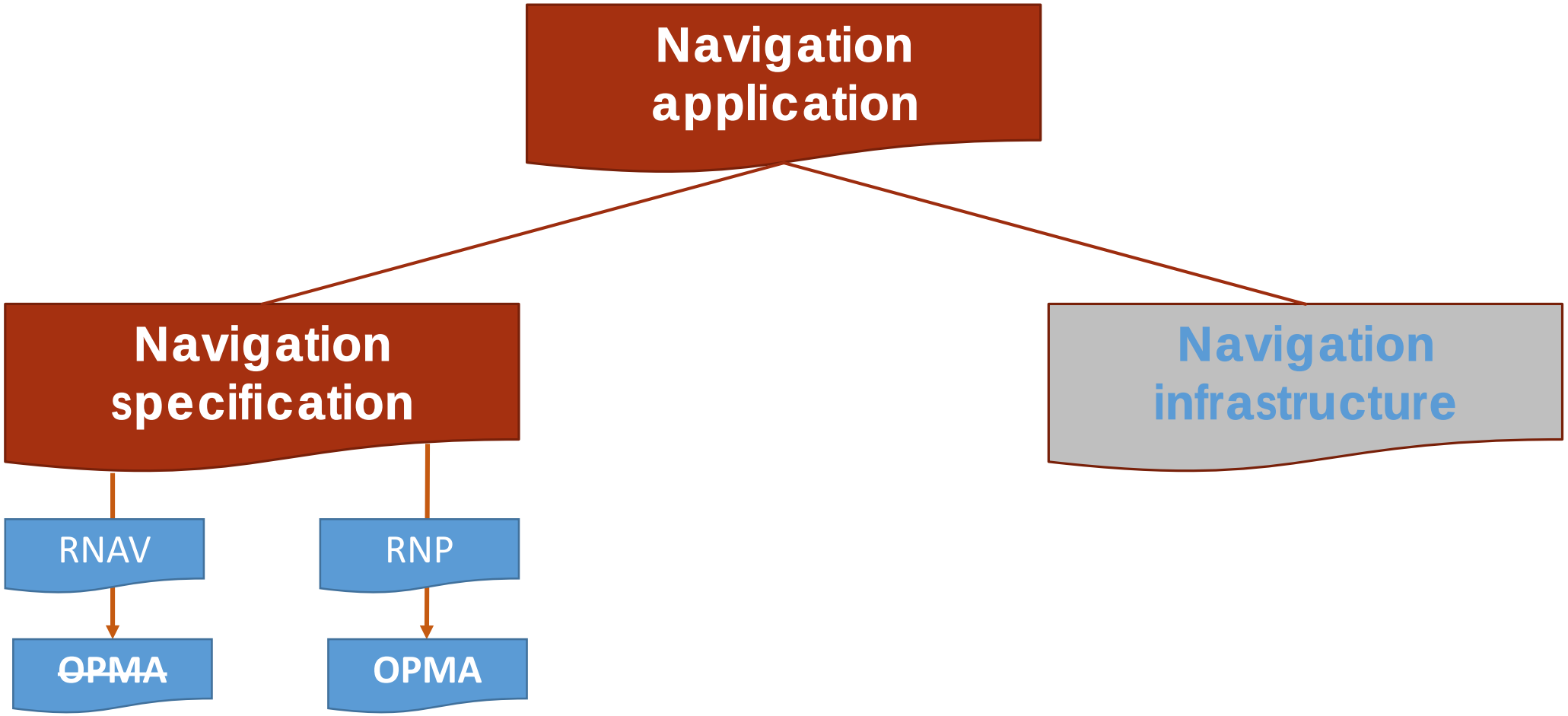
- What are the required performances of the system?
- Which functionalities are needed to reach the required performances?
- Which sensors are needed on board?
- Which crew and ATC procedures are needed?

One key element of the system is the "**On-board Performance Monitoring and Alerting**" functionality (OPMA)

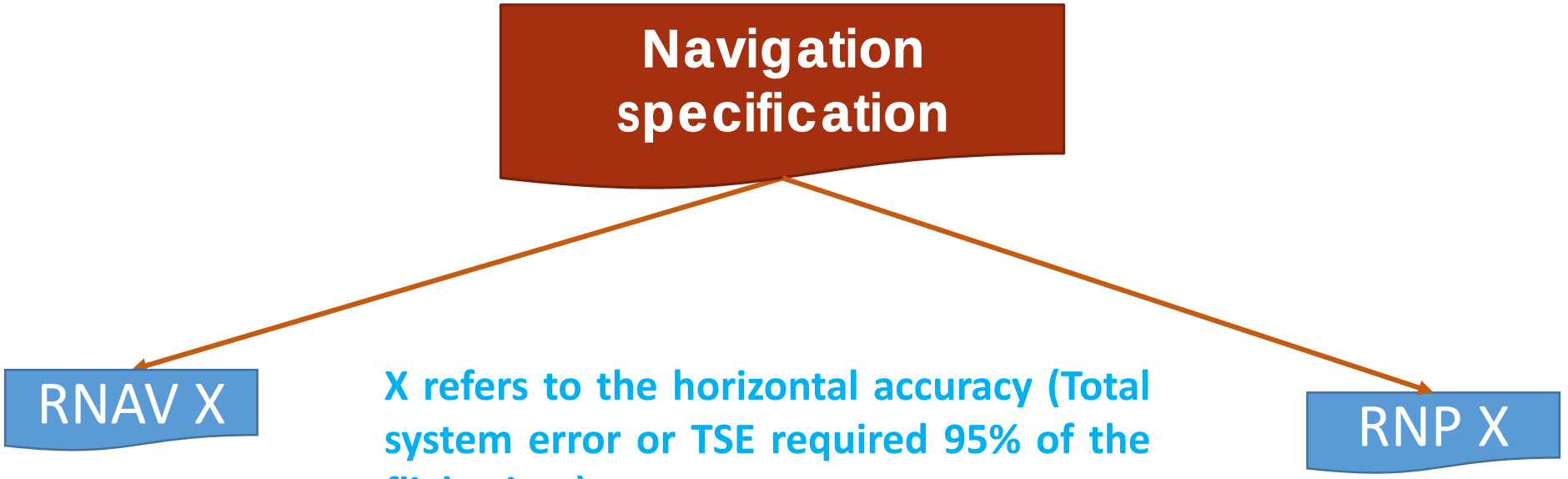
Two navigation specifications have been defined:

- **RNP specification that** requires the use of the OPMA;
- **RNAV specification** not

Performance-Based Navigation theory

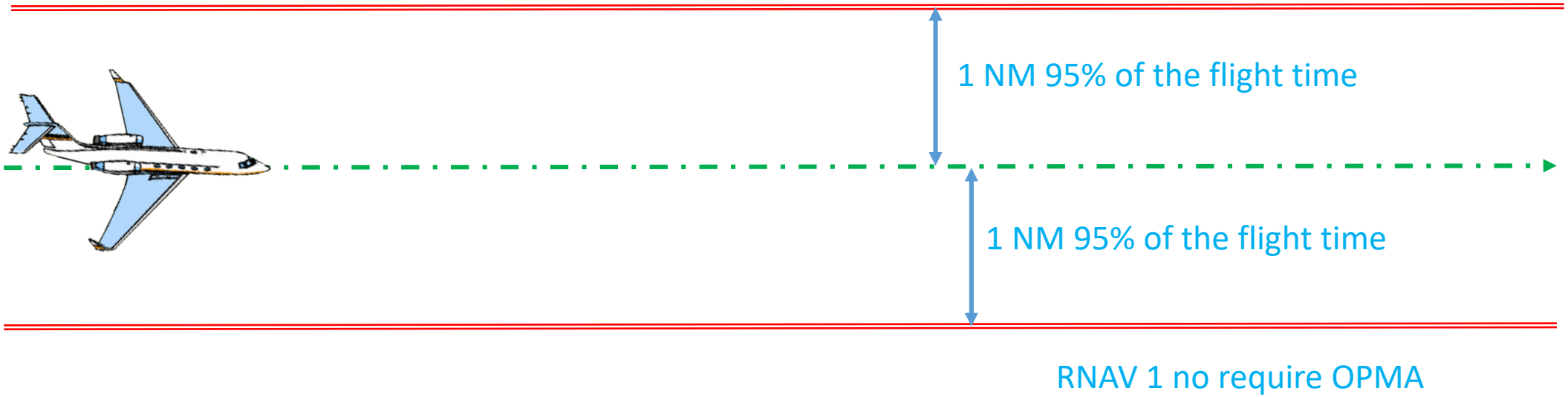


Performance-Based Navigation theory



- RNAV or RNP is the Navspec designator and
- X is the navspec descriptor

RNP 1 require OPMA



RNAV 1 no require OPMA

- OPMA allows the aircrew to detect that the navigation system is not achieving, or cannot guarantee the navigation performance required for the operation.

Performance-Based Navigation theory

- Correct terminology is important for clarity:
  - **Area Navigation** is the generic term used for area navigation and should never 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.

Performance-Based Navigation theory

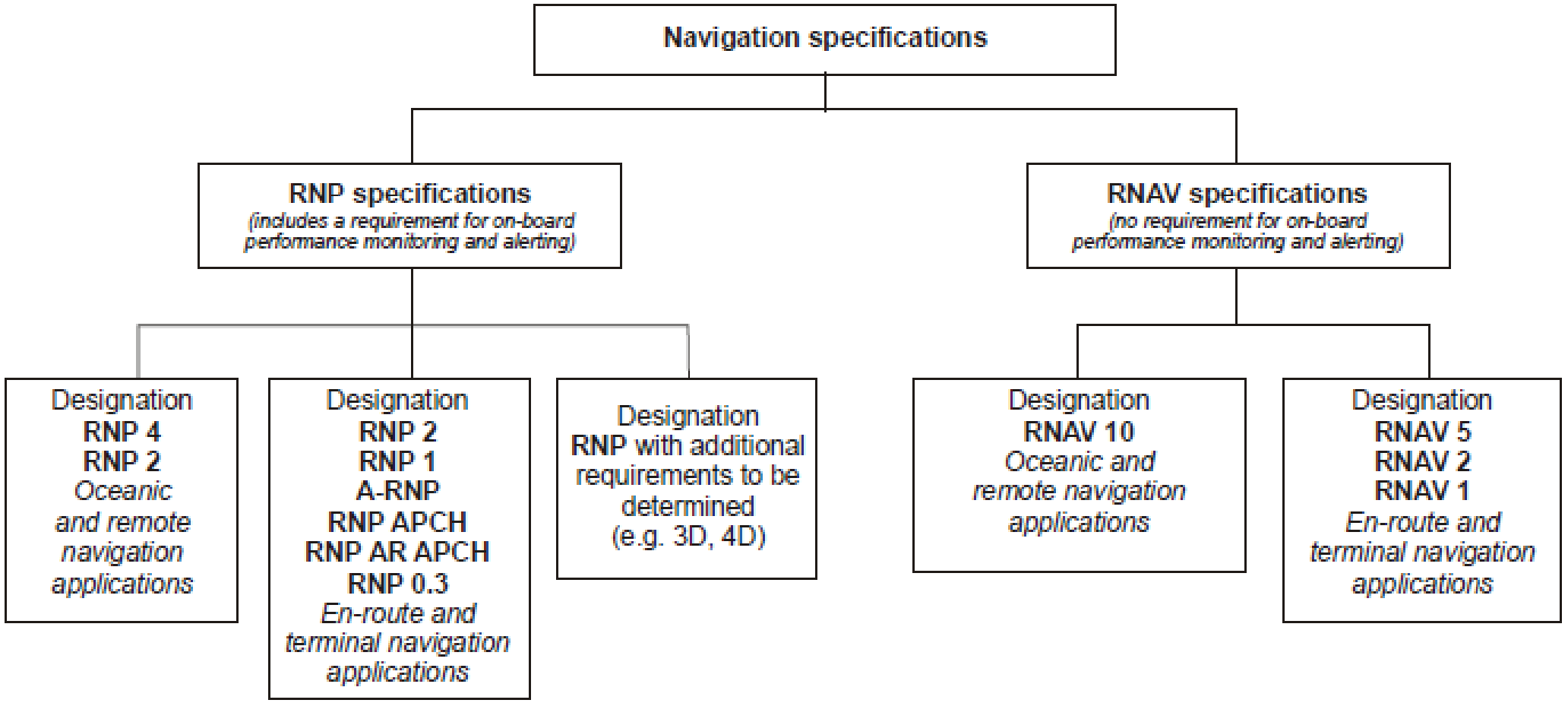
NAVIGATION APPLICATION: Use of a navigation infrastructure and a navigation specification to fly into a given airspace, on a route or a procedure.

- **Navigation specifications have been developed for all phases of flight (area of operation)**

A navigation application may require many airspace concept enablers:

- **Communication : COM;**
- **Surveillance : SUR;**
- **ATM procedures :**
  - **Route spacing;**
  - **Separation minima;**
  - **Etc.**

Performance-Based Navigation theory



PBN Specifications

Area of operation	RNP	RNP + additional req.	RNAV
Remote Continental & oceanic	RNP 4, RNP 2	❑ 3D ❑ 4D ❑ Time of arrival control ❑ RNP scalability ❑ Higher continuity ❑ Baro VNAV ❑ Etc.	RNAV 10
En route continental	RNP 2, A-RNP, RNP 0.3		RNAV 5, 2, 1
Terminal	RNP 1, A-RNP 1, RNP 0.3		RNAV 5, 2, 1
Approach	RNP APCH, RNP 0.3, A-RNP, RNP AR		

No RNAV specification in Approach area!

Relationships between navigation specifications and navigation infrastructure

	Navigation specifications						
	RNAV 10	RNP 4	RNAV 5	RNAV 2	RNAV 1	RNP 1	RNP APCH
Navaid	GNSS, INS	GNSS	VOR-DME, DME/DME, GNSS, INS	DME/DME, GNSS, INS	DME/DME, GNSS, INS	GNSS	GNSS
Sensor	GNSS, INS	OPMA	VOR-DME, DME/DME, GNSS, INS	DME/DME, GNSS, INS	DME/DME, GNSS, INS	OPMA	OPMA

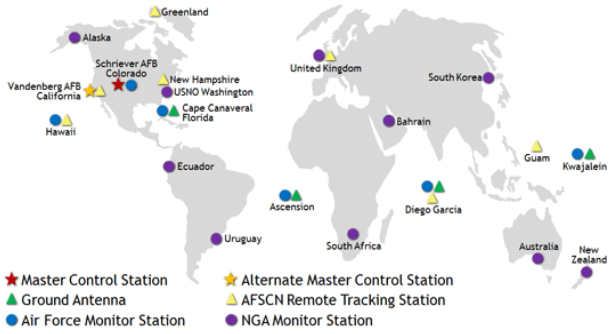
Conclusion:

- ❑GNSS is the main component of the PBN infrastructure
- ❑GNSS is the main infrastructure for the RNP specifications

Global Navigation Satellite System (GNSS) overview

Background

- GNSS was made possible by the implementation of two core satellite constellations:
  - The USA Global Positioning system (GPS) and
  - The Russian Global Navigation Satellite System (GLONASS)
- Other global positioning systems under development Galileo (Europe, Beidou (China), etc.



Global Navigation Satellite System (GNSS) overview

Background

- 1994: USA offered GPS to support the needs of the international civil aviation (offer reaffirmed in 2007);
- 1996: The Russian federation offered the public use of their Global Navigation satellite System (GLONASS);
- Both States are upgrading their constellations and have committed to maintain service reliability;
- Upcoming systems (Europe, China, etc.) will be interoperable with upgraded GPS and GLONASS;
- 2007: ICAO issued the performance-Based Navigation (PBN) concept.

GNSS performances vs ICAO performance requirements

- Four performances parameters are defined to support a particular airspace concept:
  - **Accuracy:** Difference between computed and true position;
  - **Integrity and time-to-alert:** integrity is the measure of the trust that can be placed in the correctness of the provided information and ability of the system to alert the user in case of not compliance with the intended operation:
  - **Continuity:** system capability to run without unscheduled interruption (%);
  - **Availability:** Portion of time during which the system the required accuracy and integrity are simultaneously delivered:

GNSS performances

Position accuracy	GPS	GNSS
Horizontal (m)	≤ 9 (95%), global average	≤ 5 (95%), global average
	≤ 17 (95%), worst site	≤ 12 (95%), worst site
Vertical (m)	≤ 15 (95%), global average	≤ 9 (95%), global average
	≤ 37 (95%), worst site	≤ 25 (95%), worst site

ICAO performance requirements

Operation	Horizontal accuracy (95%)	Vertical accuracy (95%)	Integrity	Time-to-alert	Continuity	Availability
En-route	2.0 NM	N/A	$1 - 1x10^{-7}/h$	5 min	$1 - 1x10^{-4}/h$ to $1 - 1x10^{-8}/h$	0.99 to 0.99999
En-route Terminal	0.4 NM	N/A	$1 - 1x10^{-7}/h$	15 s	$1 - 1x10^{-4}/h$ to $1 - 1x10^{-8}/h$	0.99 to 0.99999
Initial approach Interm. Approach NPA Departure	220 m	N/A	$1 - 1x10^{-7}/h$	10 s	$1 - 1x10^{-4}/h$ to $1 - 1x10^{-8}/h$	0.99 to 0.99999
APV I	16.0 m	20 m	$1 - 2x10^{-7}/h$	10 s	$1 - 8x10^{-6}/h$ per 15 s	0.99 to 0.99999
APV II	16.0 m	8.0 m	$1 - 2x10^{-7}/h$	6 s	$1 - 8x10^{-6}/h$ per 15 s	0.99 to 0.99999
PA cat. I	16.0 m	6.0 to 4.0 m	$1 - 2x10^{-7}/h$	6 s	$1 - 8x10^{-6}/h$ per 15 s	0.99 to 0.99999

GNSS performance doesn't meet ICAO performance requirements

- Augmentations are needed!!!
- Three augmentation systems have been developed:
  - Aircraft-Based Augmentation System (ABAS)
  - Ground-Based Augmentation System (GBAS)
  - Satellite-Based Augmentation System (SBAS)

The ABAS

- ABAS is an on board system processing received signals to enhance them through integrity monitoring;
- Two classes of integrity monitoring:
  - Receiver Autonomous Integrity Monitoring (RAIM) and
  - Aircraft Autonomous Integrity Monitoring (AAIM)
- Integrity monitoring uses Fault Detection (FD) or Fault Detection and Exclusion (FDE) functions

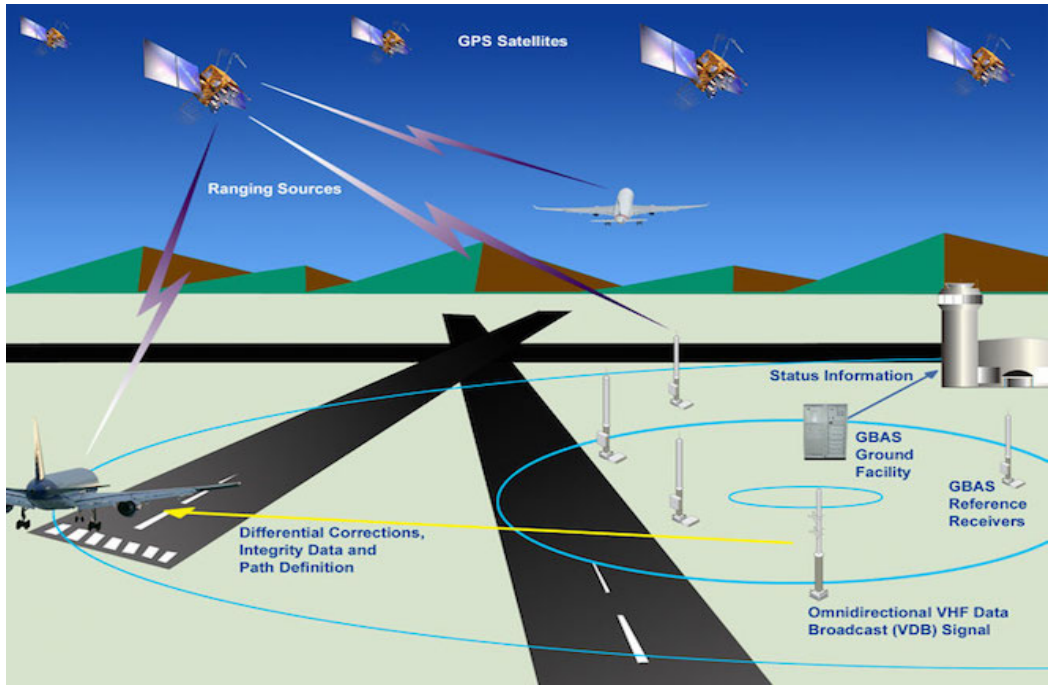
The ABAS

- ABAS operational application:
  - En-route;
  - Terminal;
  - Approach:
    - RNP APCH (with/without baro VNAV;
    - RNP AR APCH.

Global Navigation Satellite System (GNSS) overview

The GBAS

- Also referred to as LAAS (Local Area Augmentation System) or Differential GPS technique;
- Can achieve accuracy required for Cat. I to II:
  - ☞Currently only Cat. I is certified.
- Performed by locating 4 ground receivers at precisely surveilled positions (centimetric);
- A VHD Data Broadcast station is send omnidirectional corrected information to users.



Global Navigation Satellite System (GNSS) overview

The GBAS

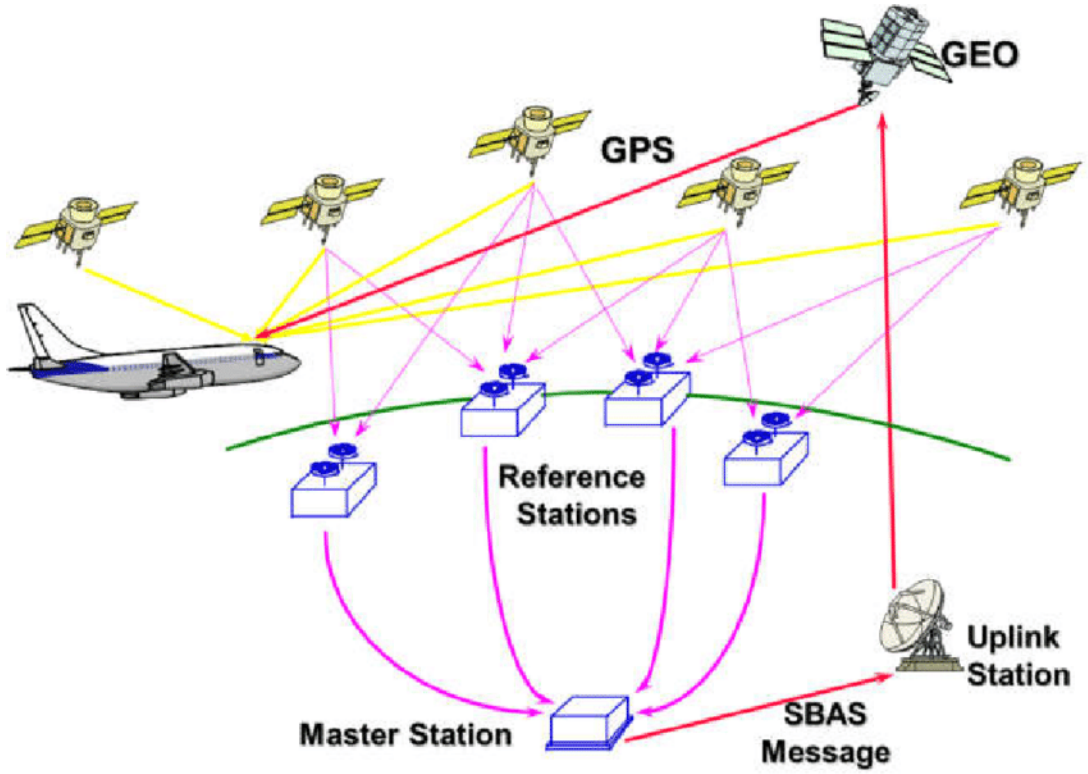
- GBAS service is available up to 30 NM radius;
- GBAS operational use: Approach and landing:
  - ☞GBAS landing System (GLS)

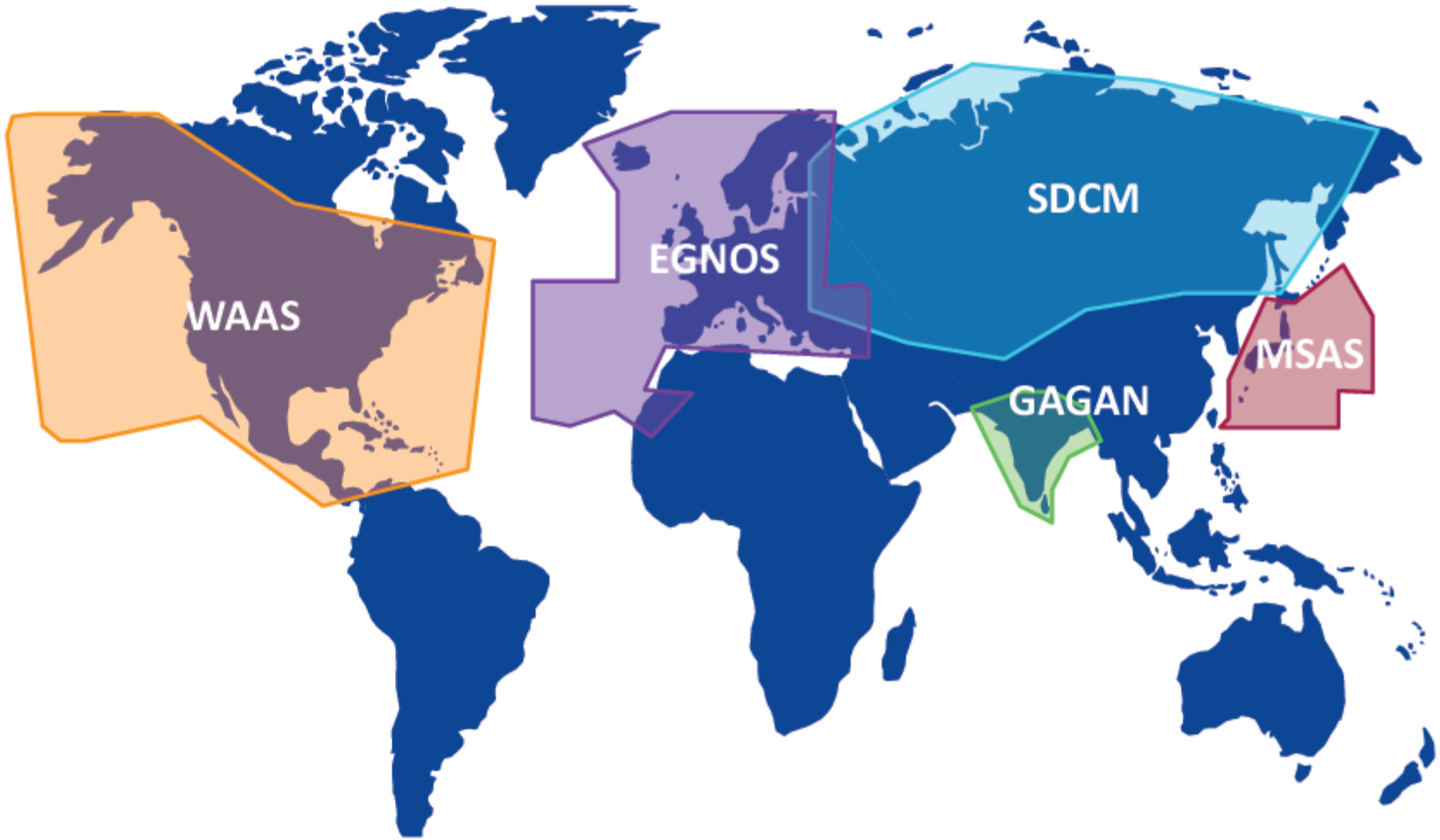
GBAS Reference Station

Global Navigation Satellite System (GNSS) overview

The SBAS

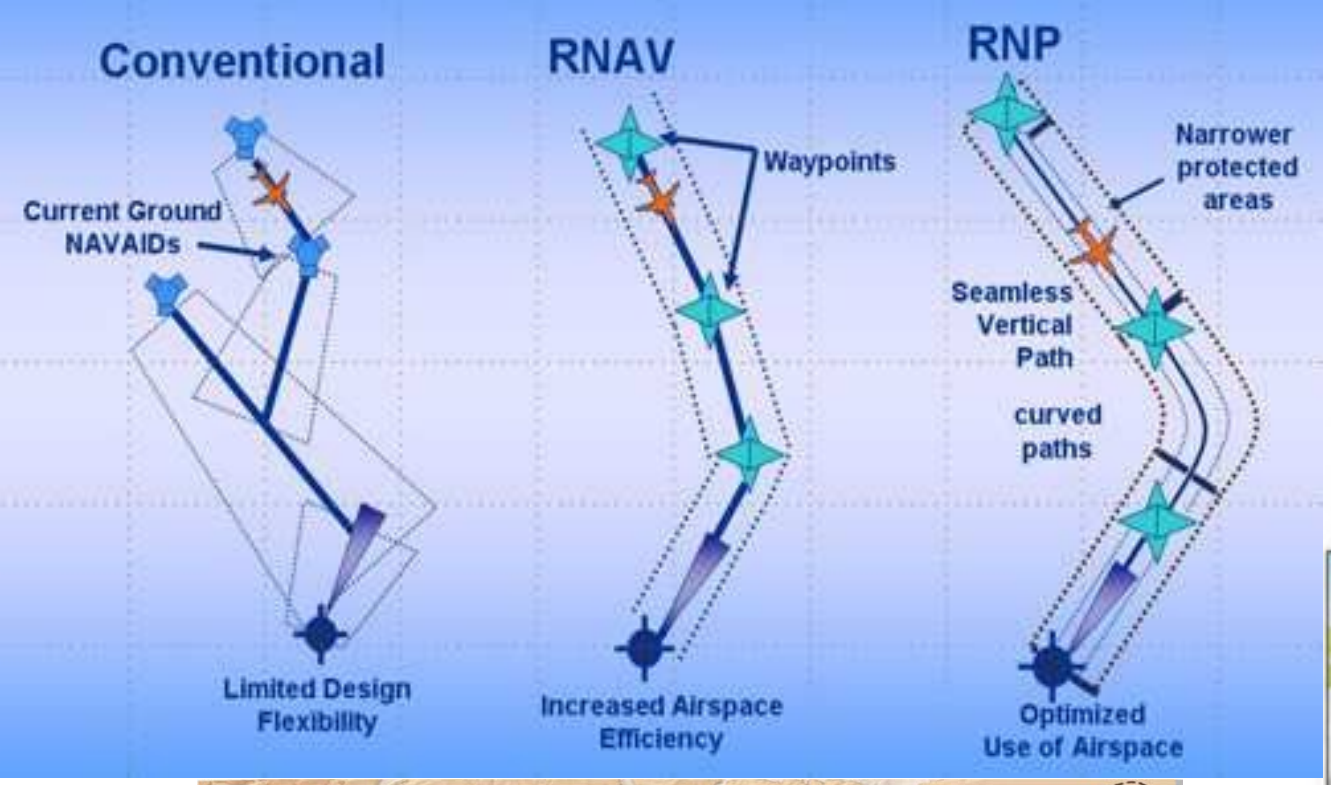
- SBAS is a geostationary satellite system providing integrity and correction information through large reference stations on ground;
- Four classes of SBAS avionics:
  - Class I: En-route, terminal and LNAV approach;
  - Class II: En-route down to LNAV/VNAV
  - Class III: En-route, Terminal, LPV, LP, LNAV/VNAV and LNAV operations

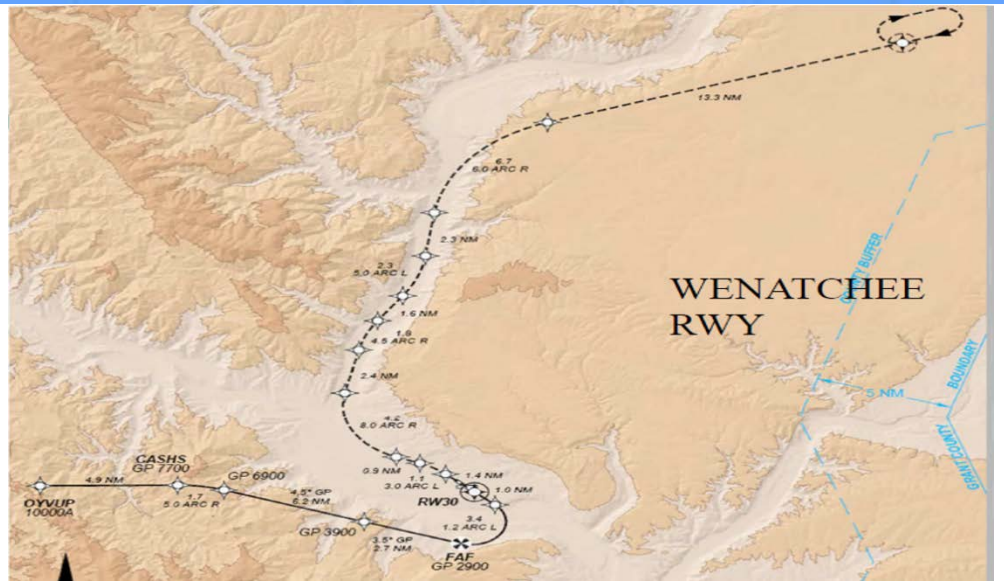


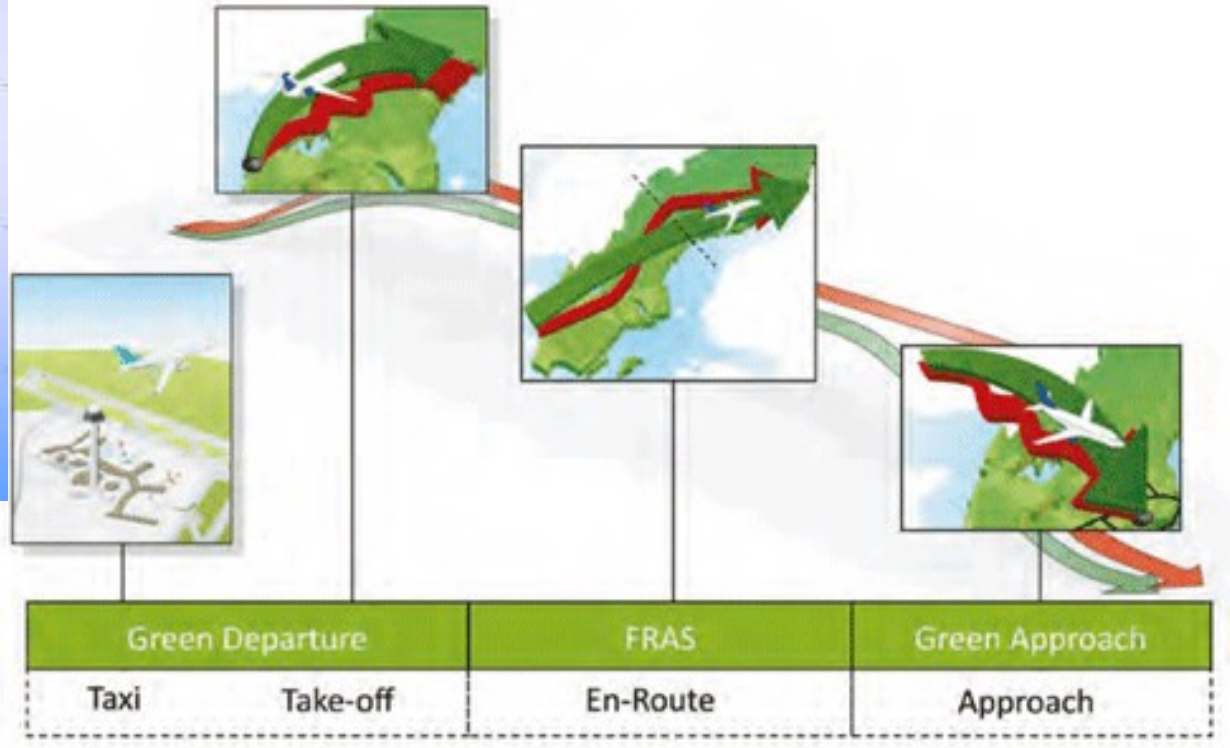

WAAS
EGNOS
SDCM
GAGAN
MSAS

PBN benefits

- PBN inherited all the GNSS benefits:
  - Direct routing;
  - More efficient use of airspace;
    - Economy (reduction of fuel burn);
    - Flight efficiency;
    - Noise abatement, etc.)
  - Safety enhancement;
  - Reduction of CO_2 emission;
  - Reduction of CFIT;
  - Easy maintenance of routes and procedures;
- PBN is a major ASBU and airspace concept enabler.


Conventional
RNAV
RNP
Current Ground NAVAIDs
Waypoints
Narrower protected areas
Seamless Vertical Path
curved paths
Limited Design Flexibility
Increased Airspace Efficiency
Optimized Use of Airspace


WENATCHEE
RWY
CASHS
GP 7700
GP 6900
OYVUP
10000A
RW30
GP 3900
FAF
GP 2900


Green Departure
FRAS
Green Approach
Taxi
Take-off
En-Route
Approach

AFI PBN roadmap

- 2007: Assembly Resolution A36-23 :
  - ☞Urged States to implement RNAV & RNP routes and approach procedures in accordance with PBN concept.
  - ☞Resolves that States and PIRGs complete PBN implementation plan by 2009.
- 2012: Assembly Resolution 37-11 (superseded A36-23):
  - ☞States to complete a PBN implementation plan as a matter of urgency to achieve:
    - Implementation of PBN operations for en-route and Terminal according to establish timelines and intermediate milestones;
    - Implementation of approach procedures with vertical guidance (APV) (Baro VNAV and/or augmented GNSS)
    - Additional requirements

AFI PBN roadmap

African Flight Procedure Programme (AFPP)

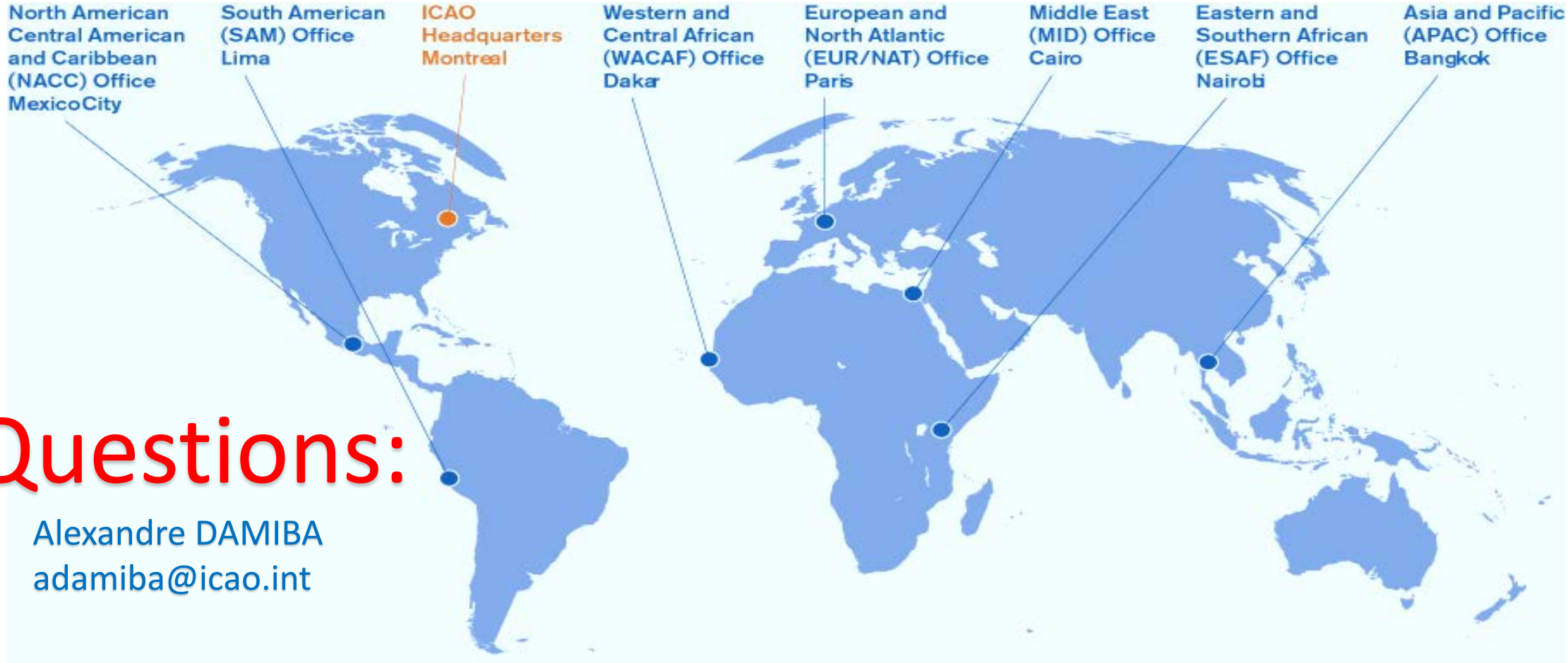
Application	Navspec (General)	Navspec (specific as required)
En-route Oceanic & Remote continental	RNAV 10	RNP 4
En-route continental	RNAV 5, RNAV 2	RNAV 1
Terminal area	Expand RNAV 1 or RNP 1	
	Mandate RNP 1 or RNAV 1 in high-density TMAs	
Approach area	Expand RNP APCH (**with APV baro VNAV or augmented GNSS**) supplemented by RNP APCH LNAV only*	RNP AR APCH

Notes :

- *Where altitmeter setting doesn't exist or aircraft of MTOW ≥ 5 700 kg, using an aerordrome are not suitably equipped for APV*
- *SBAS in included in in the AFI PBN roadmap as other augmented GNSS.*

SBAS benefits

- SBAS can be used in all flight phases (in opposition to GBAS);
- By enhancing the performance elements, SBAS grant more track keeping and therefore enhance safety;
- SBAS provide large coverage in opposition to GBAS for example;
- SBAS can provide ILS Cat. I equivalent approaches for the majority of the runways within the covered area in opposition to ILS, ABAS+ Baro-VNAV and GBAS; as a consequence:
  - ☞ Approach and landing are safer (no CFIT);
  - ☞ For ANSPs, it more economic than ILS Cat. I;



Questions:

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