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# PBN concept and implementation overview

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

**Agenda Item 2: ICAO General Provisions**





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.



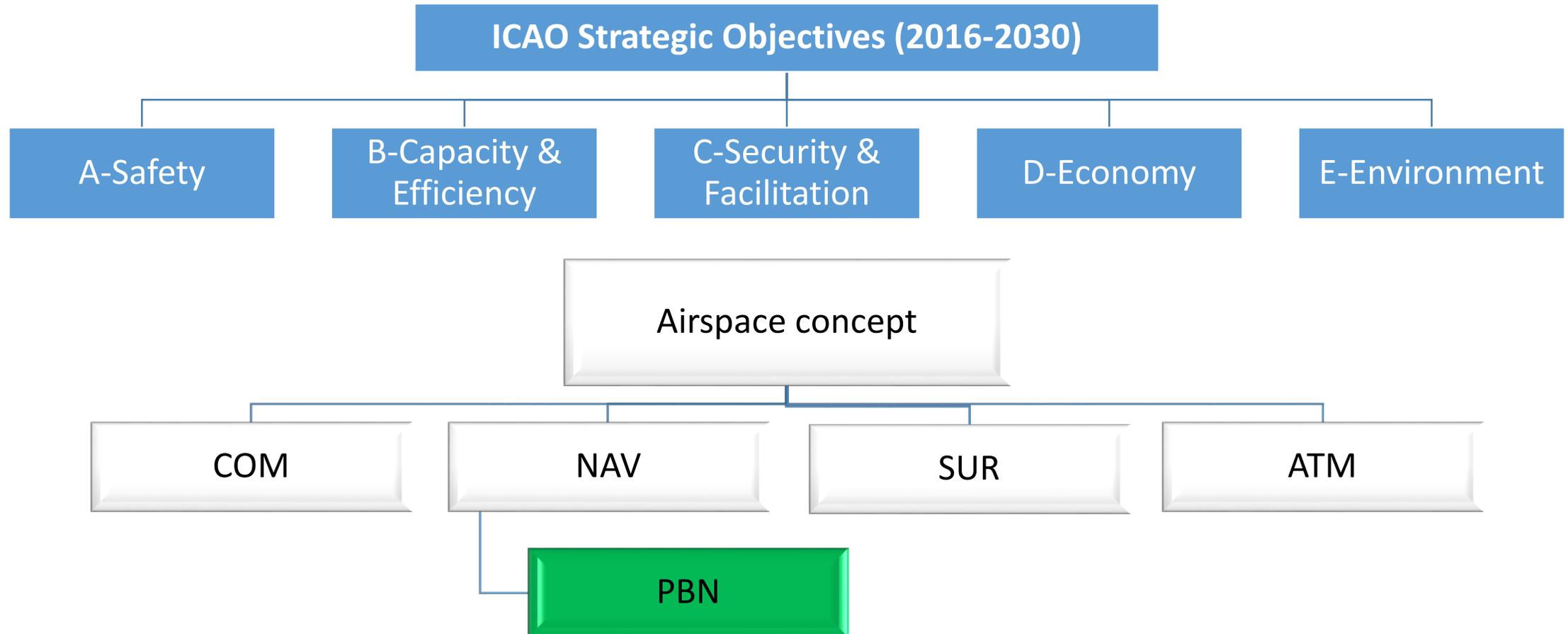
## Globally Harmonized

- 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

African Flight Procedure Programme (AFPP)

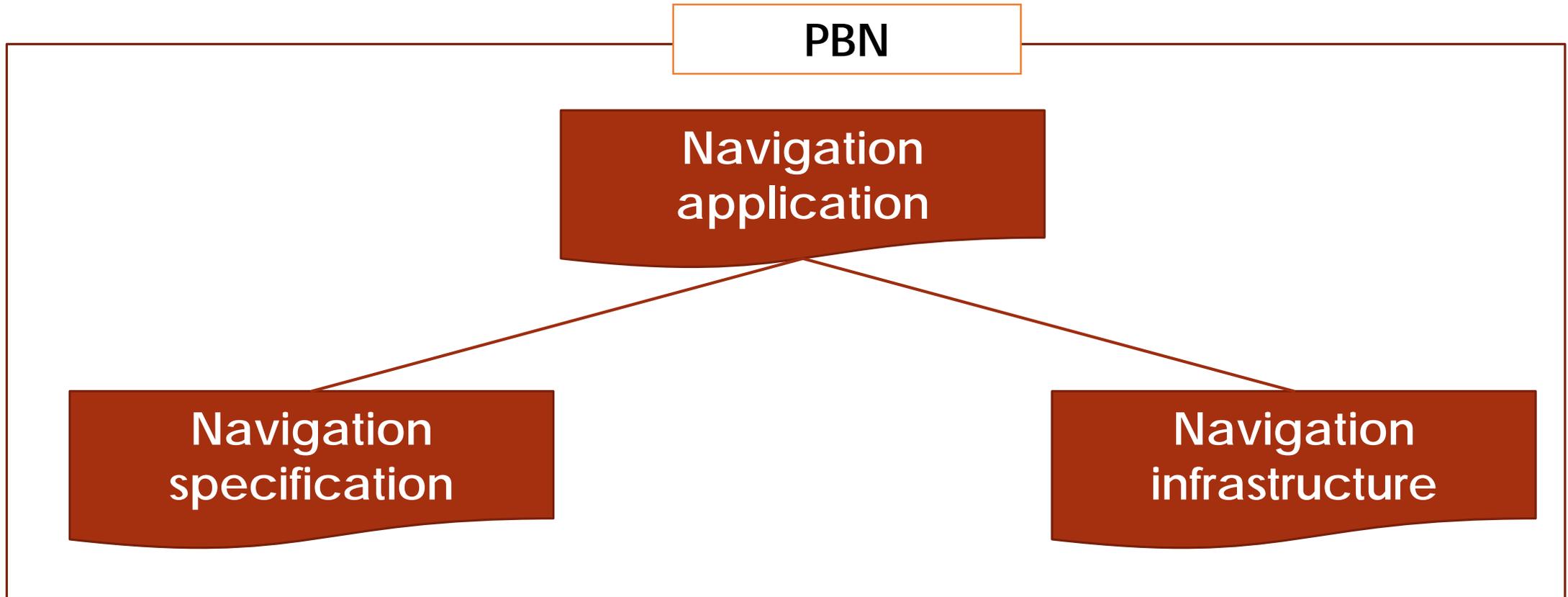




# Performance-Based Navigation theory

African Flight Procedure Programme (AFPP)

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



**NAVIGATION INFRASTRUCTURE:** Refers to ground-based nav aids (VOR-DME, DME), space-based nav aids (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

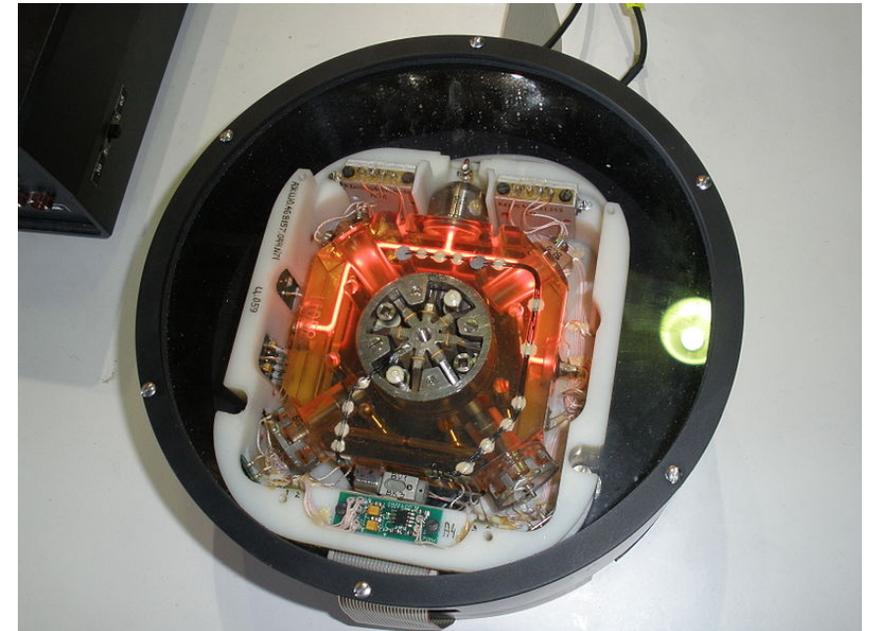
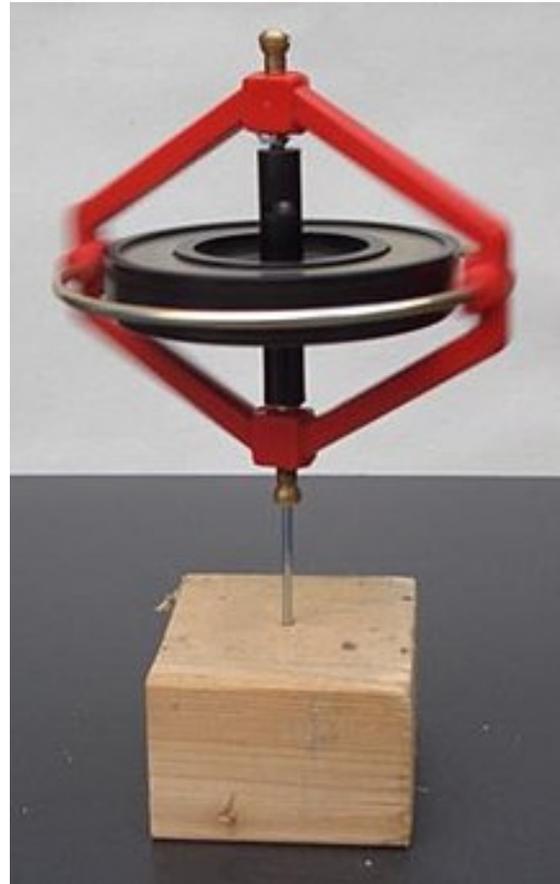


NDB is not part of PBN



# Performance-Based Navigation theory

African Flight Procedure Programme (AFPP)





# Performance-Based Navigation theory

African Flight Procedure Programme (AFPP)

**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)

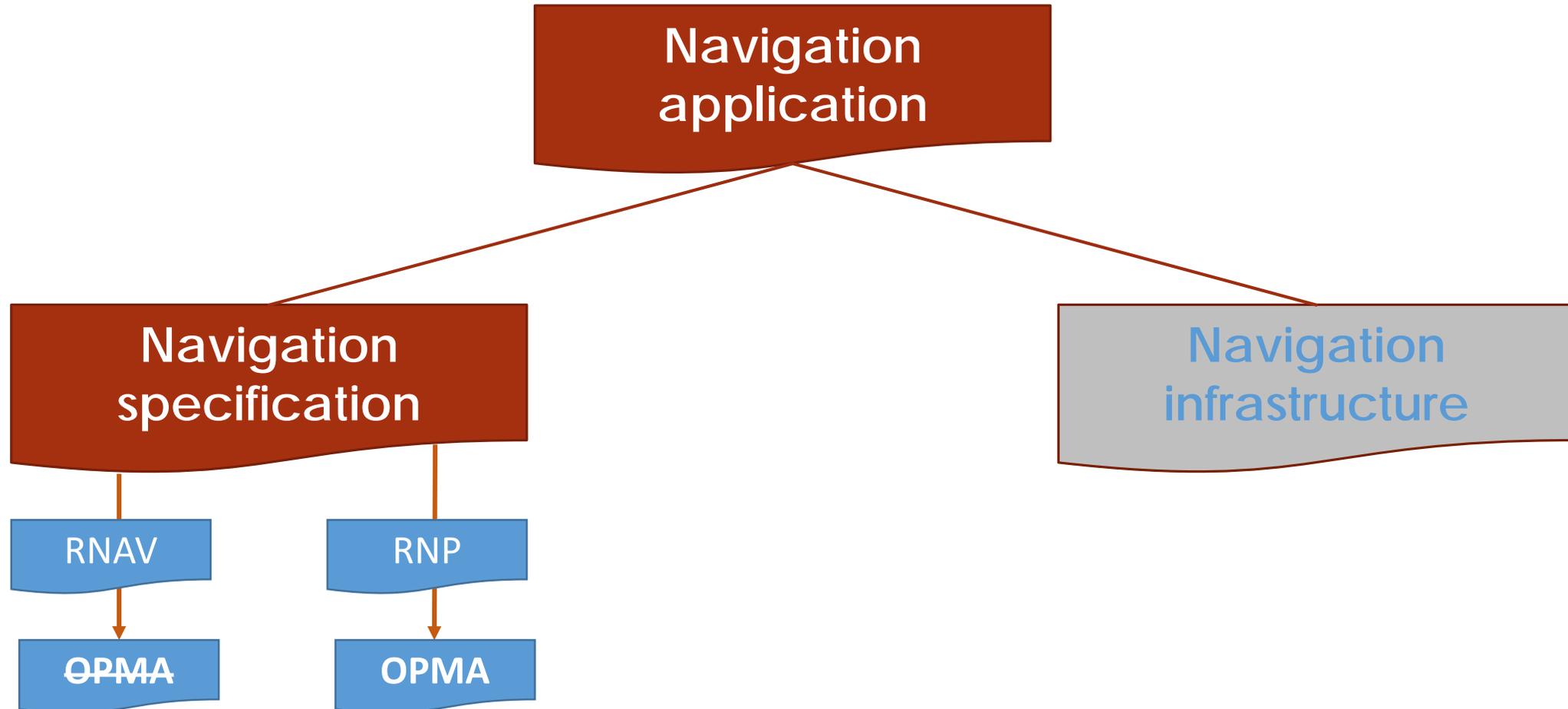
Two navigation specifications have been defined:

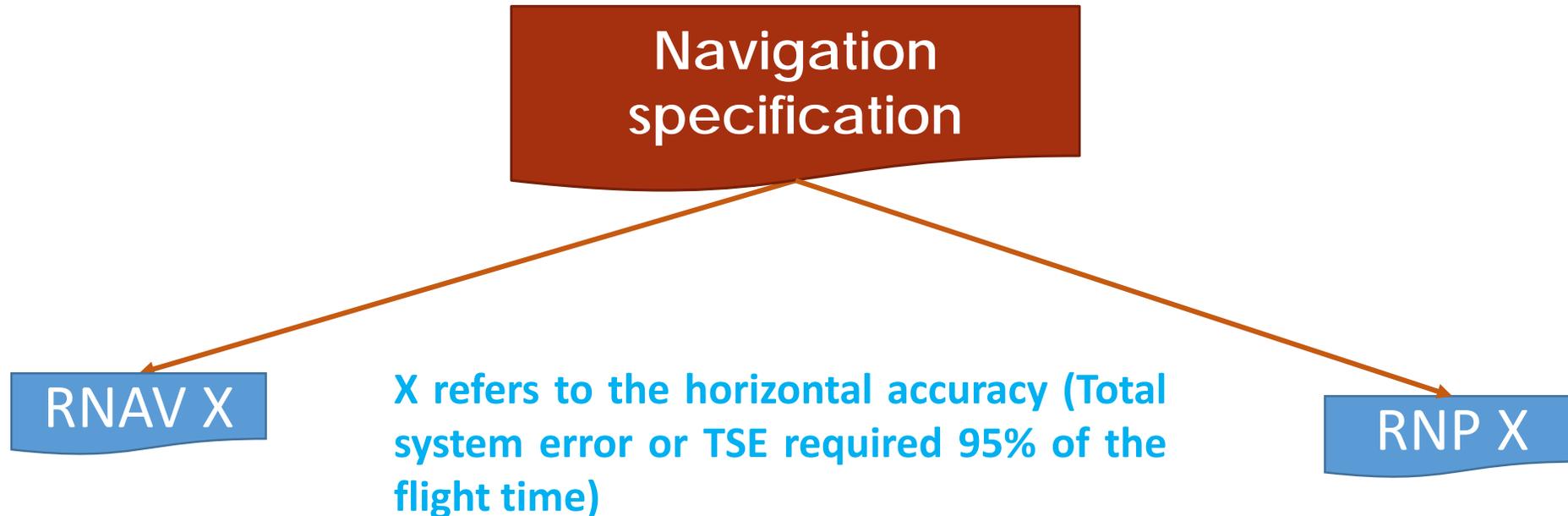
- RNP specification that requires the use of the OPMA;
- RNAV specification not



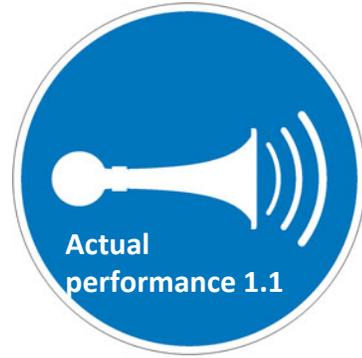
# Performance-Based Navigation theory

African Flight Procedure Programme (AFPP)

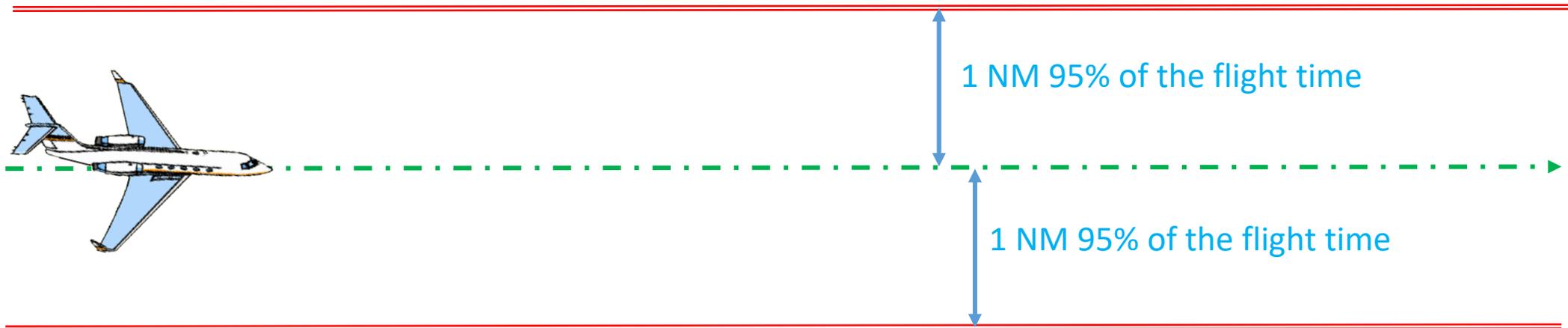




- RNAV or RNP is the Navspec designator and
- X is the navspec descriptor



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

African Flight Procedure Programme (AFPP)

## □ 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

African Flight Procedure Programme (AFPP)

**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)

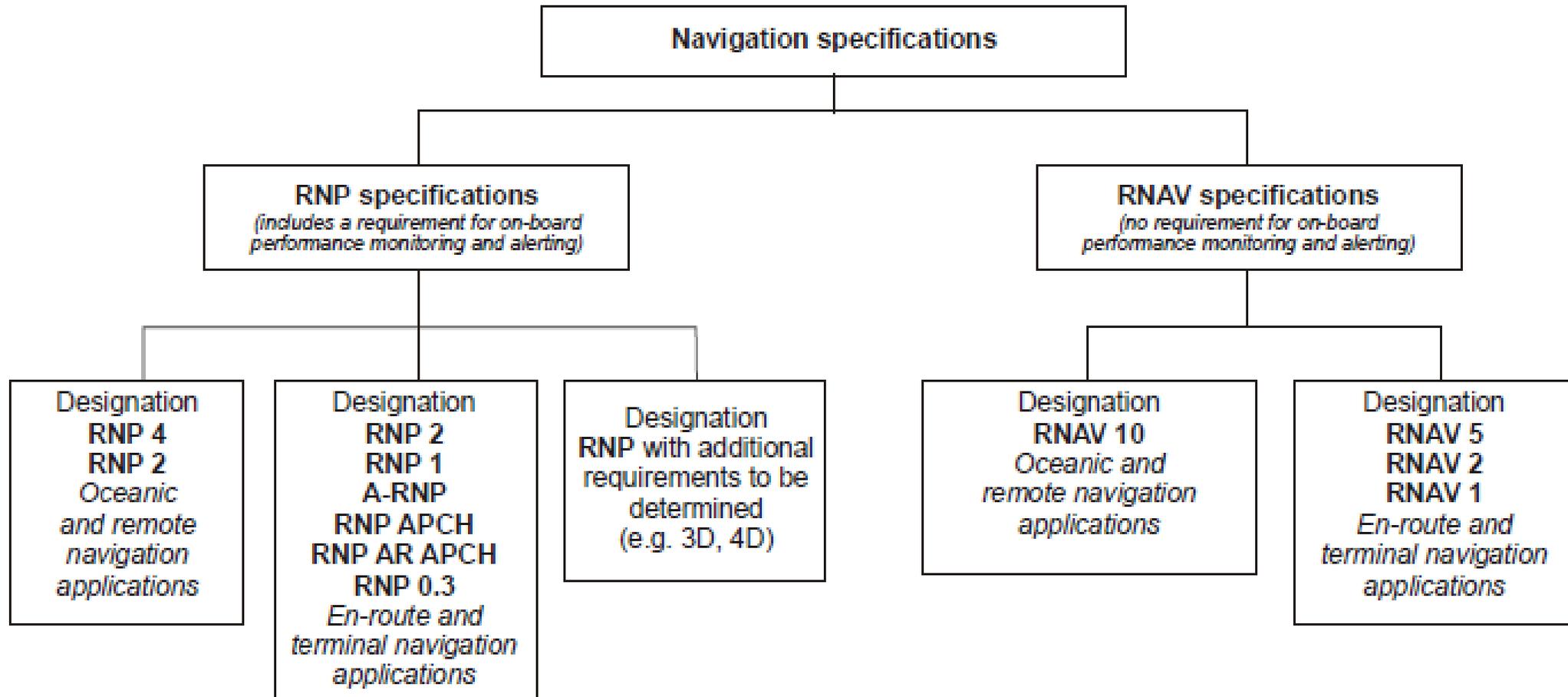
A navigation application may require many airspace concept enablers:

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



# Performance-Based Navigation theory

African Flight Procedure Programme (AFPP)



# PBN Specifications

Area of operation	RNP	RNP + additional req.	RNAV
Remote Continental & oceanic	RNP 4, RNP 2	<input type="checkbox"/> 3D <input type="checkbox"/> 4D <input type="checkbox"/> Time of arrival control <input type="checkbox"/> RNP scalability <input type="checkbox"/> Higher continuity <input type="checkbox"/> Baro VNAV <input type="checkbox"/> 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

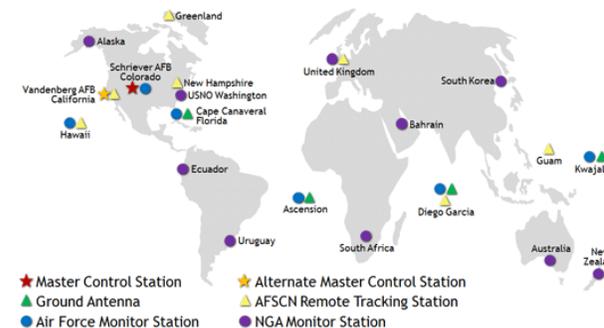


# Global Navigation Satellite System (GNSS) overview

African Flight Procedure Programme (AFPP)

## 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

African Flight Procedure Programme (AFPP)

## 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.



# Global Navigation Satellite System (GNSS) overview

African Flight Procedure Programme (AFPP)

## 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:



# Global Navigation Satellite System (GNSS) overview

African Flight Procedure Programme (AFPP)

## GNSS performances

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



# Global Navigation Satellite System (GNSS) overview

African Flight Procedure Programme (AFPP)

## ICAO performance requirements

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





# Global Navigation Satellite System (GNSS) overview

African Flight Procedure Programme (AFPP)

## 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





# Global Navigation Satellite System (GNSS) overview

African Flight Procedure Programme (AFPP)

## The ABAS

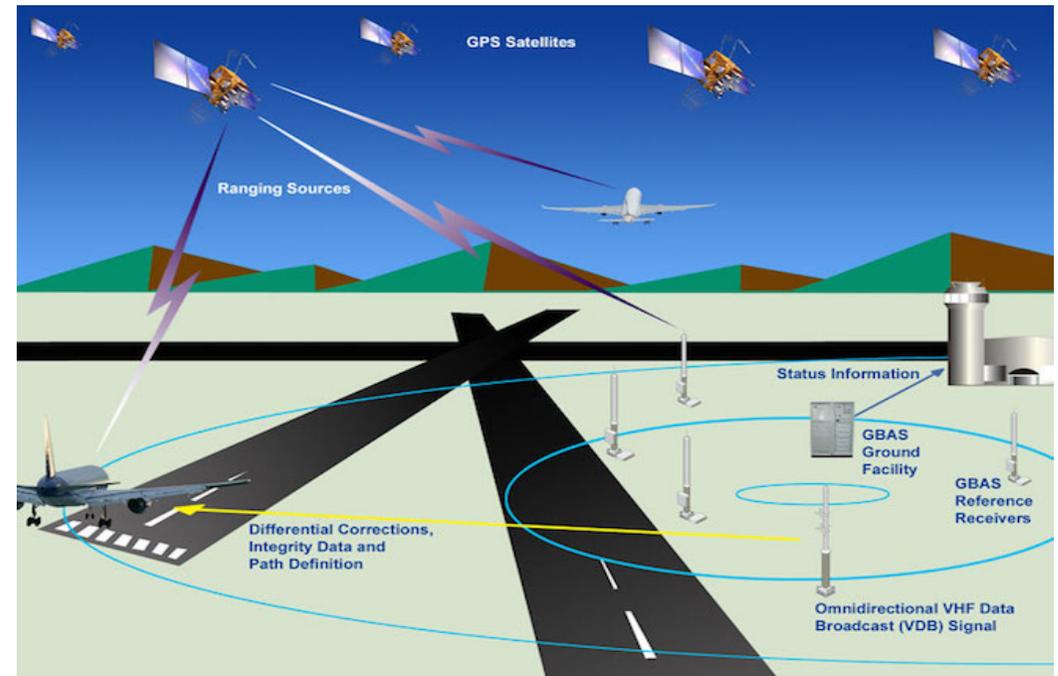
### □ ABAS operational application:

- ☞ En-route;
- ☞ Terminal;
- ☞ Approach:
  - RNP APCH (with/without baro VNAV);
  - RNP AR APCH.



## 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

African Flight Procedure Programme (AFPP)

## The GBAS

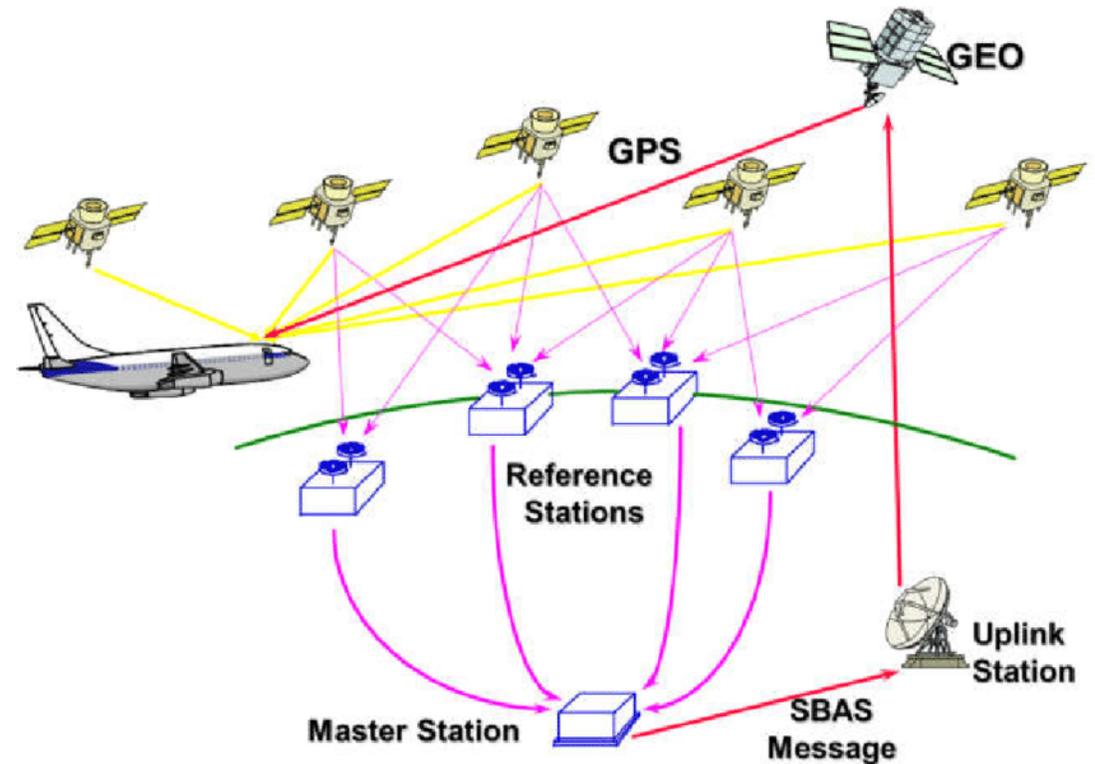
- ❑ GBAS service is available up to 30 NM radius;
- ❑ GBAS operational use: Approach and landing:
  - ☞ GBAS landing System (GLS)

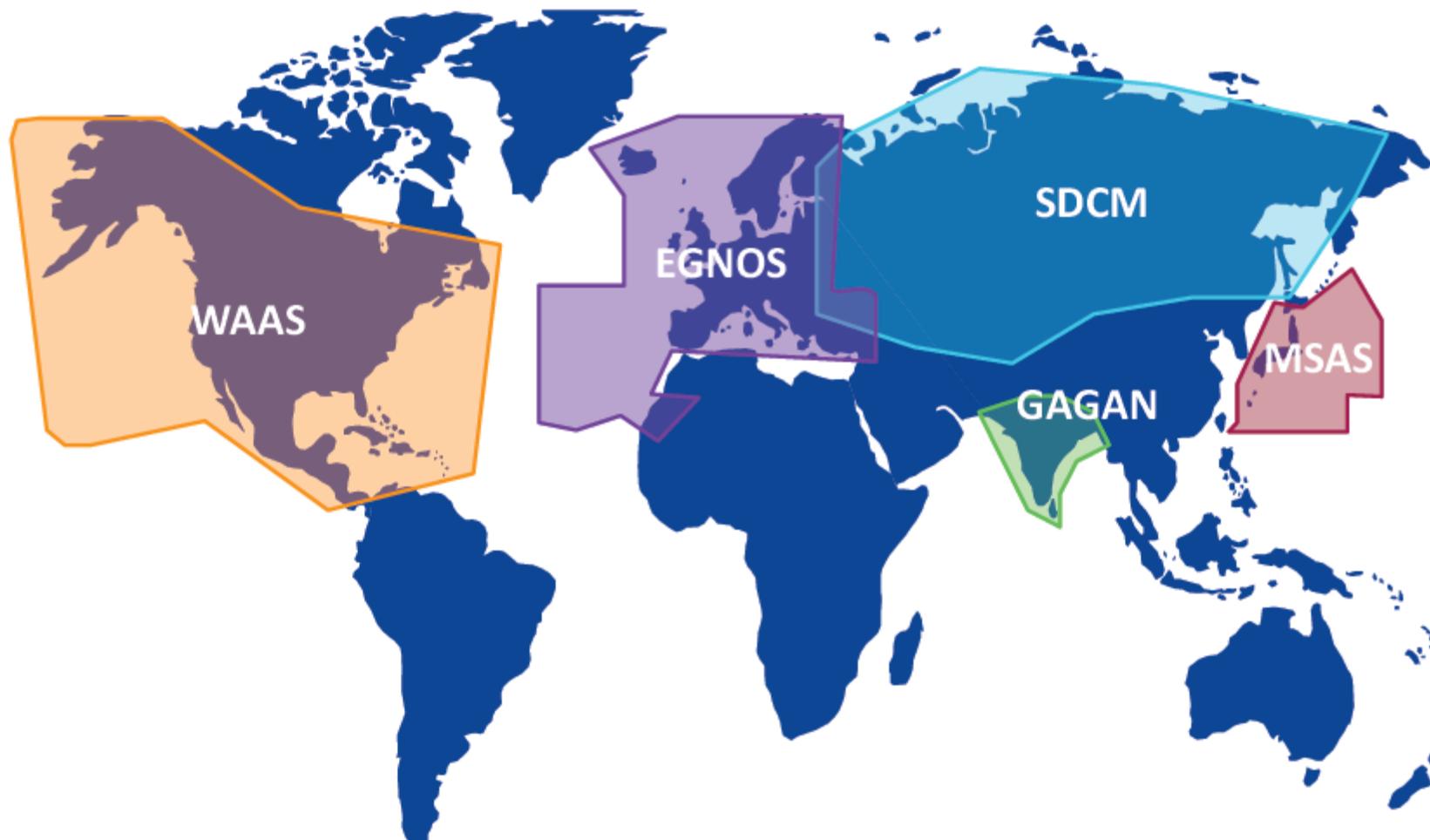


**GBAS Reference Station**

## 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



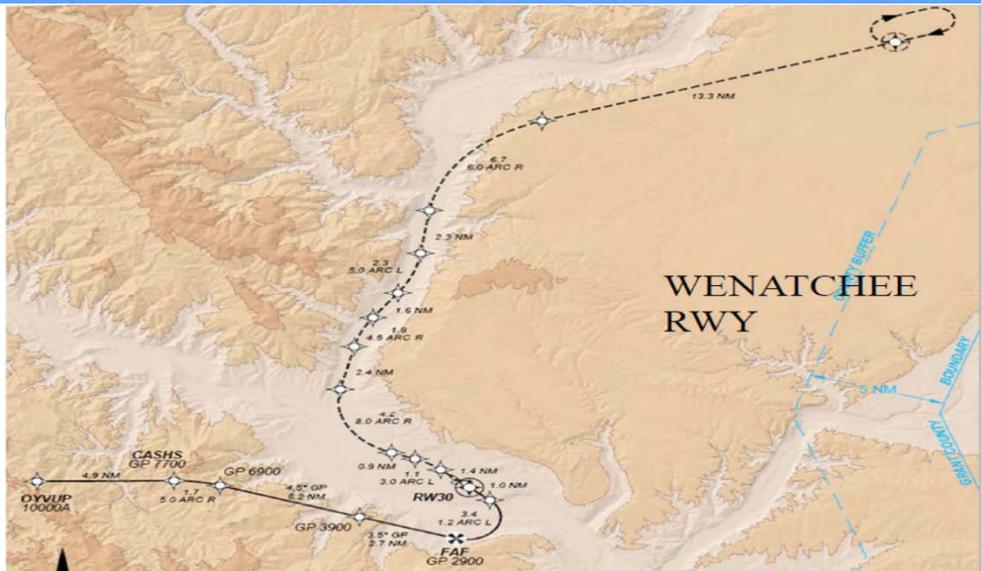
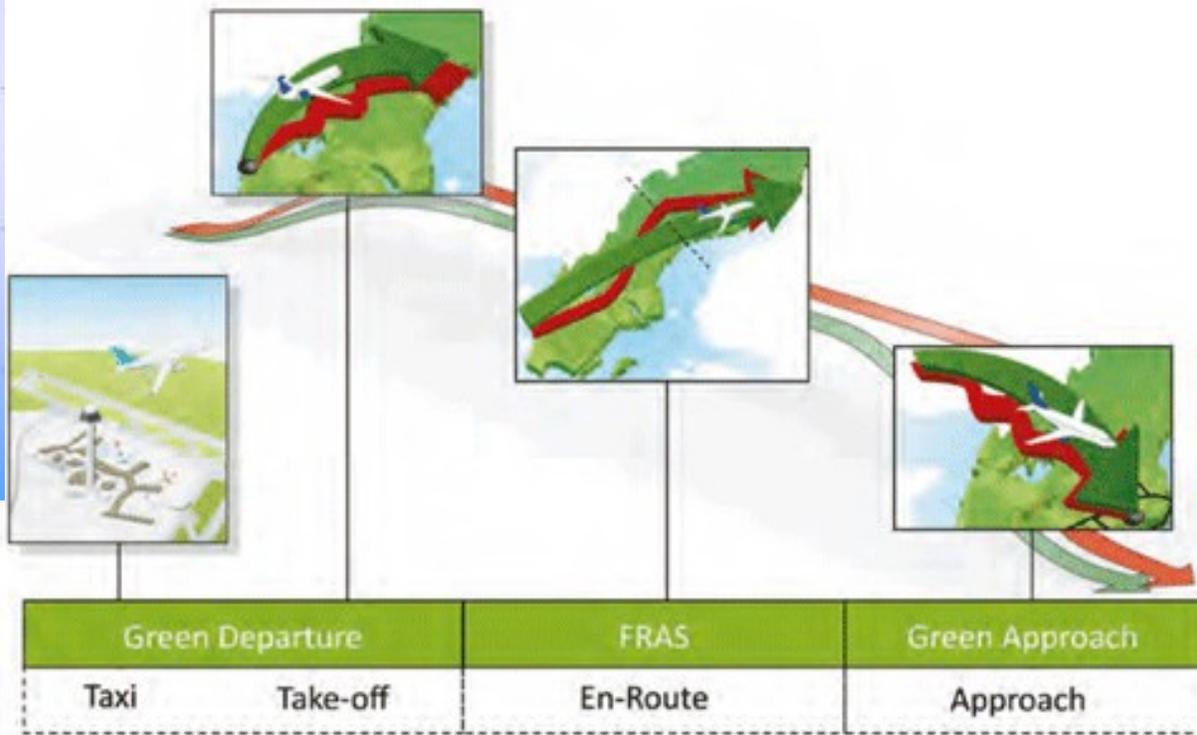
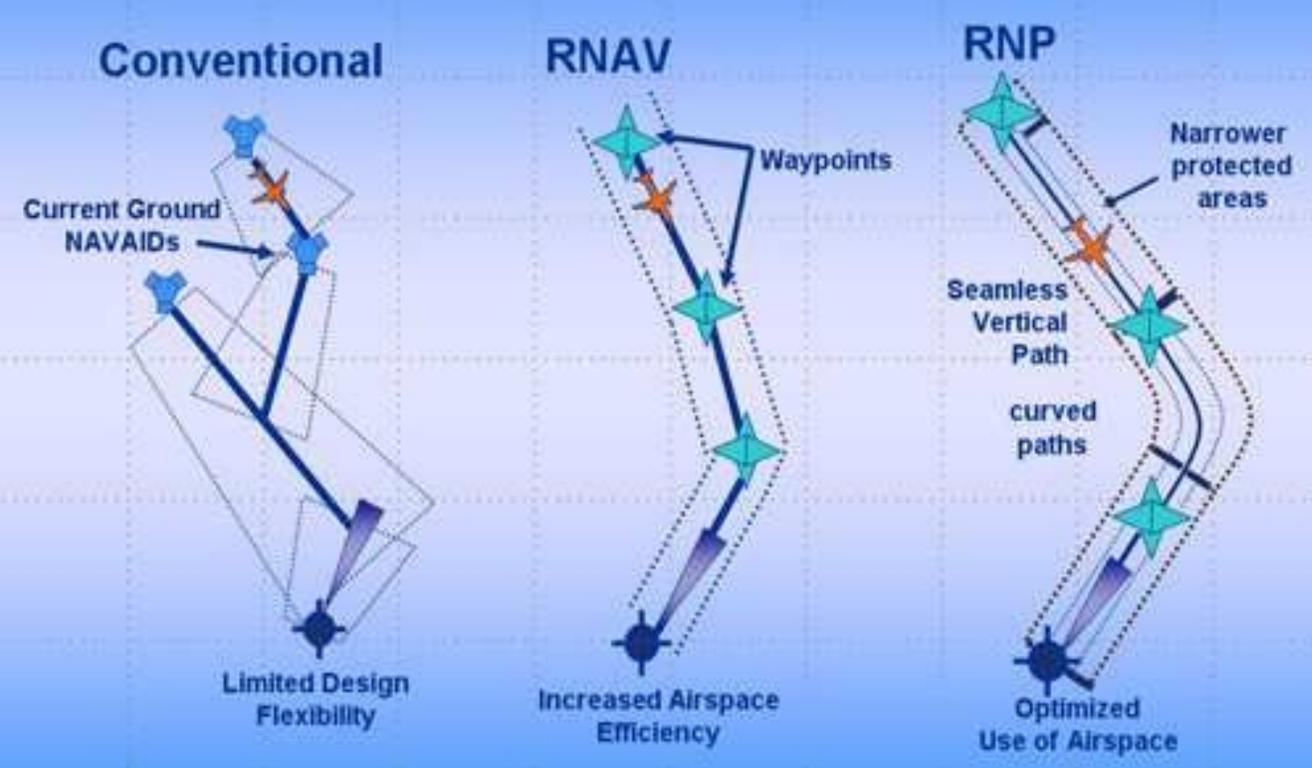




## □ PBN inherited all the GNSS benefits:

- ☞ Direct routing;
- ☞ More efficient use of airspace;
  - Economy (reduction of fuel burn);
  - Flight efficiency;
  - Noise abatement, etc.)
- ☞ Safety enhancement;
- ☞ Reduction of CO<sub>2</sub> emission;
- ☞ Reduction of CFIT;
- ☞ Easy maintenance of routes and procedures;

## □ PBN is a major ASBU and airspace concept enabler.





## □ 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 ( <b>with APV baro VNAV or augmented GNSS</b> ) supplemented by RNP APCH LNAV only*	RNP AR APCH

**\*Notes :**

- Where altimeter setting doesn't exist or aircraft of MTOW  $\geq 5\,700$  kg, using an aerodrome are not suitably equipped for APV
- SBAS is included in the AFI PBN roadmap as other augmented GNSS.



# SBAS benefits

African Flight Procedure Programme (AFPP)

- ❑ 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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