Airbus Safety

Performance-Based Navigation (PBN)

Stéphane MOREL
Airspace Solutions Project Manager, NAVBLUE

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Agenda

1. Introduction
2. What is PBN?
3. Why PBN?
4. PBN stakeholders, roles & responsibilities
5. Zoom on RNP APCH & RNP AR
6. Conclusion

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AN AIRBUS COMPANY

WHO WE ARE

OUR SOLUTIONS

- Flight Operations and Air Traffic Management solutions and services for airlines, airports and air navigation service providers

OUR POSITION

- Trusted partner for 500+ customers worldwide
- Global team delivering a reliable customized user experience
- Wholly owned Airbus subsidiary with strong partners

OUR MISSION

- Combine aircraft manufacturer expertise, flight operations know-how and agile development to enhance operational efficiency, optimize resources and increase productivity for safe and sustainable aviation

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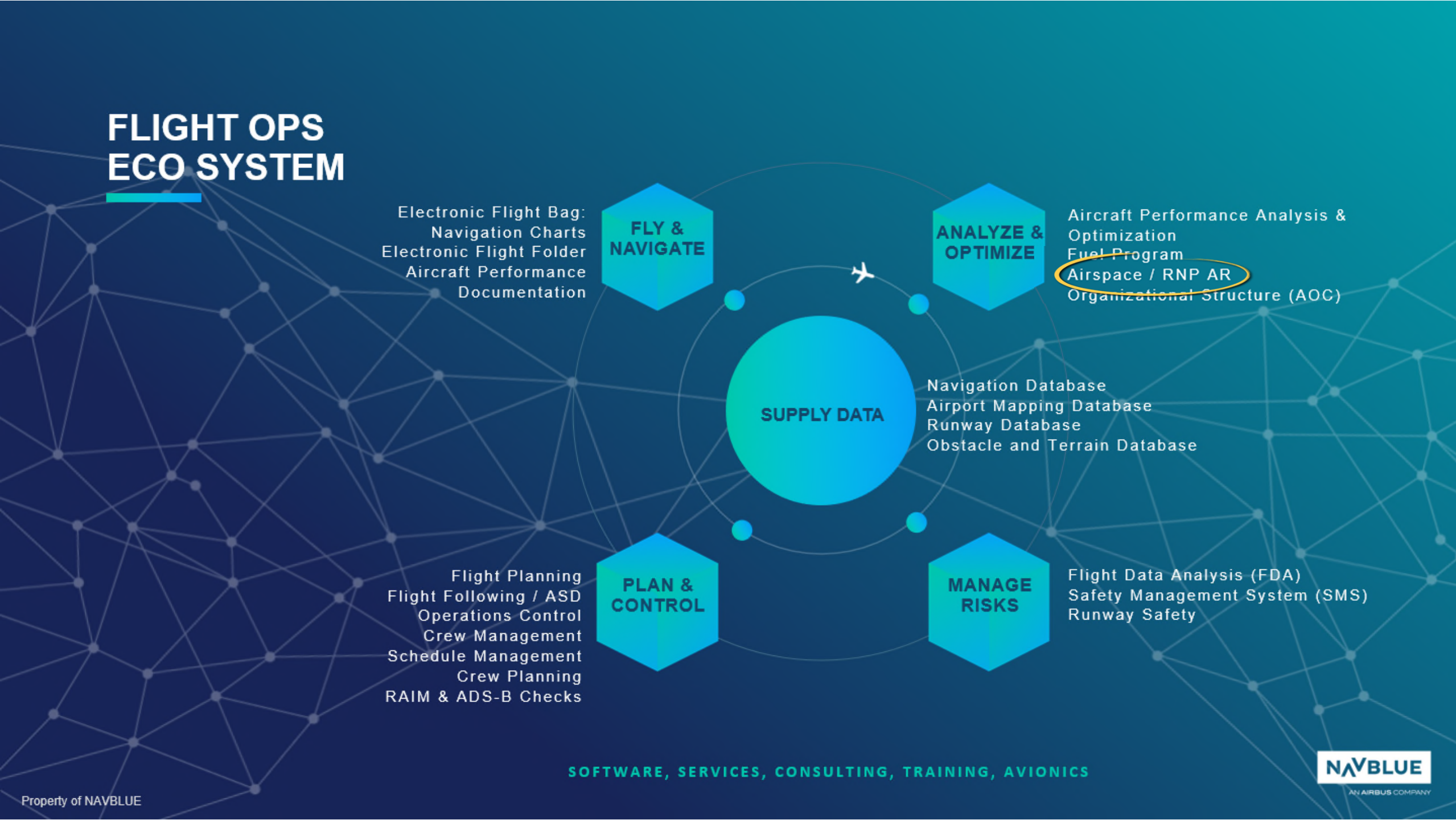
FLIGHT OPS ECO SYSTEM



SOFTWARE, SERVICES, CONSULTING, TRAINING, AVIONICS

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NAVBLUE PBN achievements around the world

Since 2009, NAVBLUE has delivered successful PBN projects:

- 855 procedures
- 66 airports
- 50 airlines
- 30 CAAs
- 12 aircraft types
  (incl. Boeing, Bombardier, Embraer, etc.)

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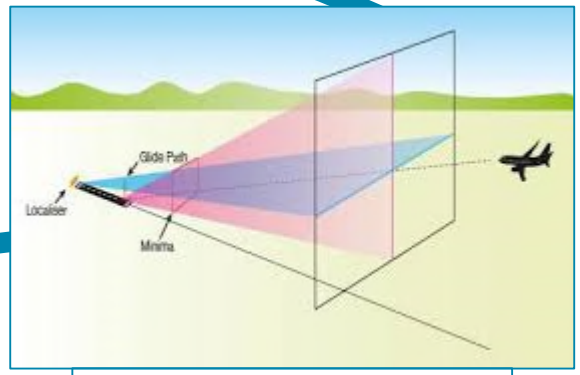
Some history

1923 Aeronautical lighthouse

1929 First instrumental flight by Jimmy Doolittle

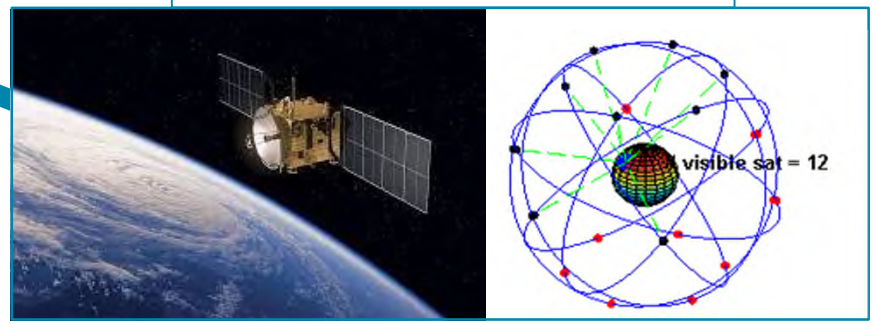


1938 First ILS approach

Up to 1970's
ILS & NAVAIDs era

1980's FMS and IRS

1990's GNSS, GPS navigation



ILS: Instrument Landing System

VOR: VHF Omni-directional Range

DME: Distance Measuring Equipment

FMS: Flight Management System

IRS: Inertial Reference System

GNSS: Global Navigation Satellite System

GPS: Global Positioning System

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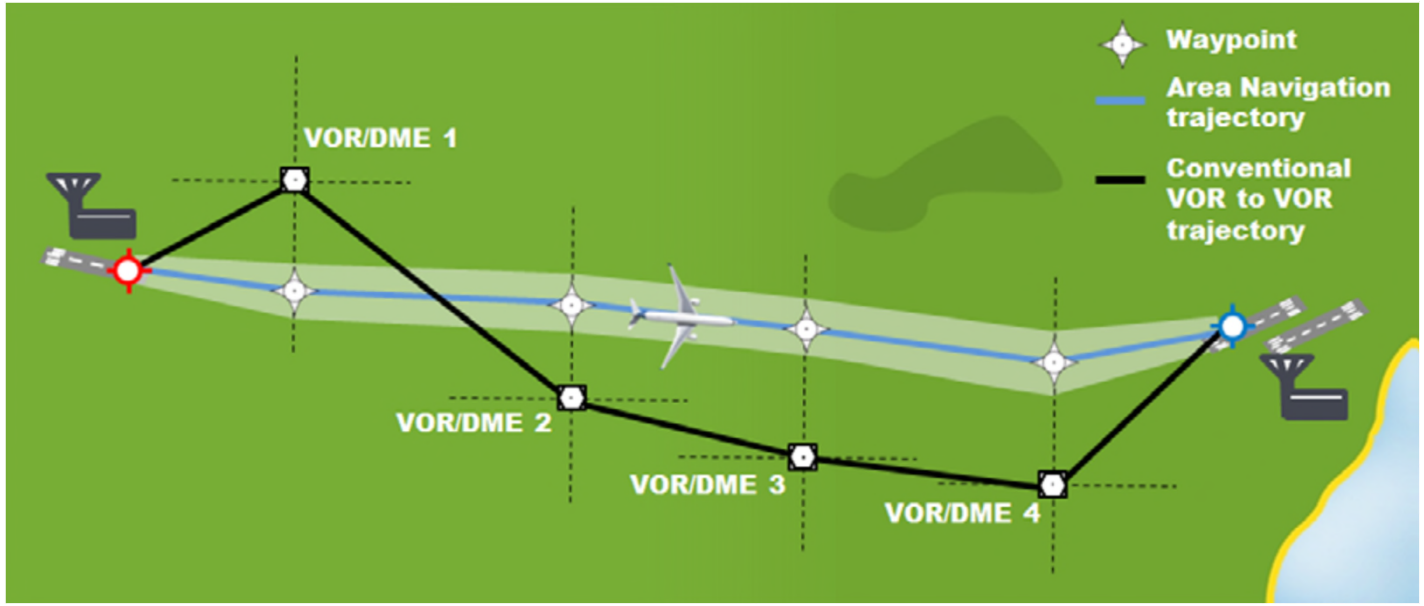
From conventional routes to PBN



Conventional

- Old aircraft capabilities and use of conventional navigation means
- Large protection areas and separation criteria to cope with limited accuracy of position estimation
- Navigation based on ground-relative position
- Limited design flexibility

The PBN concept

- **PBN** = **P**erformance-**B**ased **N**avigation
- International harmonization of navigation requirements and specifications
- Navigation based on the **accuracy / integrity** of the avionic suite
- 2 main sets of specifications:

RNAV = aRea NAVigation
→ Capability to fly any desired flight path – especially on long-range flights – defined by waypoints such as geographic fixes (LAT/LONG) and not necessarily by ground navaids

RNP = Required Navigation Performance
→ GNSS based

Navigation requirements & specifications based on accuracy / integrity of the aircraft position

RNAV

RNP

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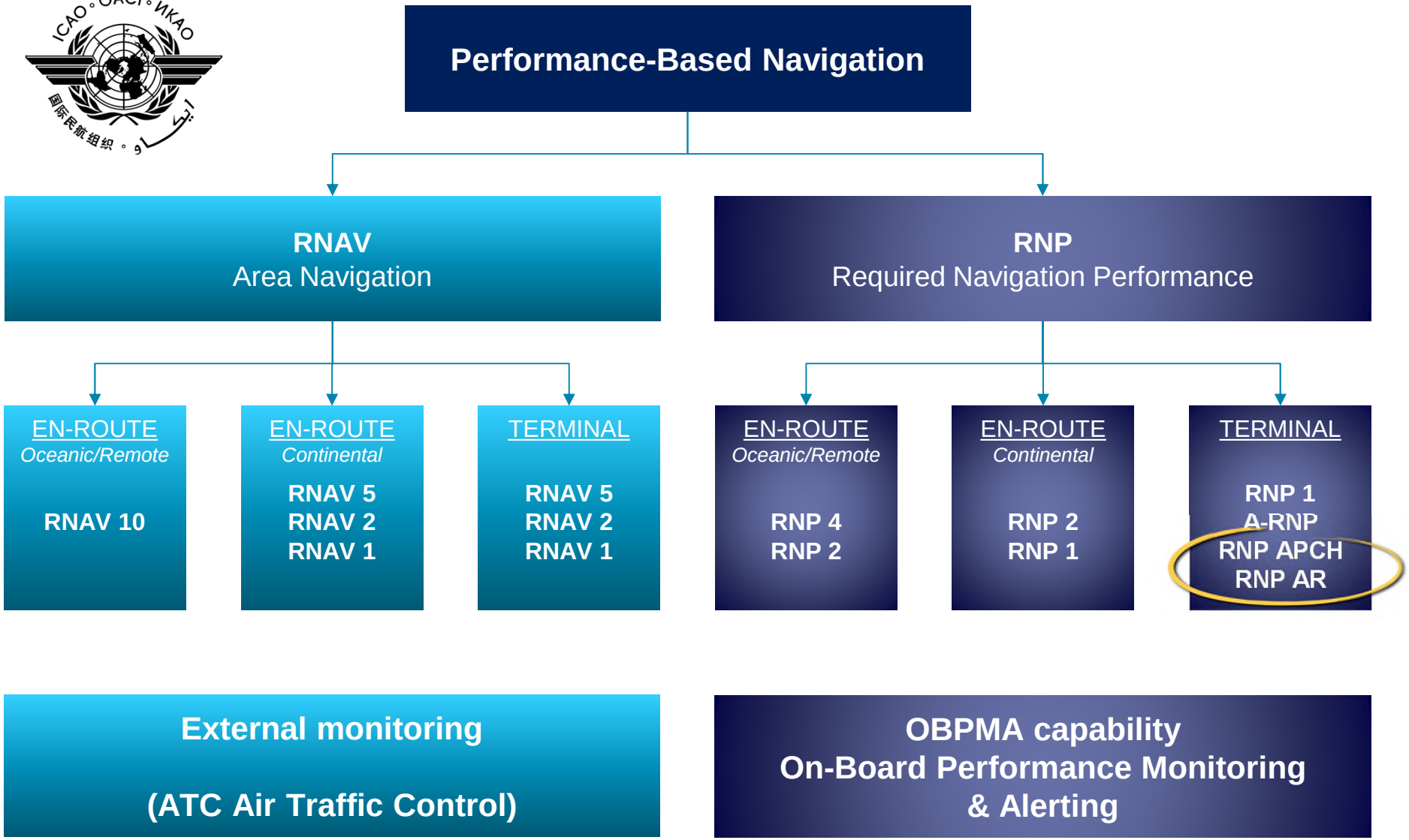
Performance-Based Navigation: definitions



RNAV-**X** / RNP-**X**: "**X**" refers to the lateral navigation accuracy in Nautical Miles

External monitoring for RNAV
Vs.
OBPMA for RNP

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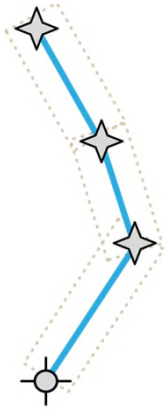
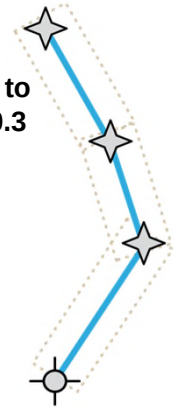
RNAV & RNP



RNAV
Area Navigation

Definition of more direct routes

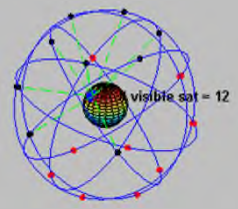


Down to
RNP 0.3

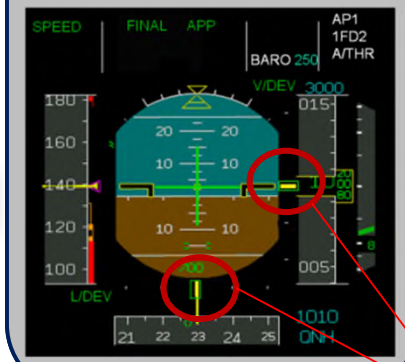
RNP
Required Navigation Performance

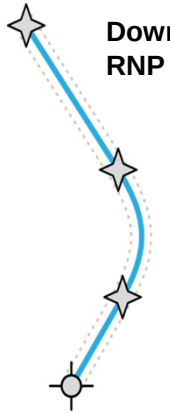
Trajectory containment

GNSS based



OBPMA
(On Board Performance Monitoring and Alerting)





Down to
RNP 0.1

RF after FAP
(Final
Approach
Point)

RNP AR
Required Navigation Performance with Authorization Required

Procedure design flexibility

Lateral & Vertical Deviations

OBPMA = On-Board Performance Monitoring & Alerting

Monitoring: aircraft ability to determine positioning error and to follow the desired path

Alerting: capability of the equipment to alert the crew if the required navigation performance (lateral & longitudinal) is not achieved

RF = Radius-to-Fix

OBPMA → Cornerstone of RNP concept

Reliable, repeatable and predictable flight operations

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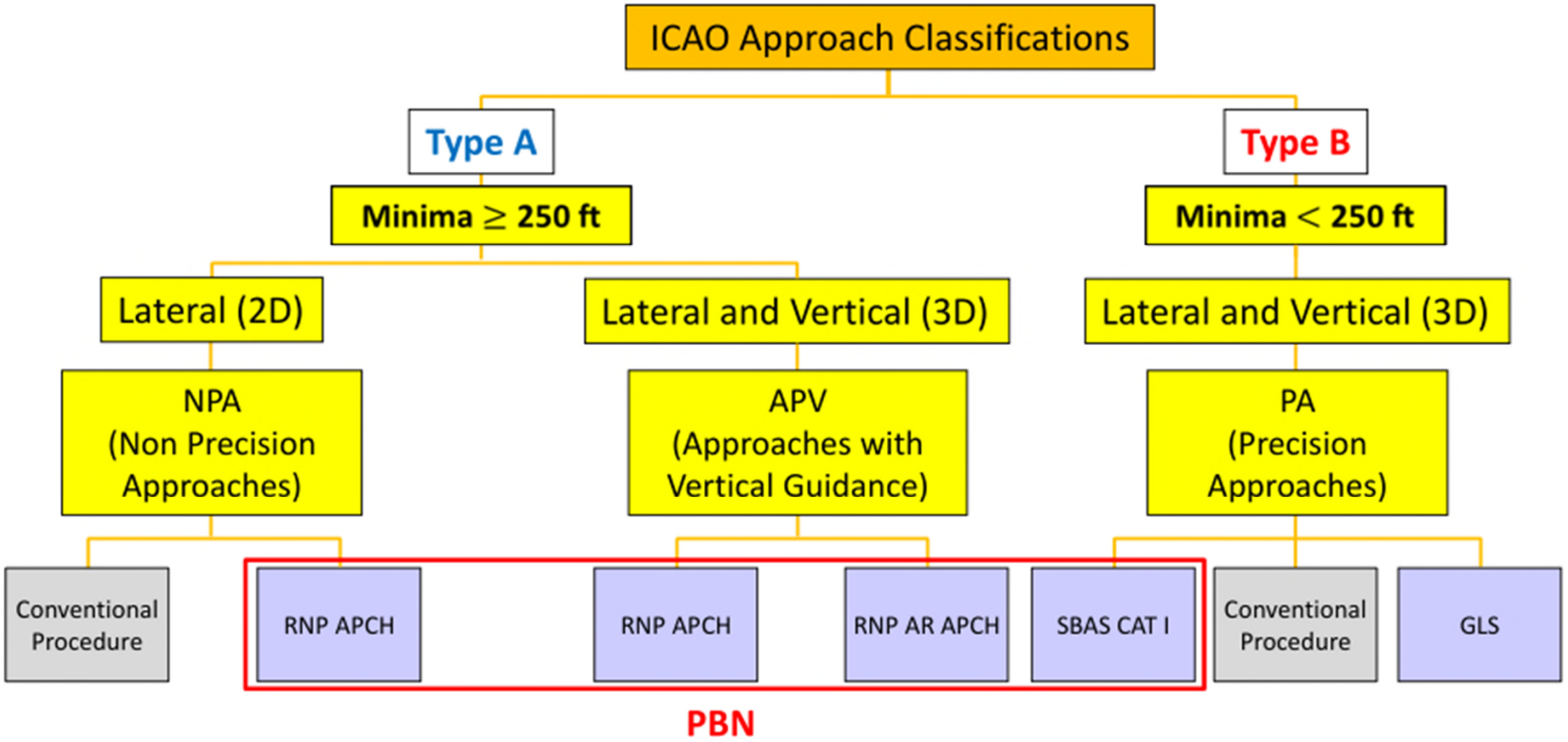
Approach: ICAO classifications



2D / 3D

NPA / APV / PA

SBAS = Satellite-Based Augmentation System
GLS = GNSS Landing System

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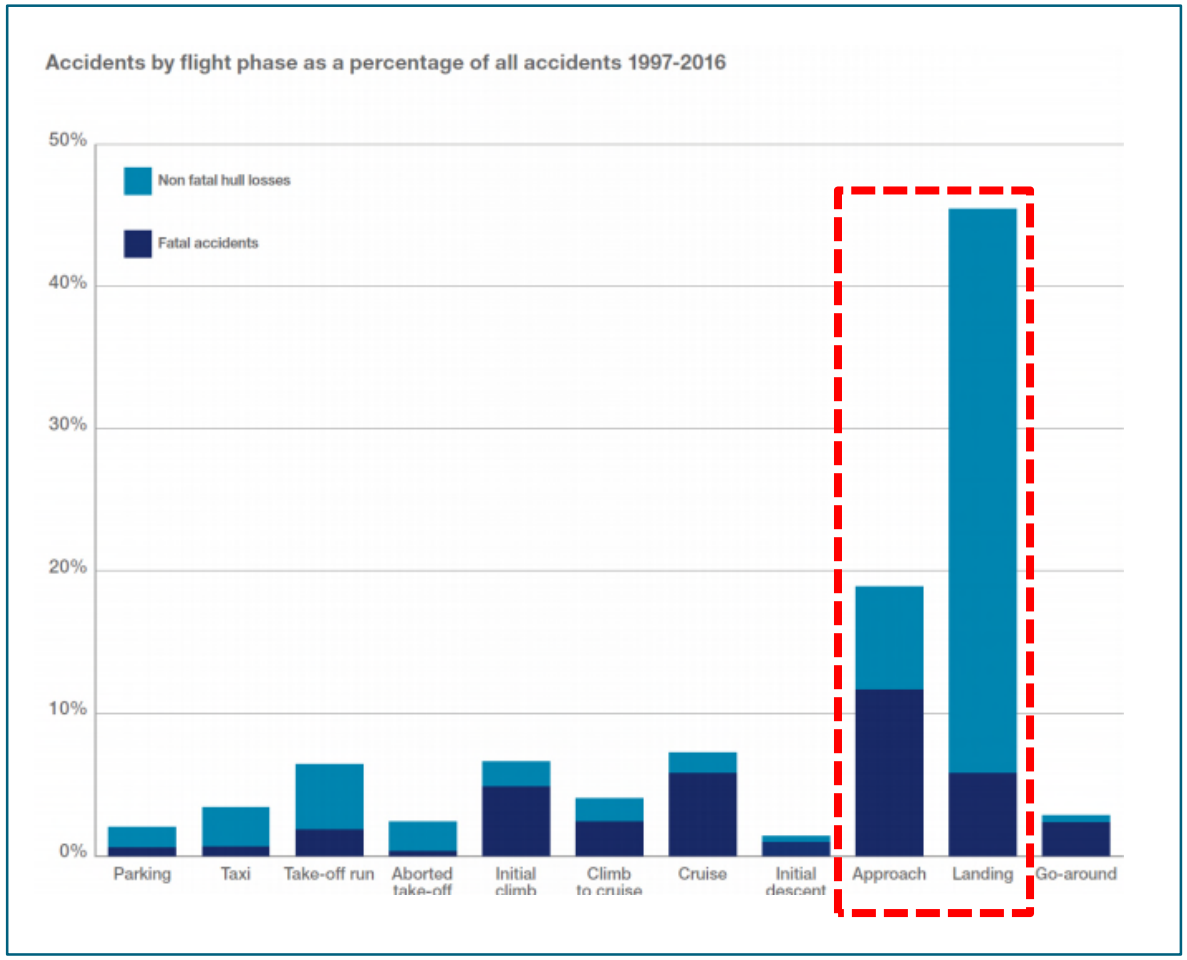
Why developing PBN approach procedures?



Distribution of accidents per flight phase (ICAO reference)

- **45%** of hull losses are happening during **Landing phase**
- **20%** of hull loss are happening during **Approach phase**, which represents more than 10% of fatal accidents

- **Automation of approaches**
- **Lateral navigation**
- **Vertical navigation**

→ Key factors for safety enhancement

*"ICAO controlled flight into terrain (CFIT) studies have shown that runway-aligned approaches (LNAV only) are **25 times safer** than circling approaches, and that once some form of vertical guidance is added to approaches the **safety margin is increased again by a factor of 8**"*

ICAO 37th Assembly - 2010

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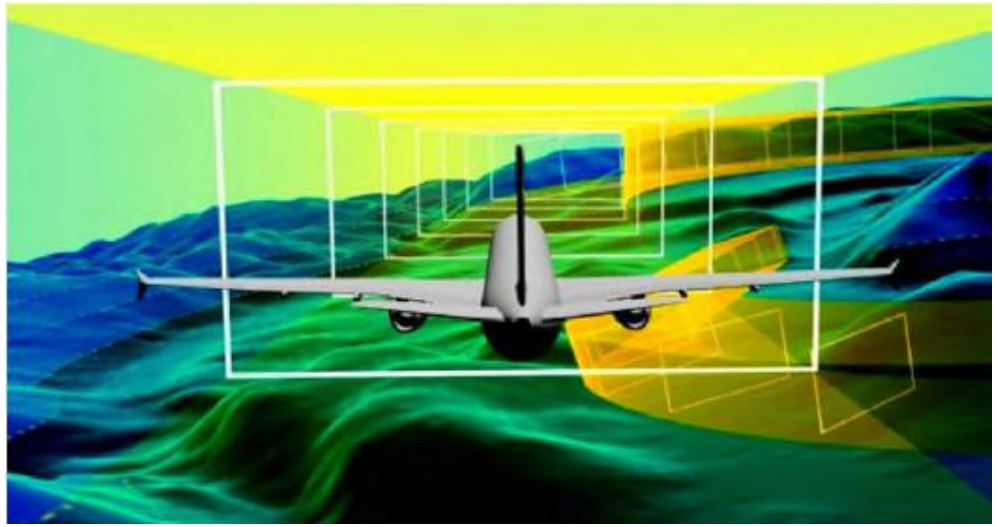
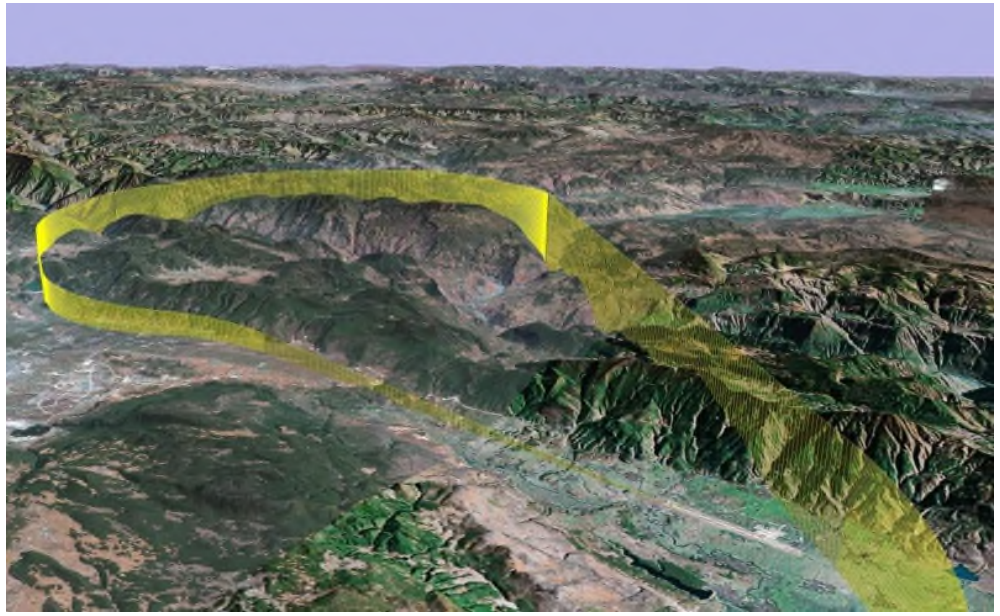
The benefits of PBN

- **Enhance Safety**
- **Improve Accessibility**
- **Reduce Fuel Burn**
  Increase Payload
- **Increase Capacity**
- **Avoid Sensitive Areas**





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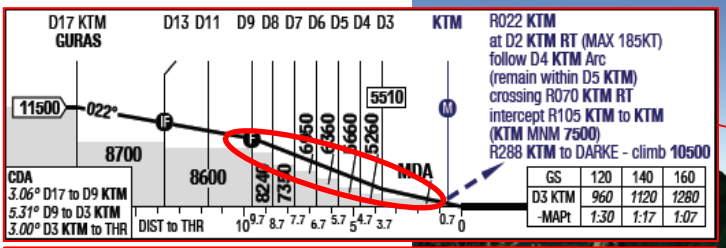
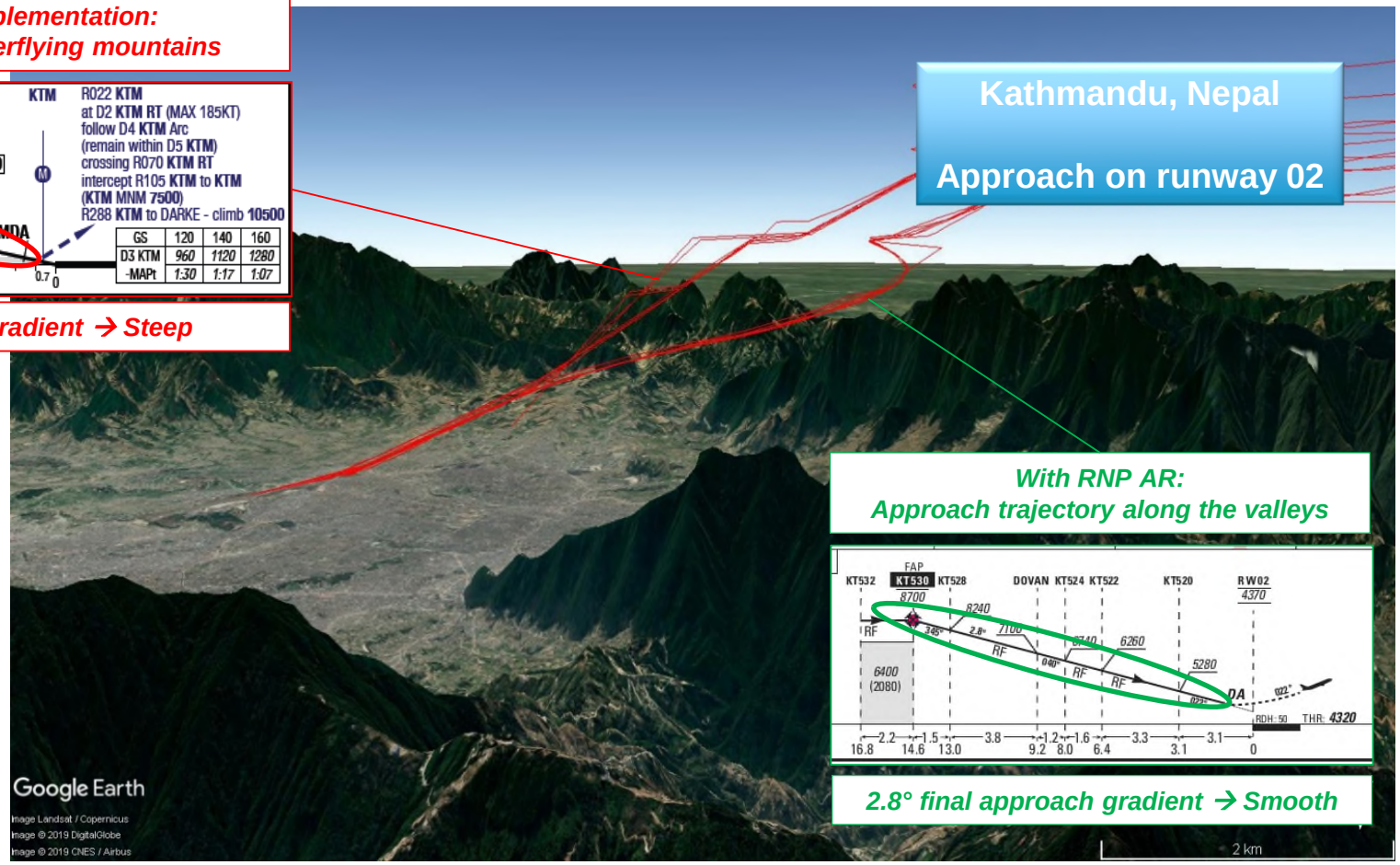
Enhance Safety

Before RNP AR implementation:
Straight-in approach overflying mountains



5.31° final approach gradient → Steep



With RNP AR:
Approach trajectory along the valleys

2.8° final approach gradient → Smooth

The benefits of PBN
→ Enhance safety

- **Reduced risk of Controlled Flight Into Terrain**
- **Consistent, predictable and stabilized approaches**
- **Safer approaches with automated operation**
- **Safer missed approaches**

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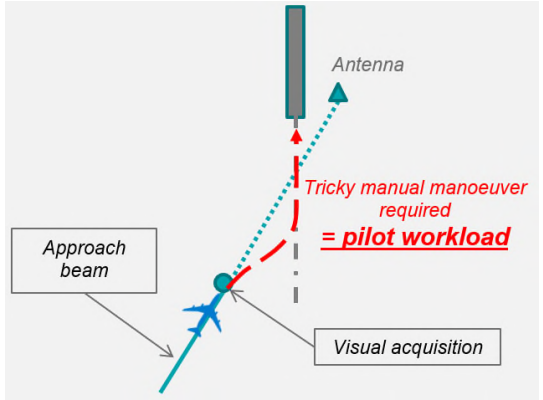
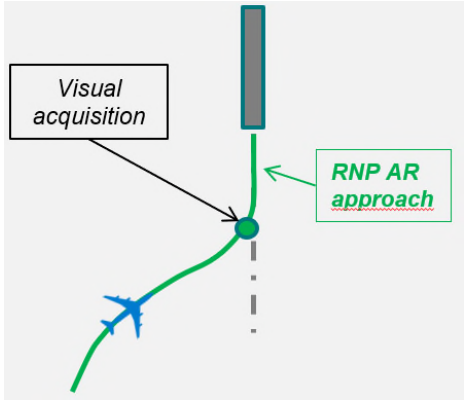
Improve Accessibility

Vagar, Faroe Islands

Before RNP AR implementation



With RNP AR



The benefits of PBN → Improve accessibility

With RNP AR:

- **Automated approach**
- **Better aircraft stability in approach**
- **Smooth alignment with runway axis**
- **Lower approach minima**

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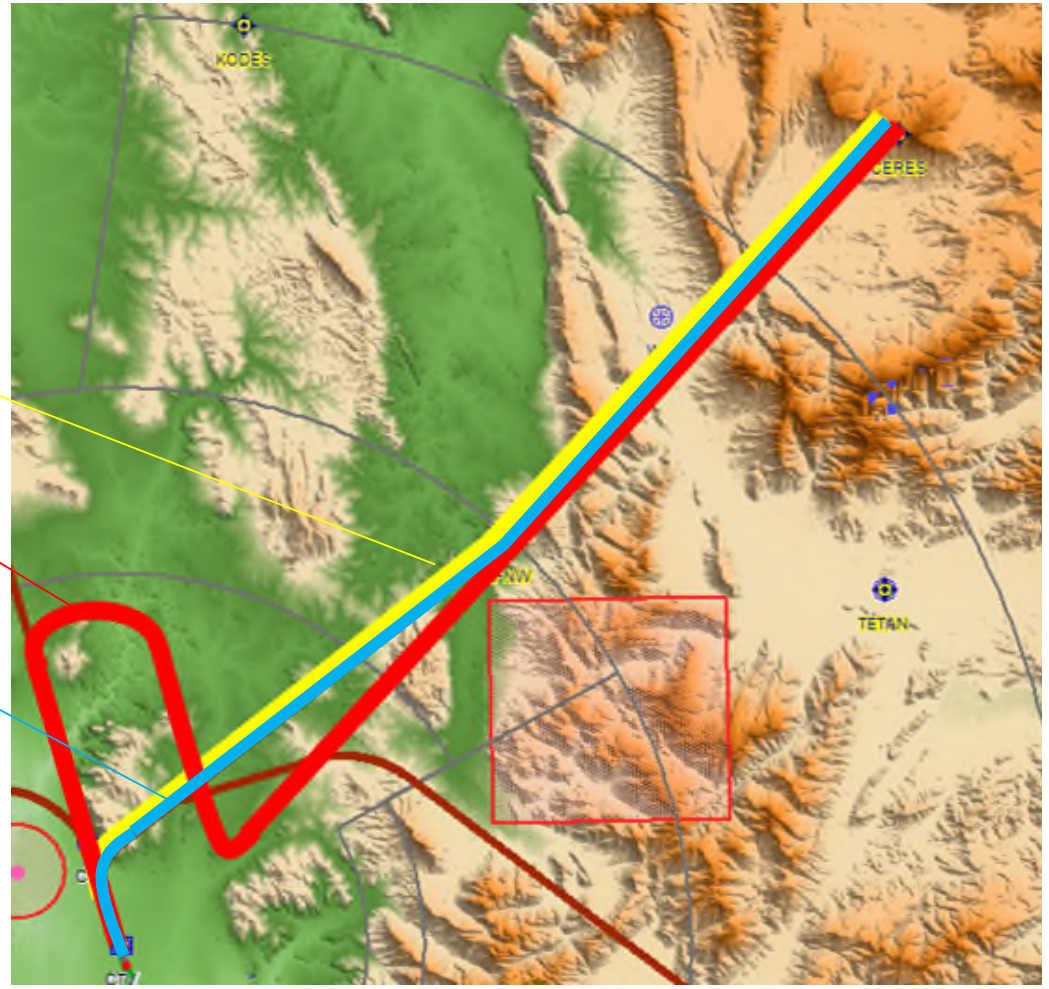
[Airbus Amber]

Reduce Fuel Burn Increase Payload

Cape Town, South Africa



Track of Visual Approach procedure

Track of Conventional procedure

Track of RNP AR procedure

The benefits of PBN → Reduce fuel burn / Increase payload

With RNP AR:

- **Shorter trajectory vs. conventional procedure**
- **Continuous descent operations**

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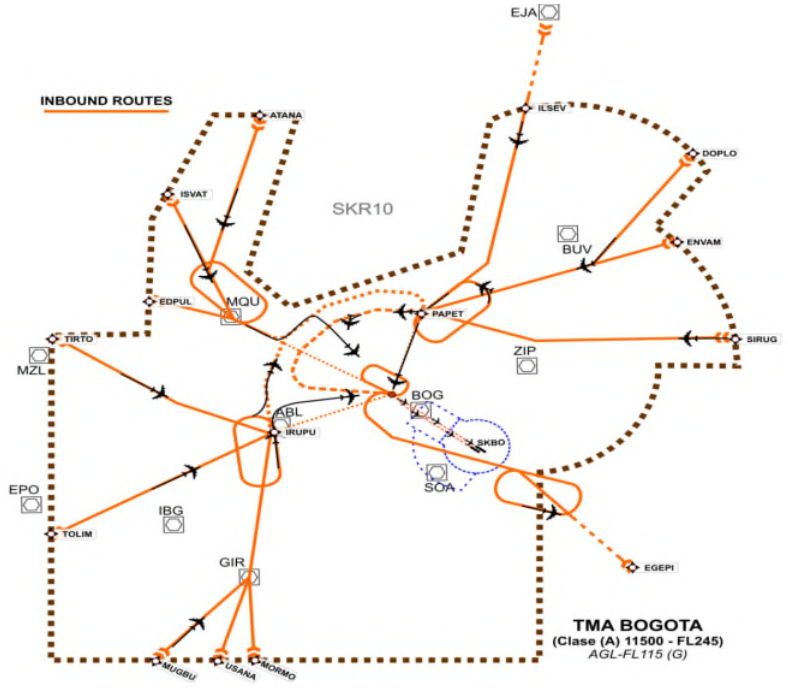
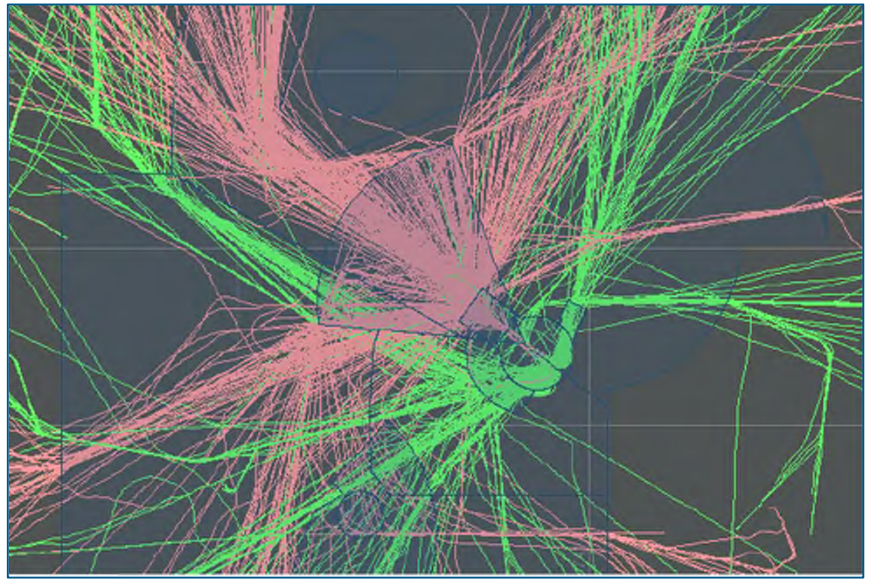
Increase Capacity

Bogota, Colombia



Redesign of the Terminal Manoeuvring Area

- Capacity RWY 13 increased **from 72 to 93 movements / hour**
- Capacity RWY 31 increased **from 30 to 68 movements / hour**



[Airbus Amber]

The benefits of PBN → Increase capacity

- **De-conflicting arrivals and departures**
- **Optimizing airspace usage while reducing Air Traffic Control workload with much less vectoring**

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Avoid Sensitive Areas

Brussels, Belgium

The benefits of PBN

Avoidance of noise sensitive zones

(+ Reduction of holding times
+ Reduction of average distance flown in TMA)

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PBN stakeholders

PBN implementation: a multiplayer project

CAA = Civil Aviation Authorities
ATC = Air Traffic Control
ANSP = Air Navigation Service Provider

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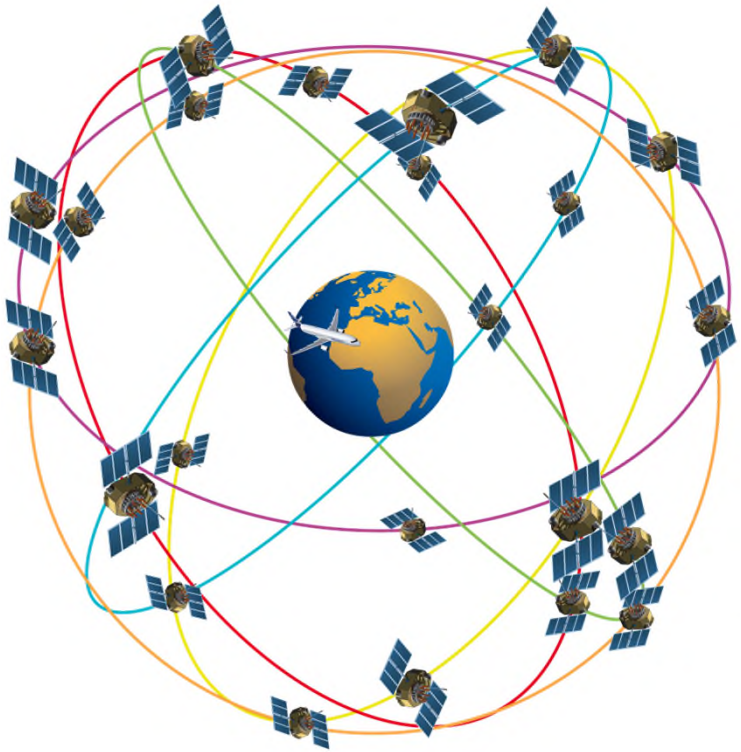
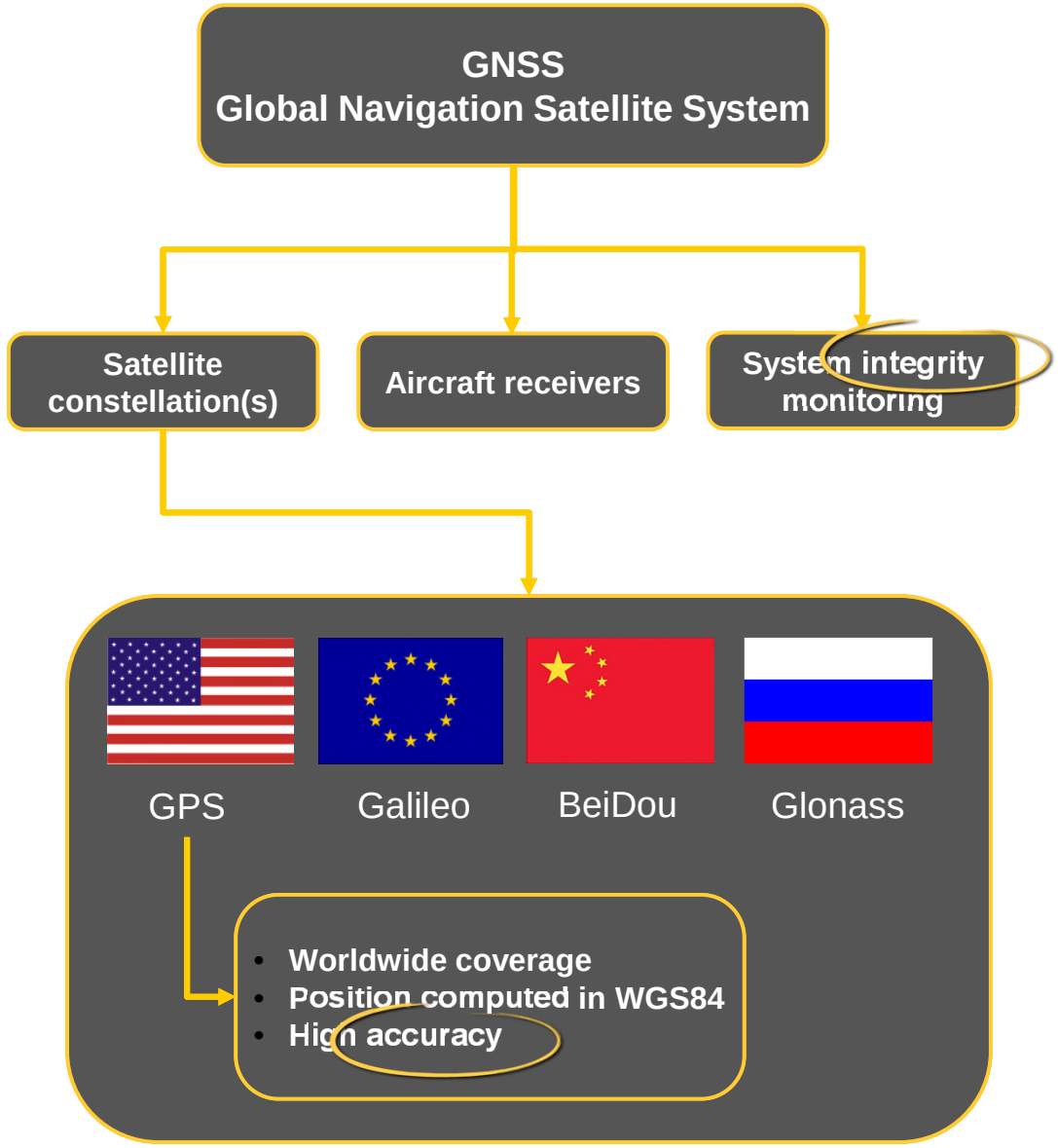
Aircraft positioning





GNSS as the enabler for RNP

GNSS = Global Navigation Satellite System
GPS = Global Positioning System
WGS = World Geodetic System

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Aircraft positioning

Integrity & Accuracy at the heart of the RNP concept

GPIRS position
Global Positioning Inertial Reference System

Integrity

→ Measure of trust that can be placed in the correctness of the position information supplied by the total system

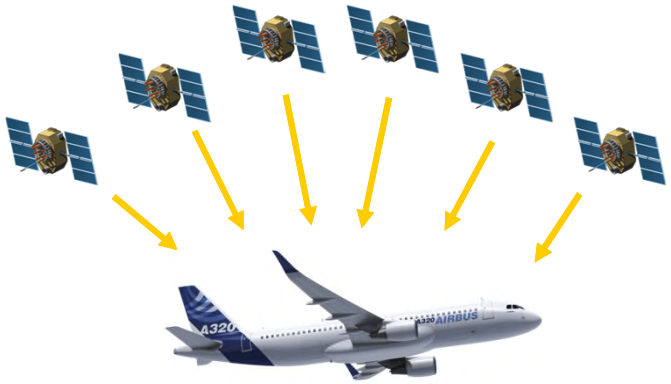
Integrity includes the ability of the system to provide timely and valid warnings to the user.

Accuracy

→ Difference between the computed position and the actual position of the aircraft

The RNP Value (e.g. RNP 0.3) defines the required accuracy

The Estimated Position Error (EPE) shall not exceed the required accuracy (RNP value).



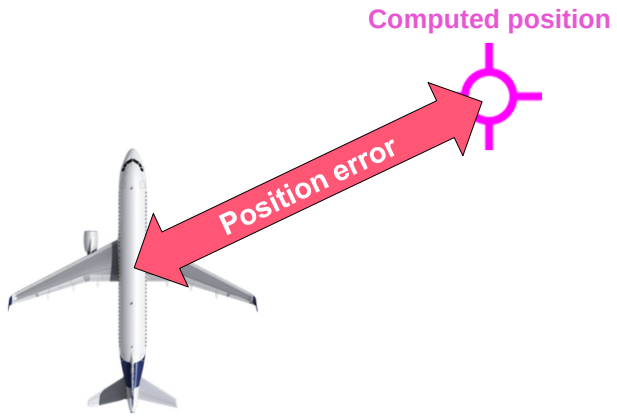
4 satellites ⇨ NAV position

Min 5 satellites ⇨ FD (Fault Detection)

Min 6 satellites ⇨ FDE (Fault Detection & Exclusion)

RAIM
Receiver Autonomous Integrity Monitoring

⇨ Integrity & Warning



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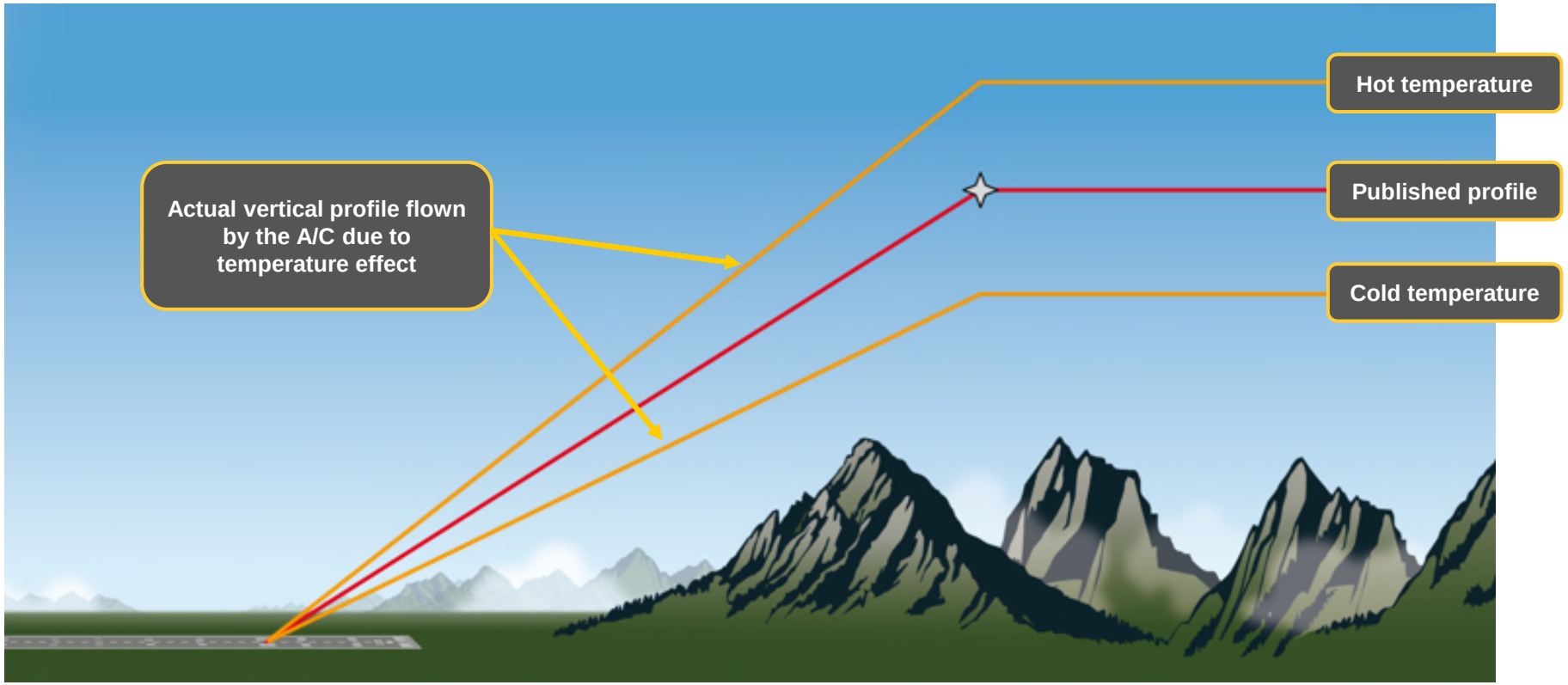
Baro-VNAV



FMS assumes ISA temperature → No temperature compensation

Barometric Vertical Navigation

No temperature compensation

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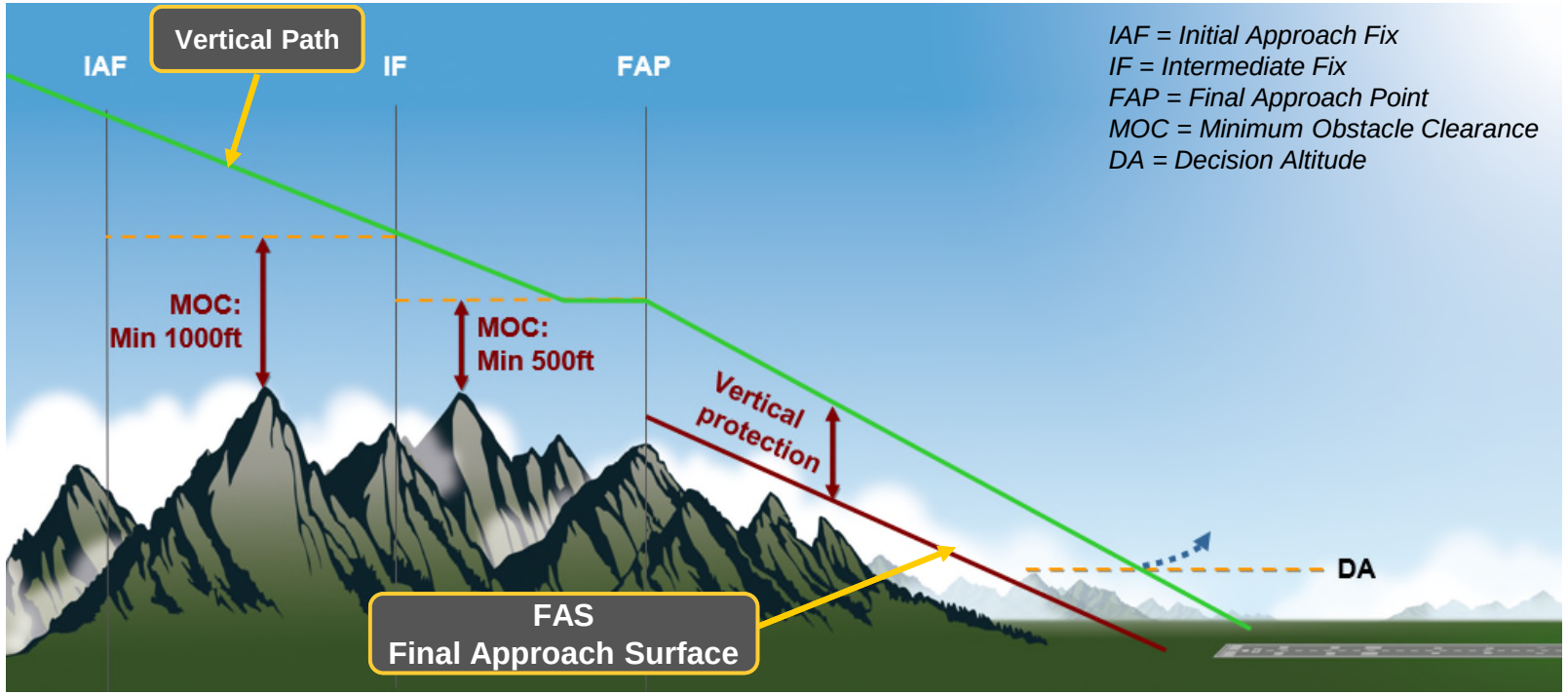
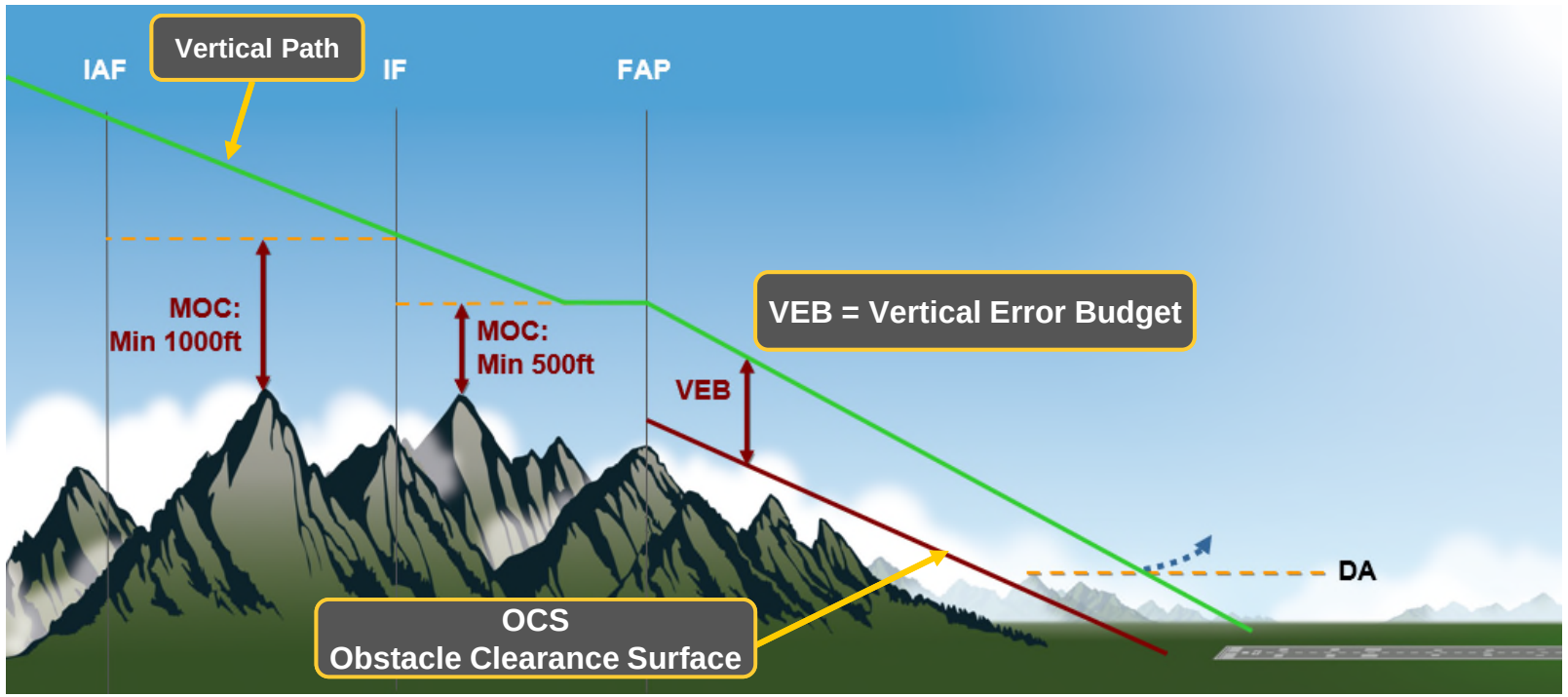
[Airbus Amber]

Vertical protection for RNP

RNP



RNP AR



Similar principles

Different parameters & equations

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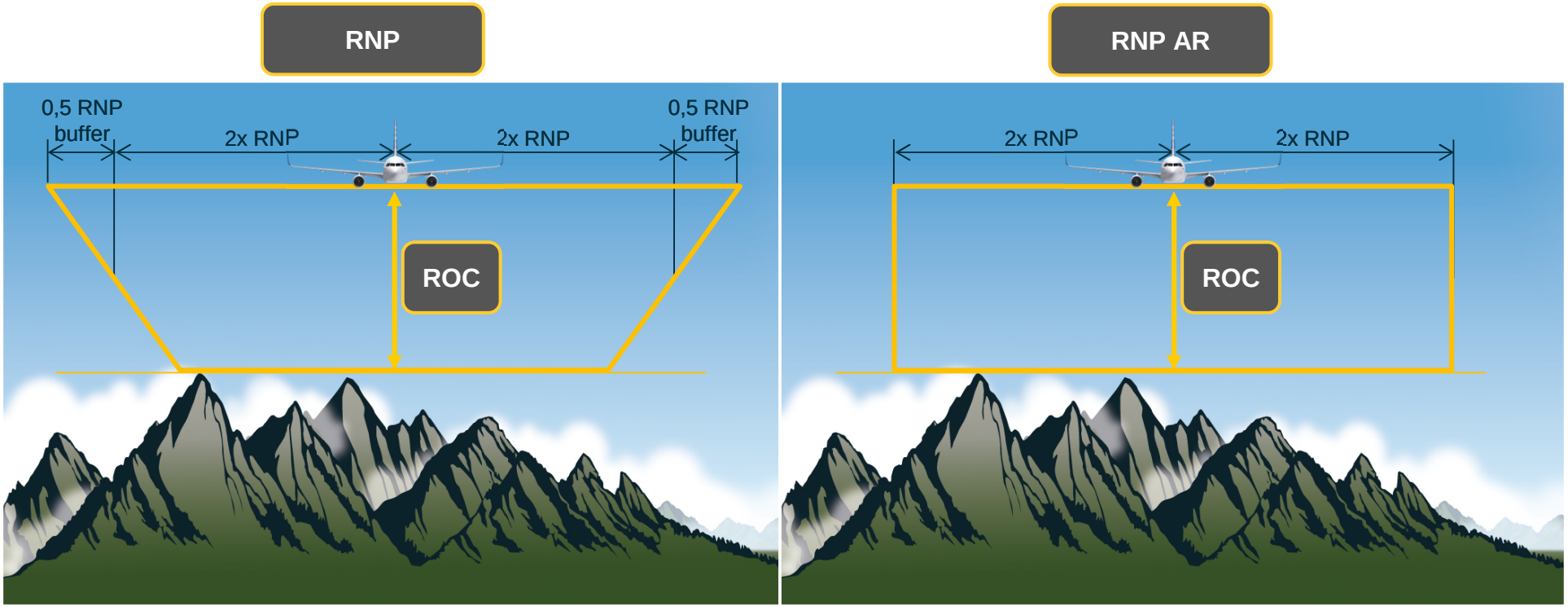
Lateral obstacle clearance corridor

Lateral protection

Lateral protection in addition to the vertical protection



ROC = Required Obstacle Clearance

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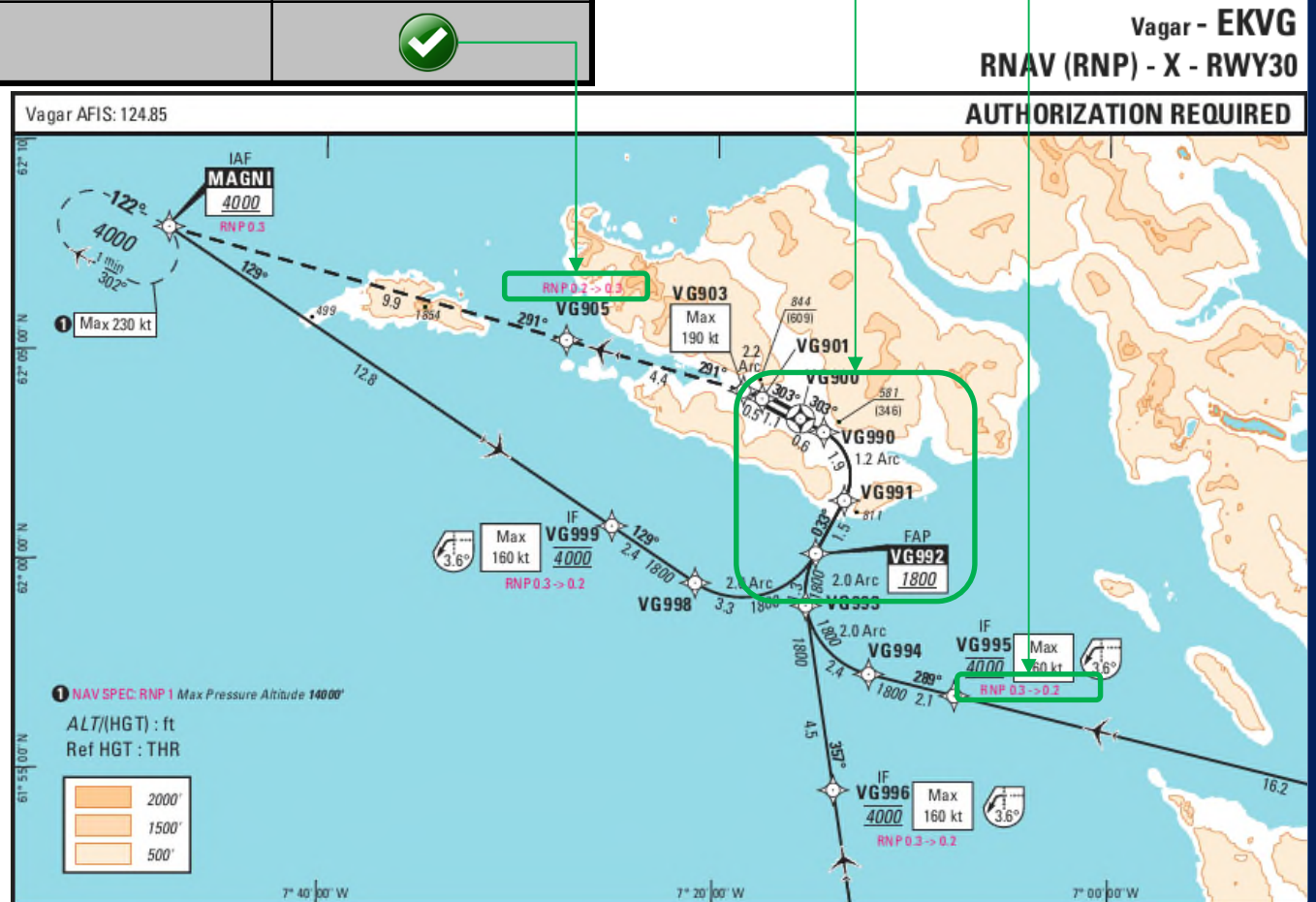
RNP procedures design characteristics

More flexibility in RNP AR procedure design

	RNP OPERATION	RNP AR OPERATION
RNP Value 0.3	✓	✓
RNP Value < 0.3 (down to 0.1)		✓
Straight segment between FAP and RWY	✓	✓
Curve between FAP and RWY		✓
Minima DA / DH could be as low as 250ft	✓	✓
Departure and/or missed approach RNP Value < 1		✓

FAP = Final Approach Point
DA = Decision Altitude
DH = Decision Height



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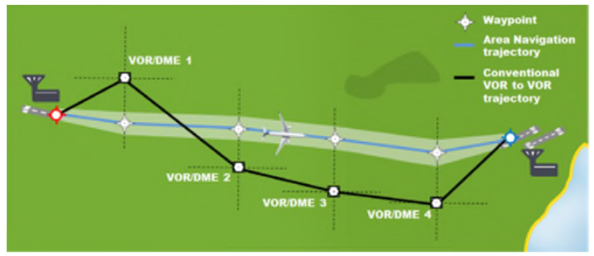
Summary



What is PBN?

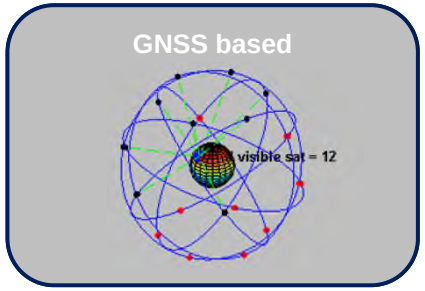
Navigation requirements and specifications,
based on the **accuracy / integrity** of the avionic suite
→ RNAV & RNP

Why PBN?

- **Enhance Safety**
- Improve Accessibility
- Reduce Fuel Burn
  Increase Payload
- Increase Capacity
- Avoid Sensitive Areas

PBN stakeholders, roles & responsibilities
A multiplayer scheme

Zoom on RNP APCH & RNP AR



Baro-VNAV concept
Vertical & lateral protection

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The benefits of PBN: example

RNP AR Approach Queenstown, New Zealand, RWY 05

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Thank you

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