

Infraestructures del Transport Aeri

Area Navigation (RNAV) and Performance Based Navigation (PBN)

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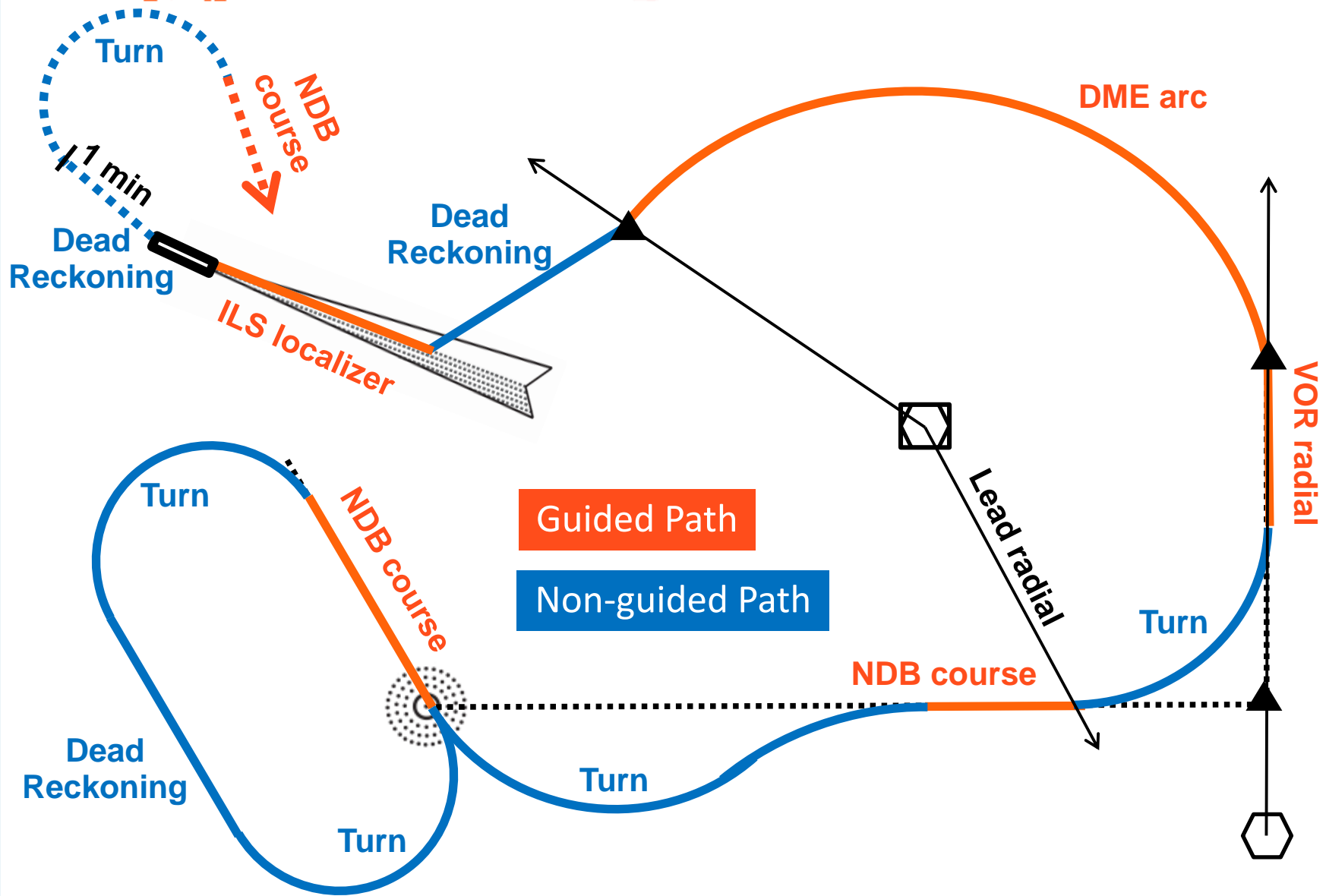
September 2014 – Version 1.0



Escola d'Enginyeria de Telecomunicació
i Aeroespacial de Castelldefels

UNIVERSITAT POLITÈCNICA DE CATALUNYA

Conventional Procedures



RNAV Concept

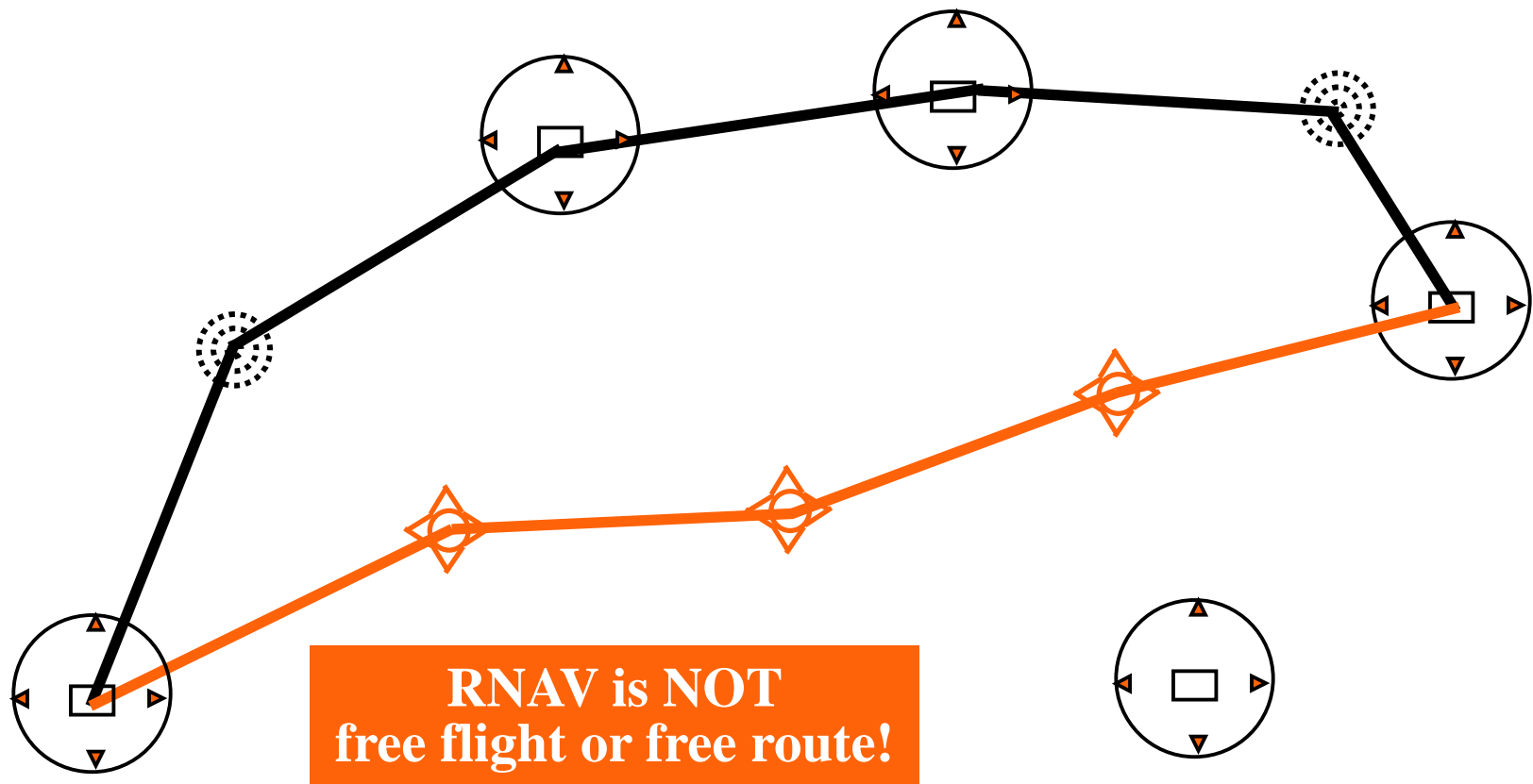
RNAV = Area/Range Navigation

A **method of navigation** which permits aircraft operation on **any desired flight path within the coverage** of station-referenced navigation aids, or a combination of these

A **method of navigation** using flight tracks joining **any two points without** the need for **overflying** specific ground **facilities** (e.g. VOR)

RNAV Concept

RNAV = Area/Range Navigation



The **ANSP** can **publish** ATS routes (or terminal procedures: SIDs, STARs or approaches) requiring a RNAV capable navigation system

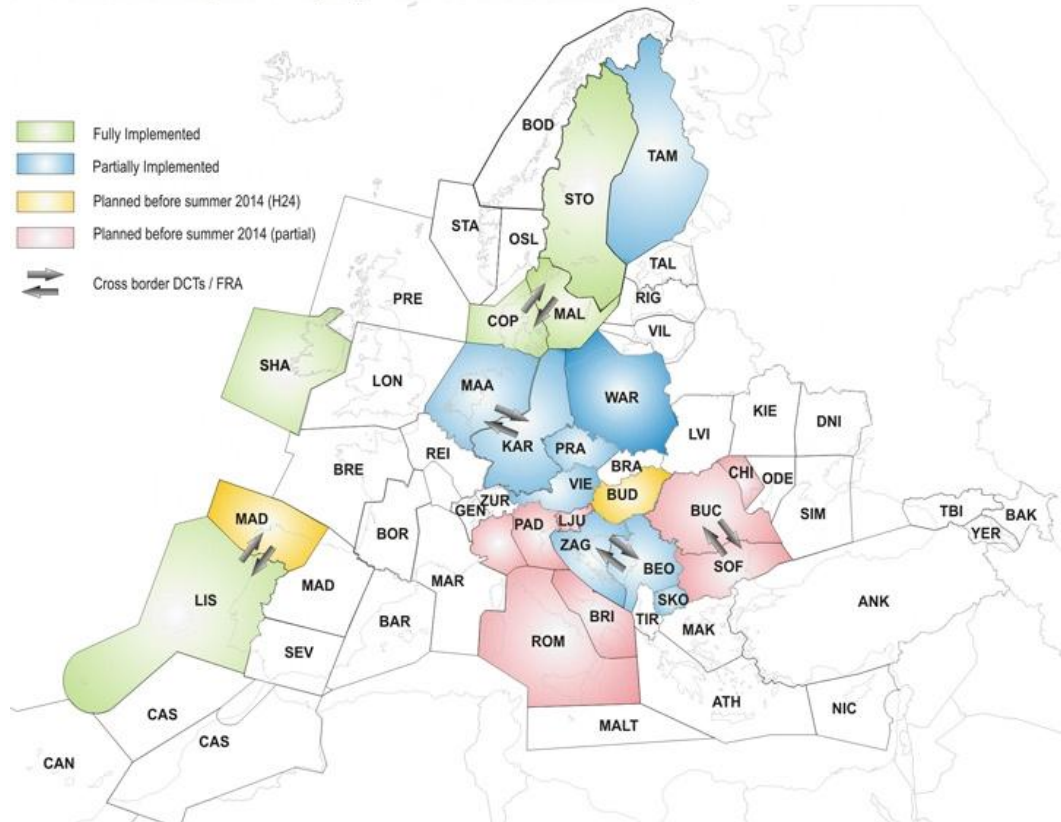


Free route concept

The **operator** can freely **plan** routes between entry and exit points without reference to ATS route network.



Free Route Airspace Deployment before Summer 2014



<http://www.eurocontrol.int/news/free-route-airspace-deployed-europe>

Free flight concept

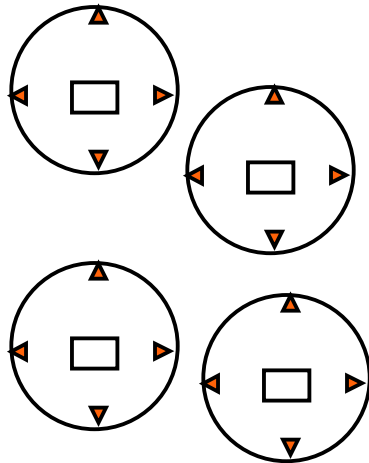
The aircraft crew can freely choose a trajectory within a free flight area and assure self-separation with other aircraft (non centralized air traffic control)



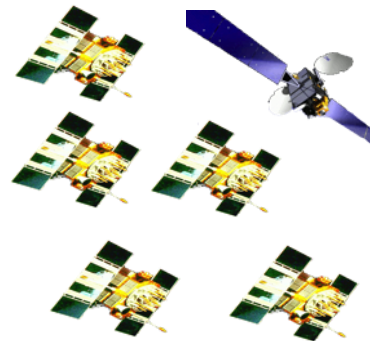
http://www.eurocontrol.int/airspace/public/standard_page/1492_concept.html

RNAV capable system

Aircraft position



DME/DME
VOR/DME



GNSS
(with augmentation system)



INS/IRS
(Loran C)

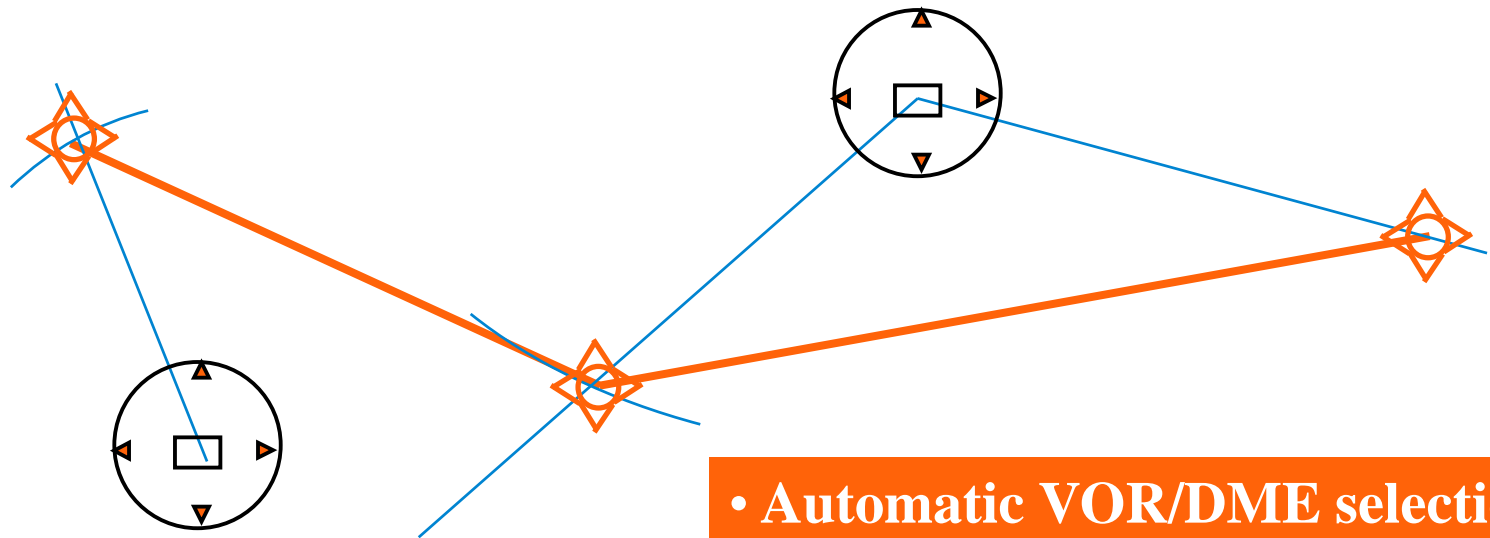


FMS + DB

RNAV positioning

RNAV System

VOR/DME

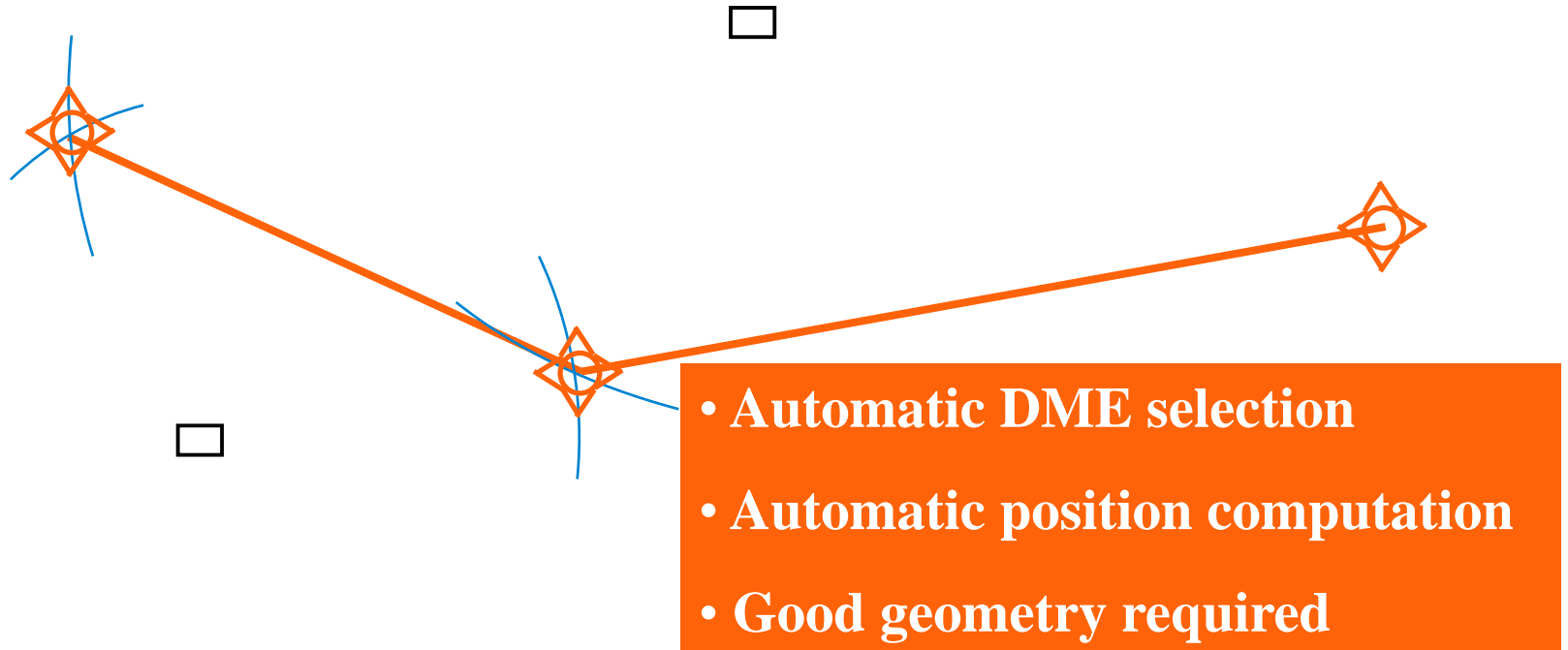


- Automatic VOR/DME selection
- Automatic position computation

RNAV positioning

RNAV System

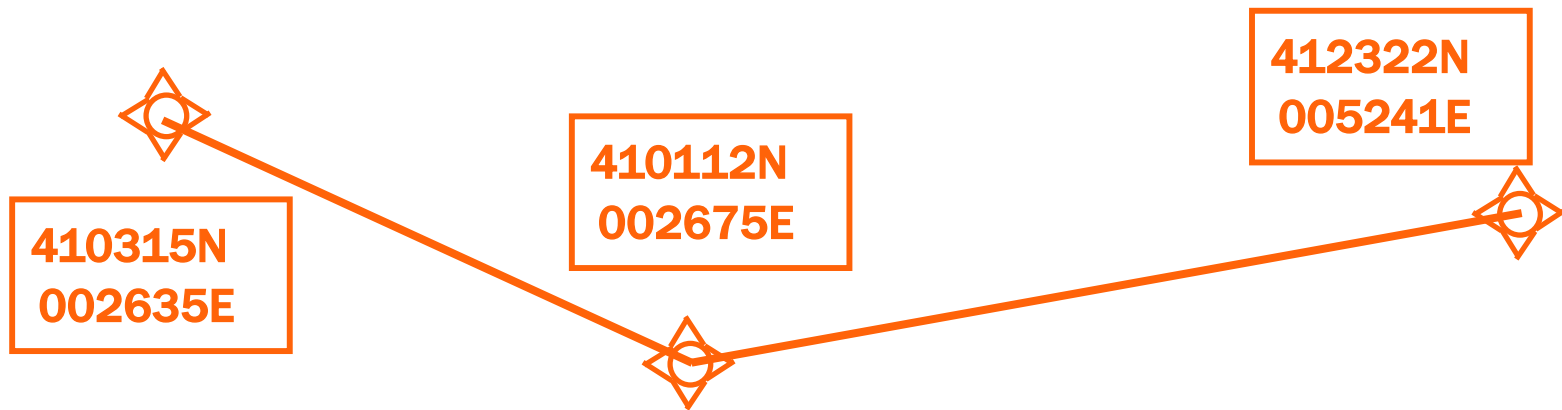
DME/DME



RNAV positioning

RNAV System

GNSS, INS/IRS, (Loran C)

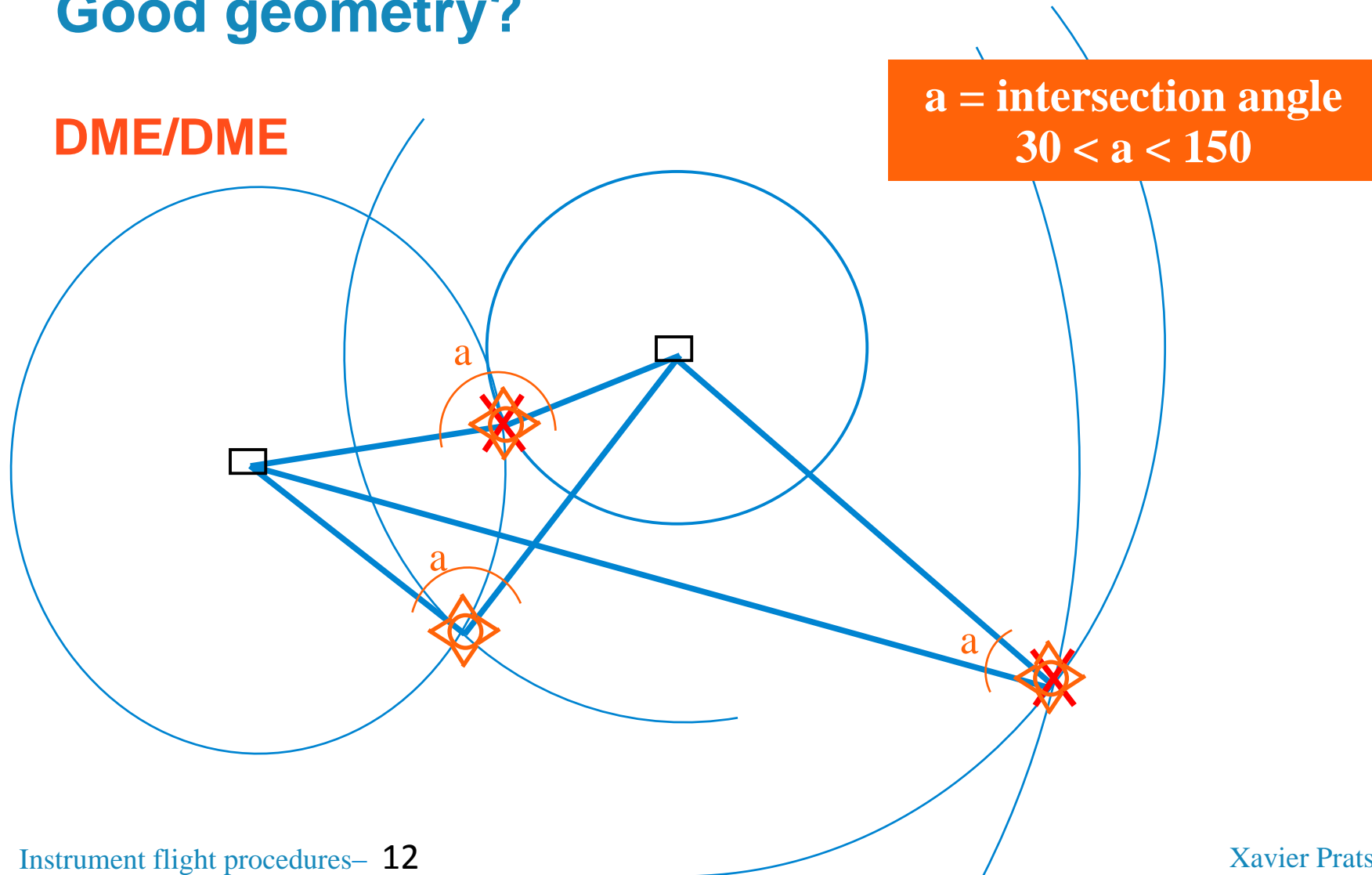


• GNSS: Good geometry required

RNAV positioning

Good geometry?

DME/DME

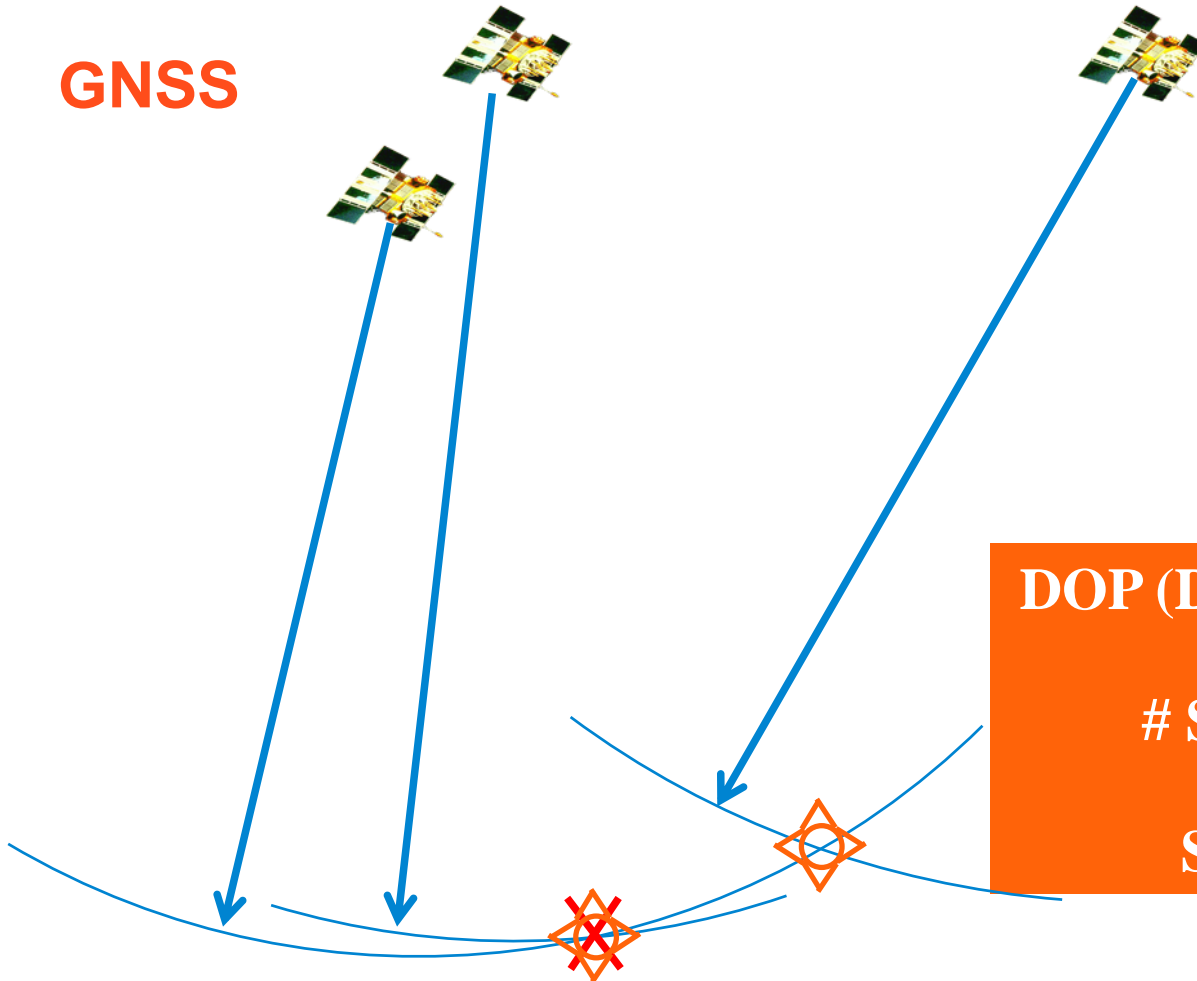


$a = \text{intersection angle}$
 $30 < a < 150$

RNAV positioning

Good geometry?

GNSS



DOP (Dilution of precision):

**# Satellites in view
Geometry
Satellite outage**

RNAV positioning

The RNAV system:

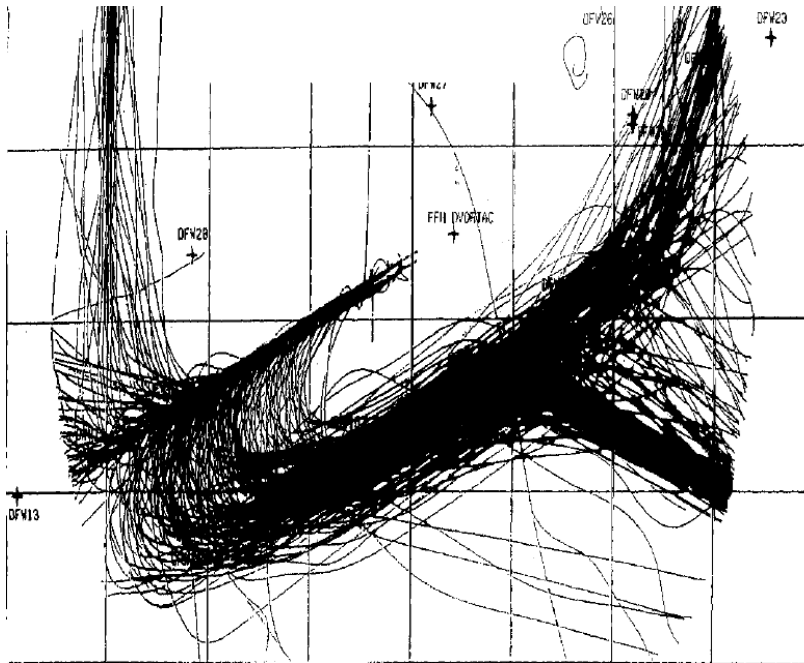
- **Selects the best source of navigation** if more than one is available
- Always flies to the **next waypoint** and provides **guidance data** to the autopilot system
- Provides **guidance data** to the **flight director (FD)** in order to fly **manually**
- Express waypoints in **WGS84 coordinates**

RNAV advantages

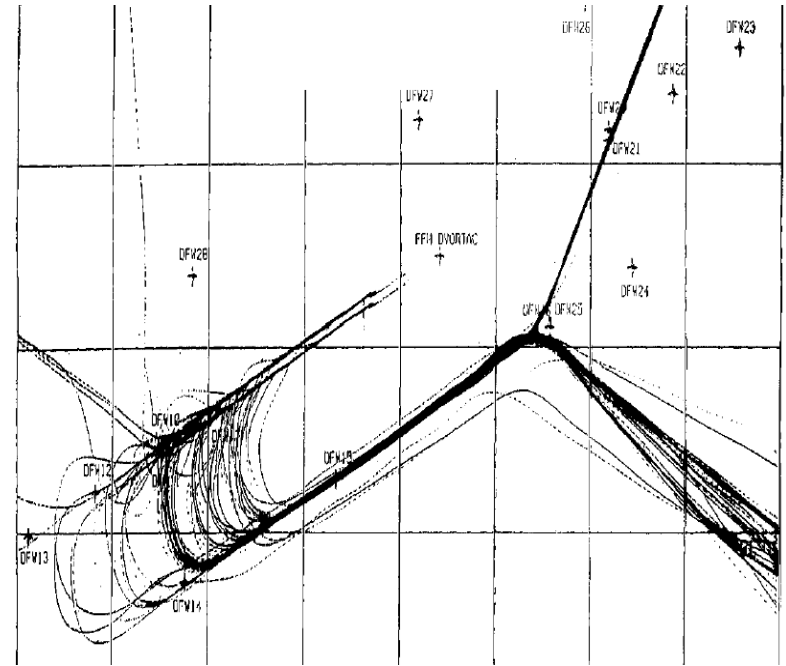
RNAV navigation vantages:

- More direct routes (flight time reduction)
- Less fuel consumption
- Delay reduction (more routes, no bottlenecks)
- Noise reduction
- Less track dispersion

RNAV advantages



**Conventional
Navigation**



**RNAV
Navigation**

Same procedure flown with different nav concepts!!

RNAV procedures

- **Fly-Over** waypoints



- **Fly-by** waypoints



Named waypoints:

IAF

Initial Approach Fix



IF

Intermediate Fix



FAF

Final Approach Fix



MAPt

Missed Approach Point



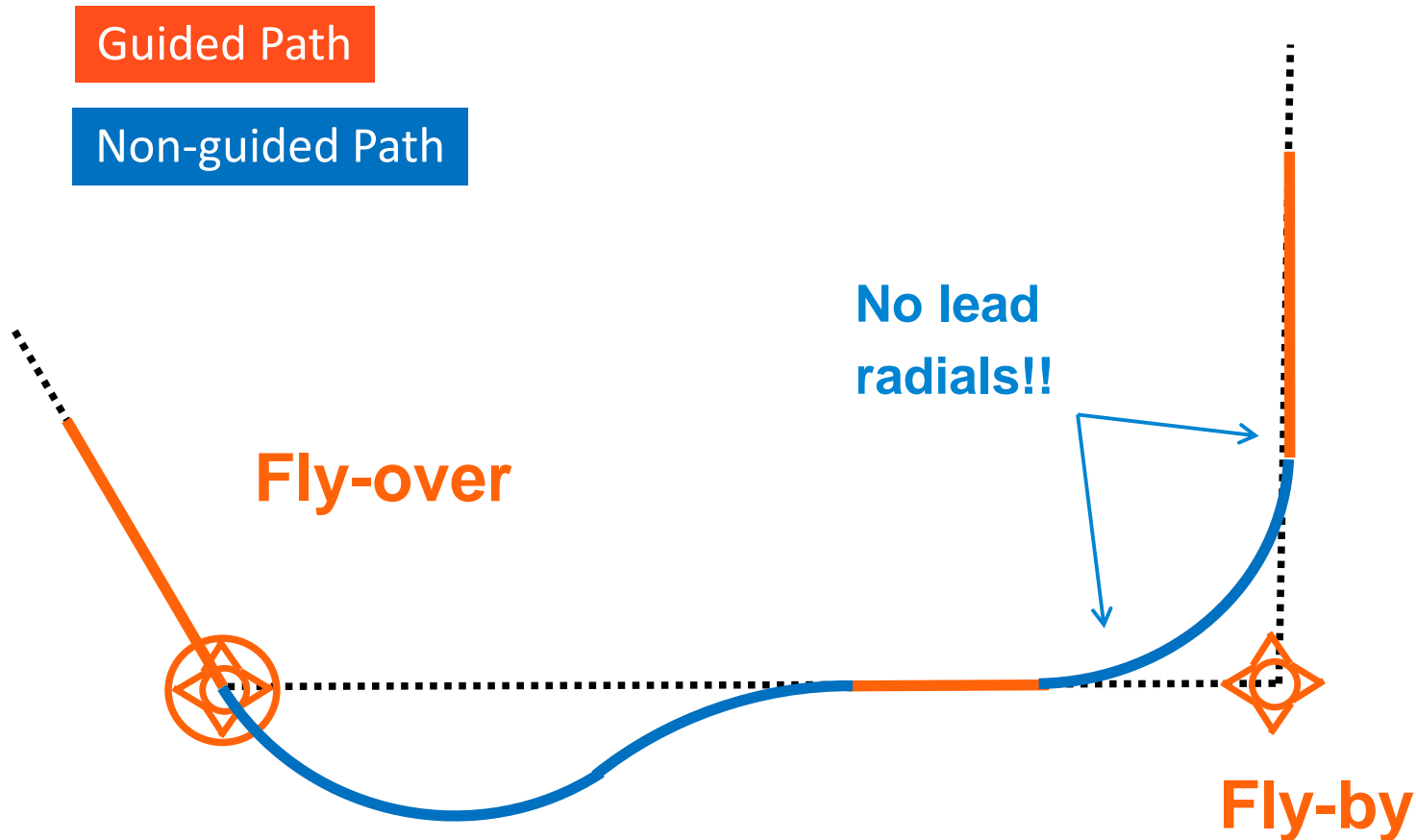
MAHF

Missed Approach Holding Fix



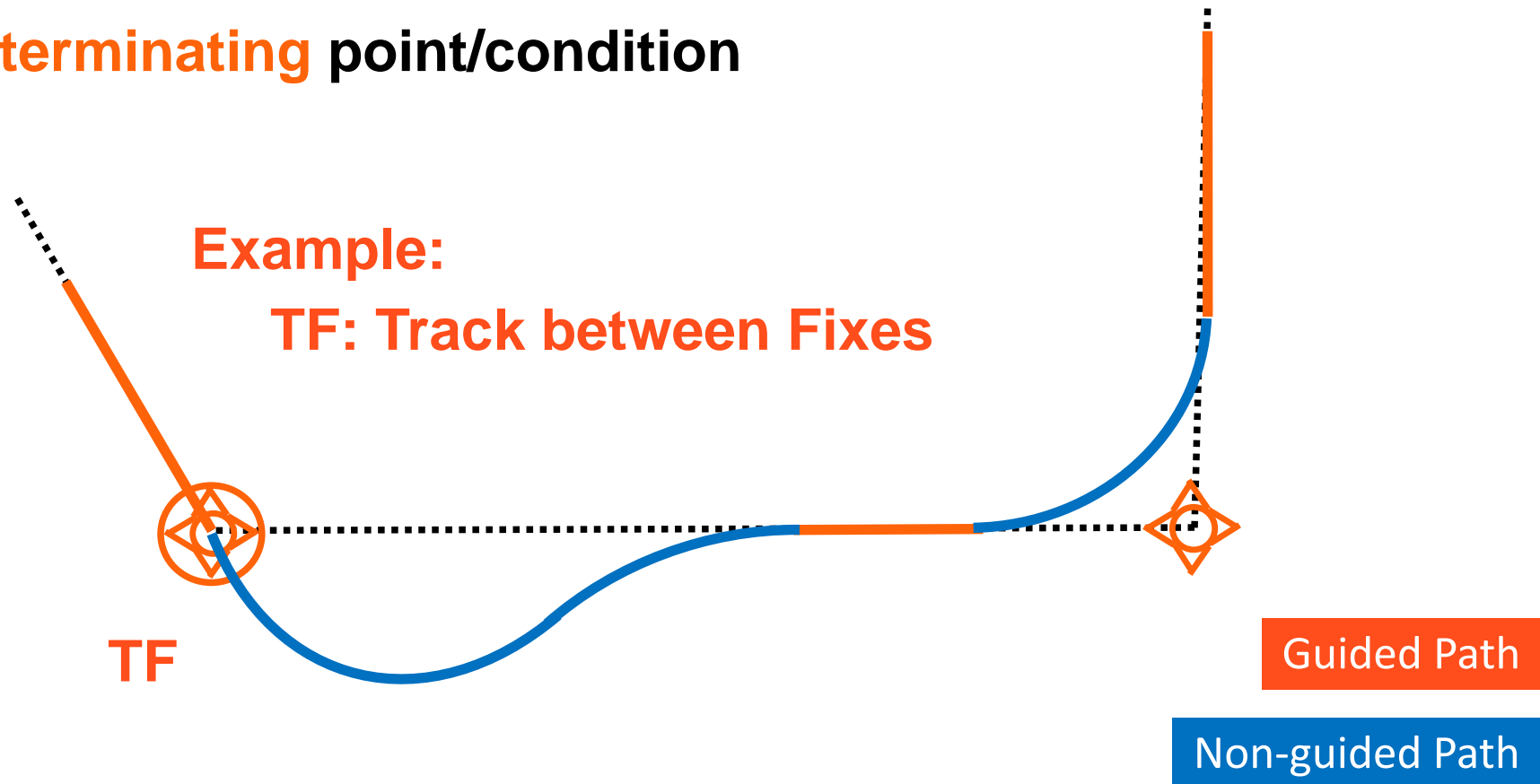
[NOTE: IAWP, IWP, FAWP, MAWP removed in amendment 12, ICAO Doc 8168]

RNAV procedures



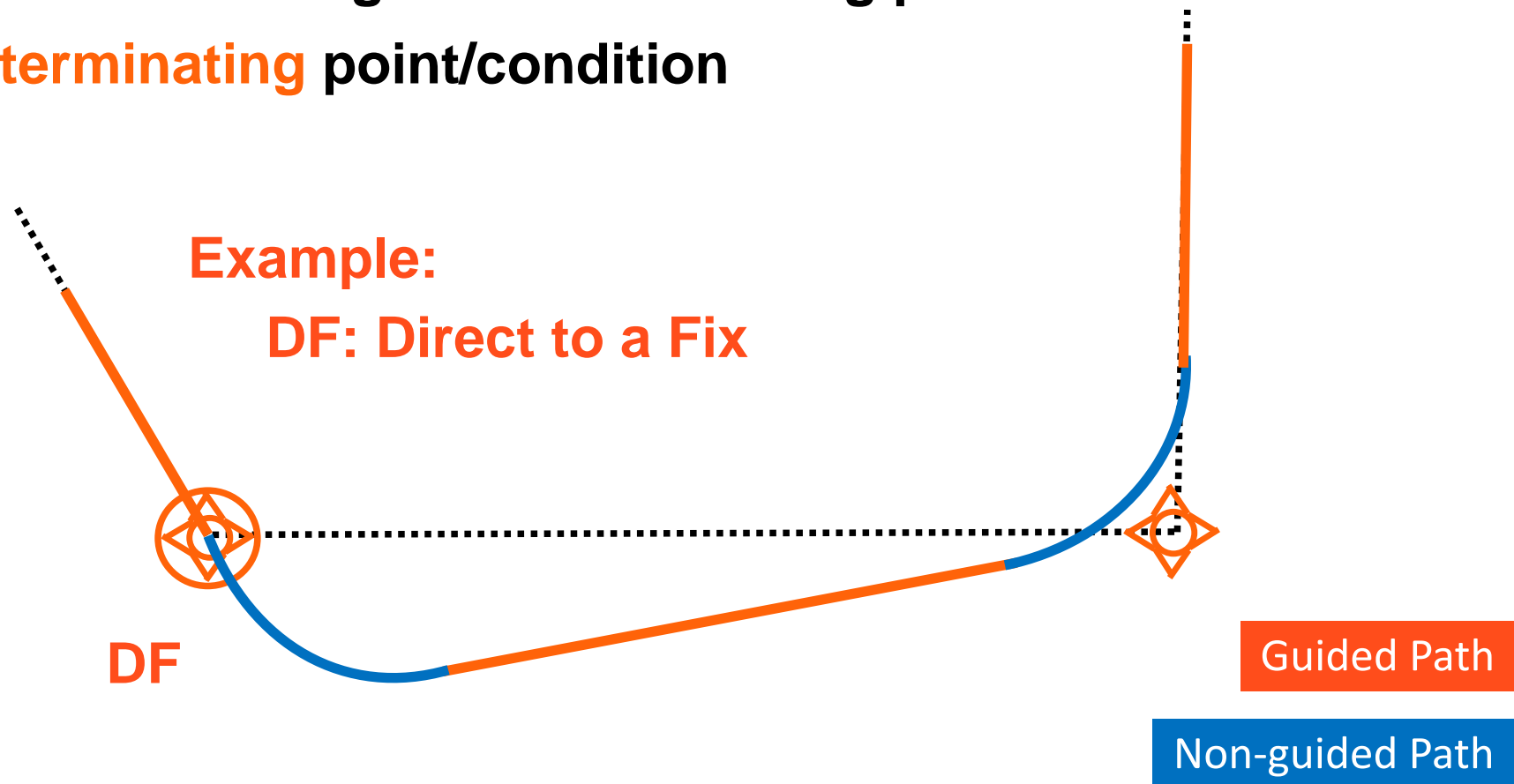
RNAV Path & Terminators

- Transform **procedures** into **coded** flight path
- **How to** navigate **from** a starting point/location to a **terminating** point/condition



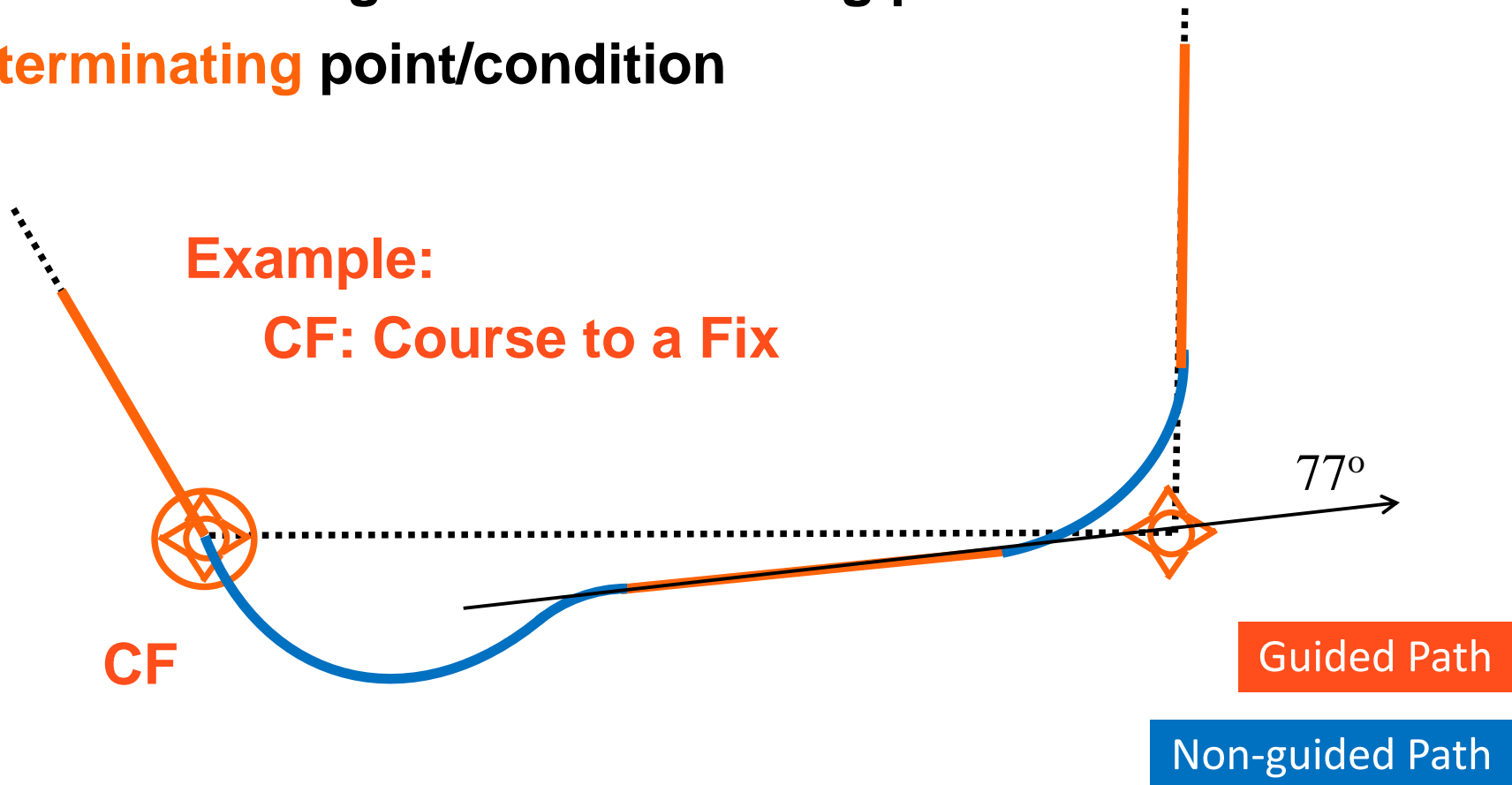
RNAV Path & Terminators

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RNAV Path & Terminators

- Transform **procedures** into **coded** flight path
- **How to** navigate **from** a starting point/location to a **terminating** point/condition



RNAV Path & Terminators

Path & Terminator

- Specification: **ARINC 424** standard
- Set of two alphabetic characters
- Instructions to navigate to a **specific point** or a **terminating condition**
- **23** different path terminators
- Procedures transformed into a **coded flight path**

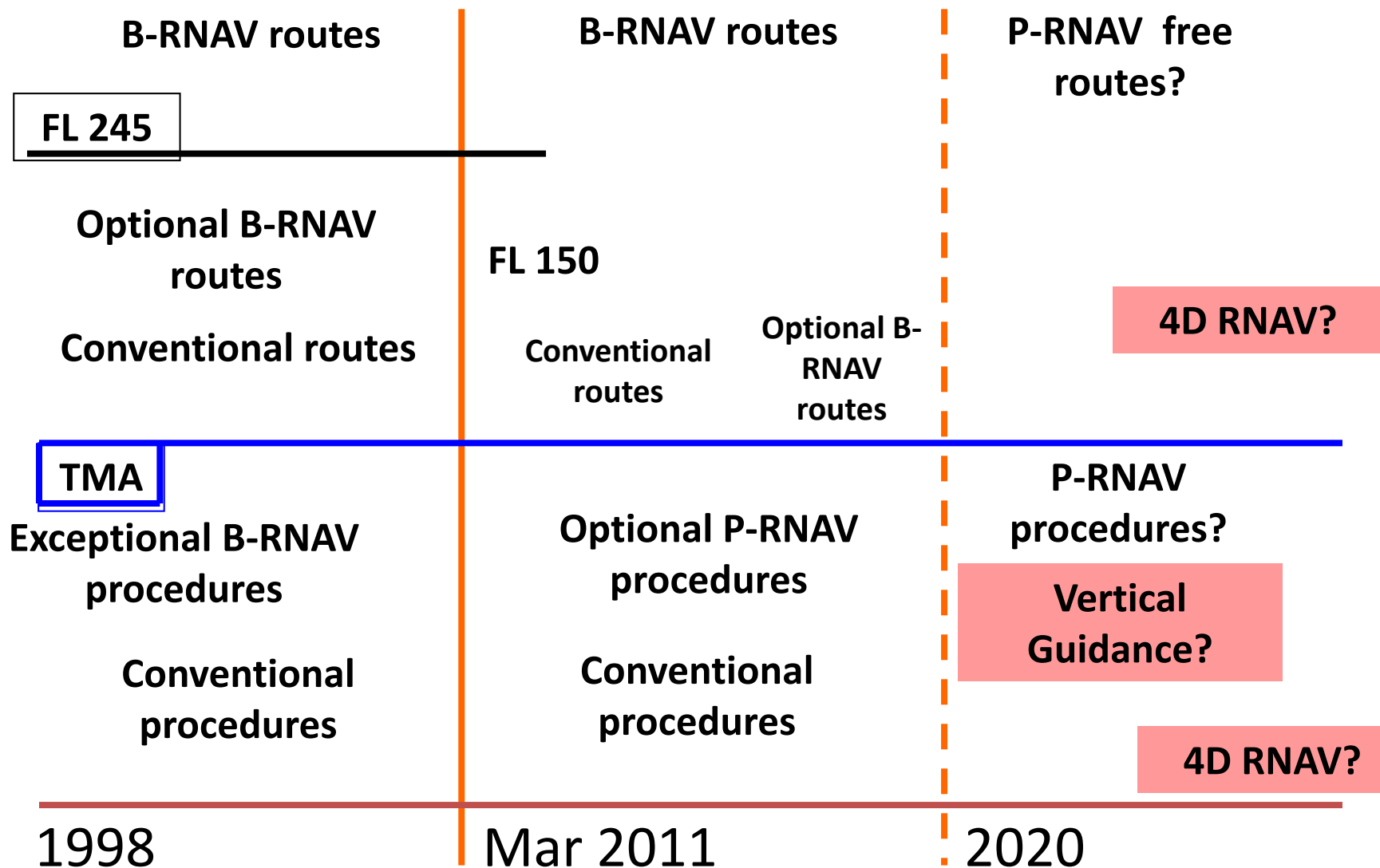
With RNAV the aircraft flies according to the data base, not to the charts!!!

RNAV Path & Terminators

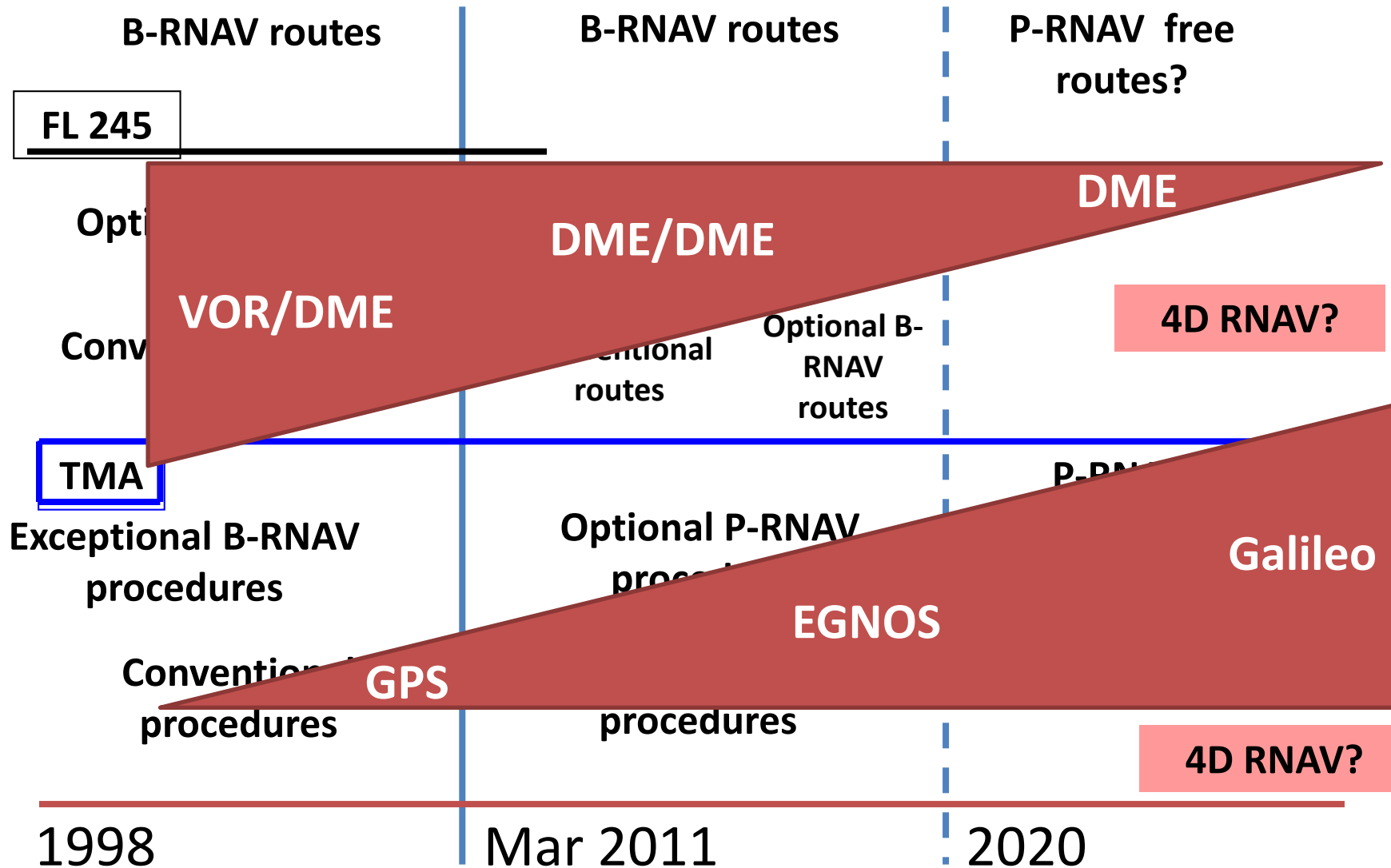
IF	Initial Fix	PI	Procedure turn to intercept next leg
DF	Direct to fix	FC	From fix to a distance
TF	Track between fixes	FD	From fix to a DME arc
RF	Radius to fix	FA	From fix to an altitude
CF	Course to fix	FM	From fix to manual termination
CD	Course to DME arc	AF	DME arc to fix
CR	Course to VOR radial	VD	Heading to DME arc
CA	Course to altitude	VA	Heading to altitude (climb)
CI	Course to intercept next leg	VM	Heading to manual termination (vectors)
HF	Hold/racetrack to fix	VI	Heading to intercept next leg
HA	Hold/racetrack to altitude	VR	Heading to VOR Radial
HM	Hold/racetrack for manual termination (clearance)		

RNAV path terminators. Others used to code conventional procedures

RNAV Implementation (Spain)



RNAV Implementation (Spain)



RNAV approaches

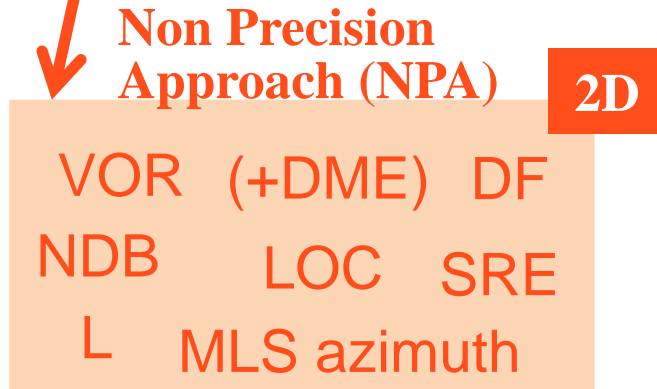
Conventional Radionavigation

Departure
En-Route
Arrival
Approach



VOR: VHF Omnidirectional Range
DME: Distance Measurement Equipment
NDB: Non Directional Beacon
SRE: Secondary Radar Equipment

Final Approach segment

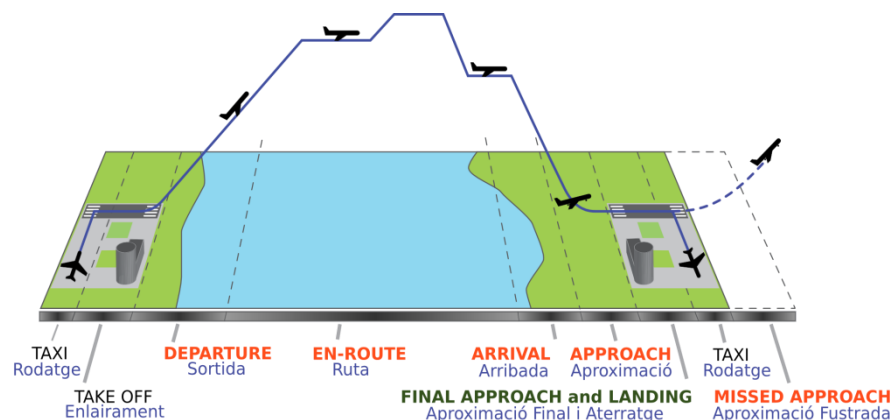


DF: Direction Finder
L: Locator
LOC (or LLZ): Localizer (ILS)
MLS: Microwave Landing System

Precision Approach (PA)



ILS: Instrumental Landing System
PAR: Precision Approach Radar



RNAV approaches

RNAV Radionavigation

Departure
En-Route
Arrival
Approach



2D

LNAV

RNAV: Area Navigation
LNAV: Lateral Navigation
LP: Localizer Performance

Final Approach
segment



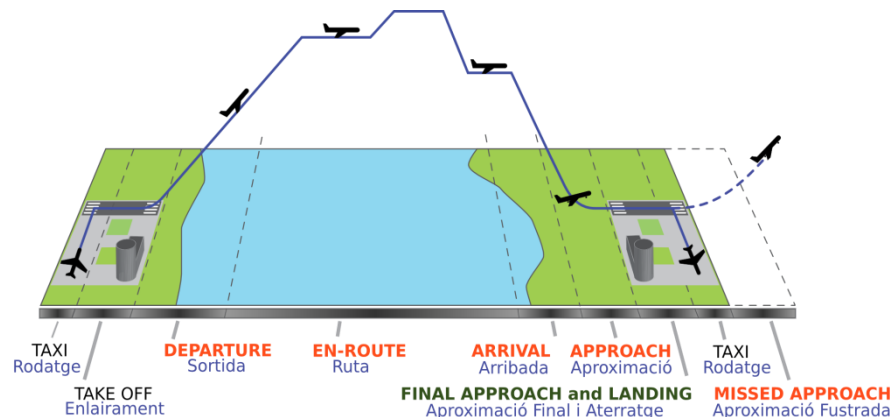
2D

LNAV

LP

Non Precision
Approach (NPA)

GLS: GNSS Landing System
LNAV/VNAV: Lateral Navigation / Vertical Navigation
LPV: Localizer Performance with Vertical guidance



Precision
Approach (PA)

3D

GLS

3D

LNAV/VNAV
LPV

Approach with Vertical
guidance (APV)

RNAV Approaches

RNAV Non Precision Approach (NPA)

- **LNAV (Lateral Navigation):** DME/DME, VOR/DME, INS/IRS, ABAS, GPS...
- **LP (Localizer Performance):** SBAS not able to provide vertical guidance

INS: Inertial Navigation System

IRS: Inertial Reference System

ABAS: Airborne Based Augmentation System

SBAS: Satellite Based Augmentation System

RNAV Approaches

RNAV Approach with Vertical Guidance (APV)

- **LNAV/VNAV (Lateral Navigation/Vertical Navigation) (APV BaroVnav):** SBAS class 2, Baro-VNAV system
- **LPV (Localizer Performance with Vertical guidance) (APV SBAS):** SBAS class 3-4

RNAV Precision Approach (PA)

- **GLS (GNSS Landing System):** GBAS, dual frequency SBAS...

RNAV Approaches

What is the cost of such implementation (APV approaches) for the airport?

- No extra radionavigation aids required at the airport.
- Current ALS (approach landing systems) is enough, no modifications required.

And for the operator?

- GNSS (SBAS) equipment



ICAO resolution 37-11

“Encourages” states to implement PBN such that all approaches have vertical guidance by 2016

RNAV Approaches

Benefits of APV approaches

- **Improved safety and prevention of CFIT (controlled flight into terrain)**
- **More airport accessibility (reduced minima) for those runways without Precision Approaches**
- **Reduction of conventional radionavigation aids**
- **Improves guidance for continuous descent approaches**
- **Due to RNAV lateral routing: more direct routes and therefore more fuel efficient and environmentally friendly procedures**

Performance based navigation (PBN)

In **conventional** navigation and **RNAV**, the procedure design (and execution) depends on the sensor (radionavigation aid)

E.j.: VOR approach, VOR-DME approach, ILS approach,...
RNAV (DME/DME) approach, RNAV (GNSS) approach,...

With the **PBN concept**, the performance and functionalities of the navigation system is specified beforehand

E.j.: B-RNAV, P-RNAV, RNAV-5, RNAV-0.3,...
RNP-2, RNP-1, RNP-0.3,...

B-RNAV: Basic RNAV

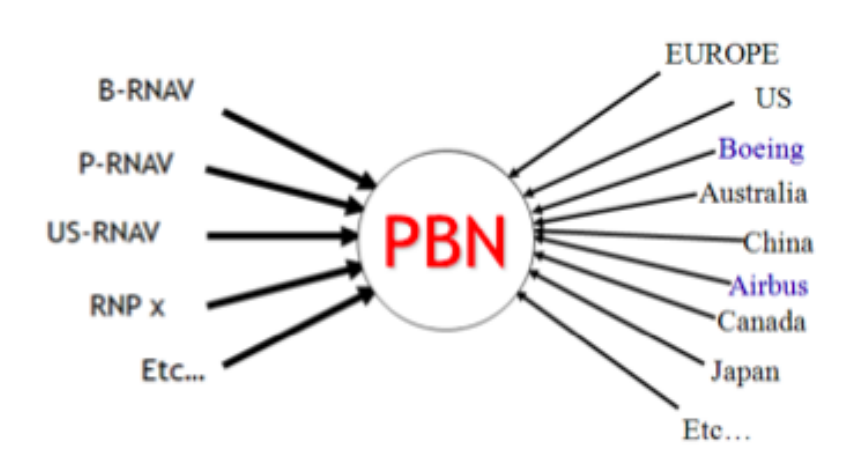
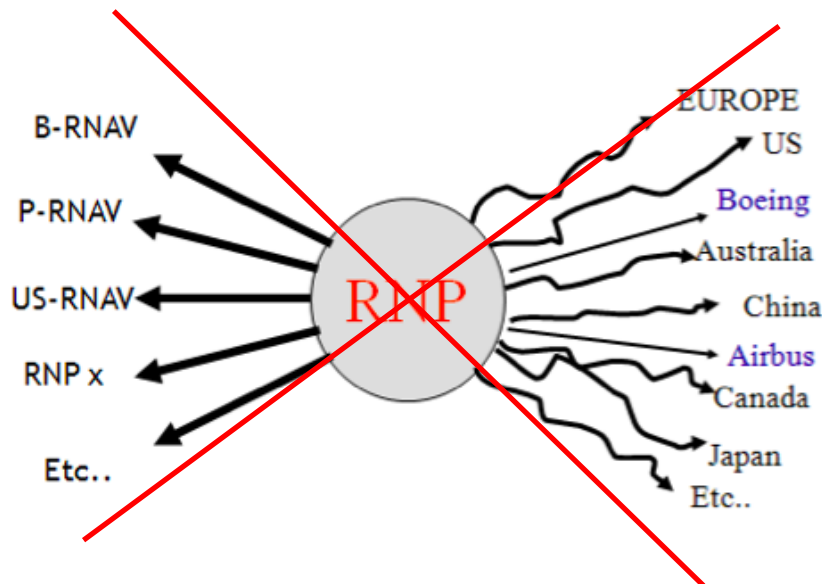
P-RNAV: Precision RNAV

RNP: Required Navigation Performance

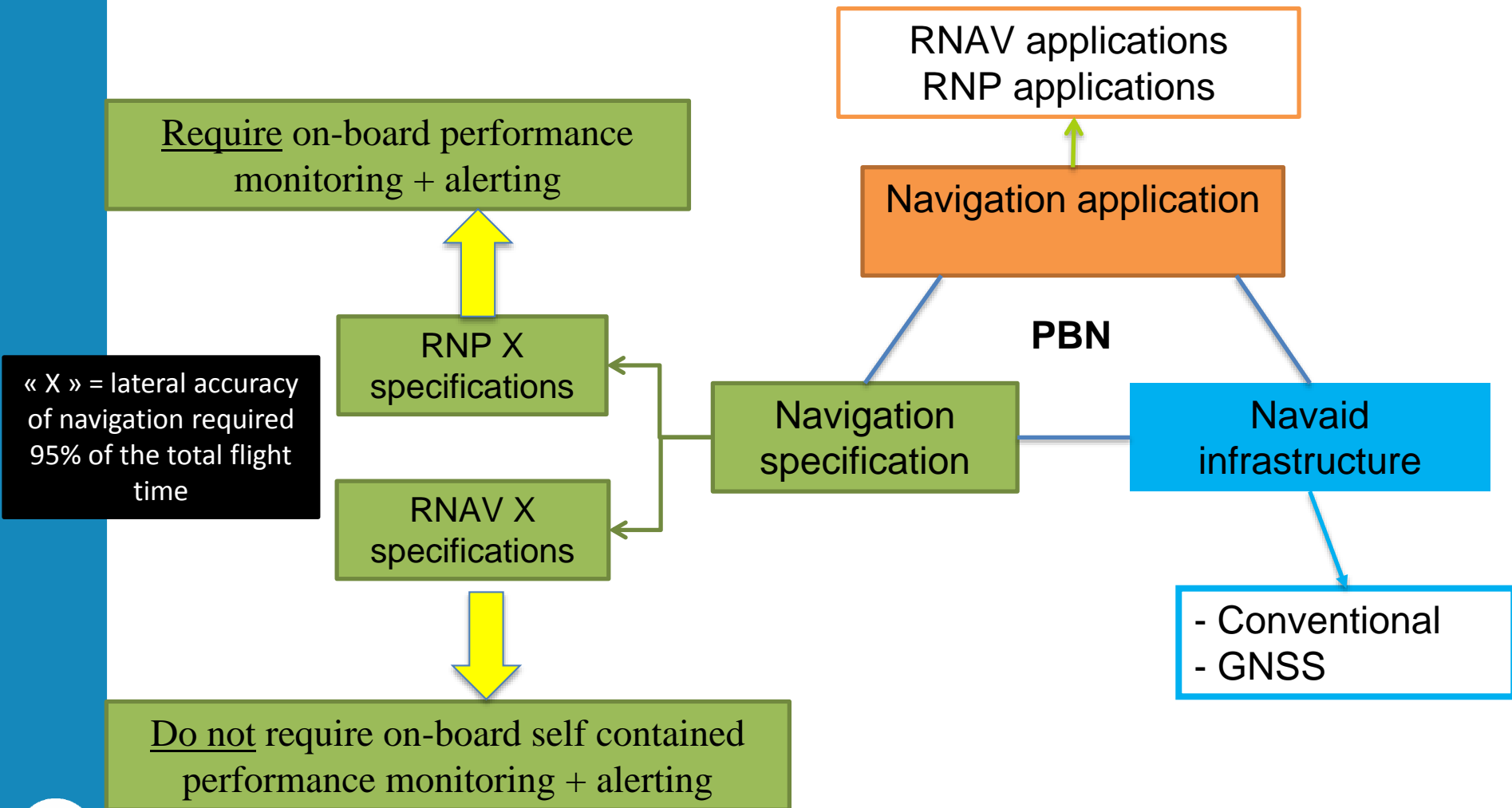
Sensor based → Performance based navigation

Performance based navigation (PBN)

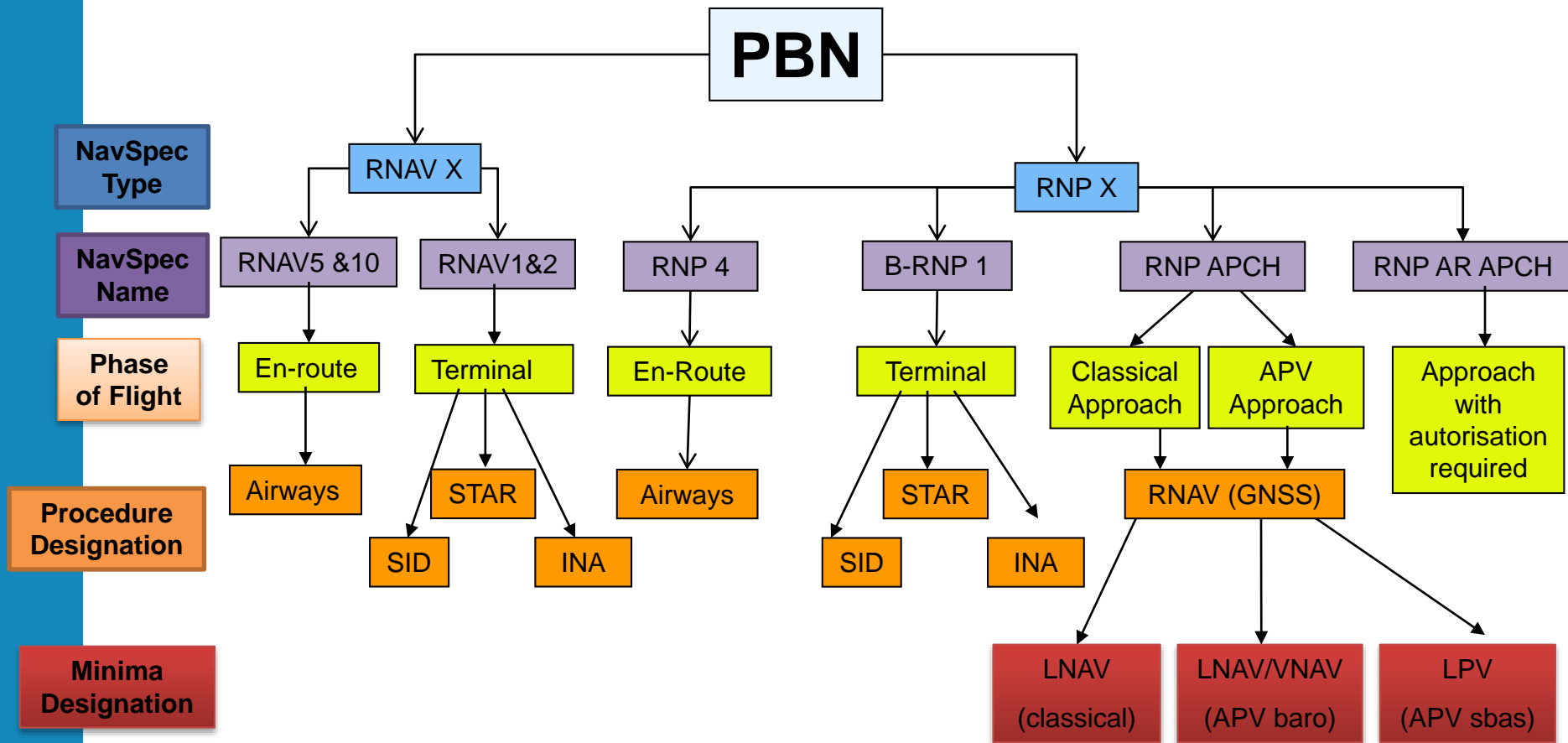
- Performance-based Navigation (PBN) defines performance requirements for aircraft navigating on an ATS route, terminal procedure or in a designated airspace. It is ICAO's effort and objective to redefine the regional differences of various Area Navigation (RNAV) and Required Navigation Performance (RNP) specifications into a globally harmonized set of PBN applications.



Performance Based Navigation

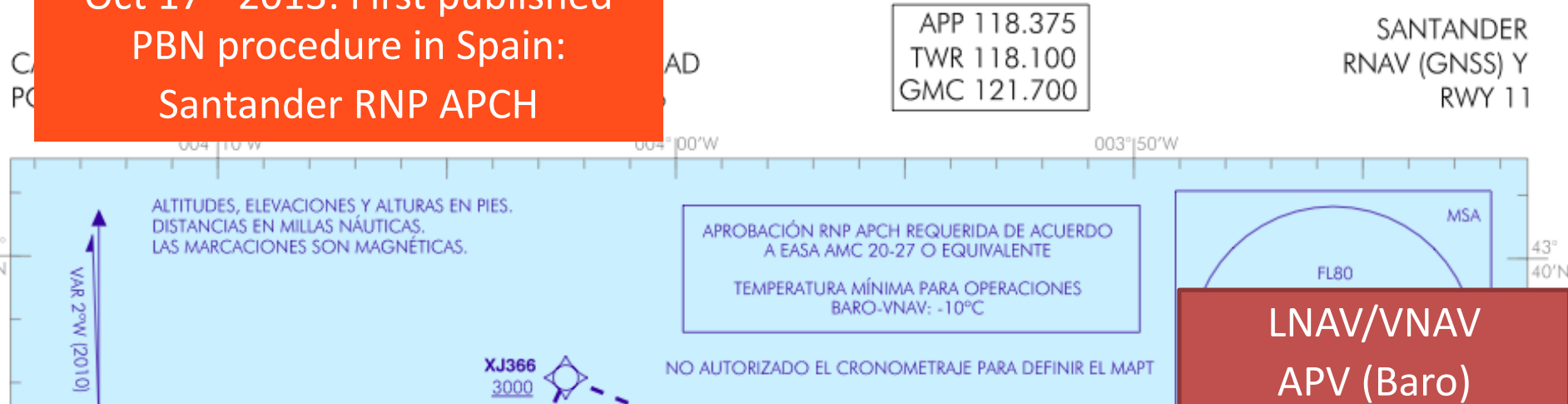


Performance Based Navigation



Performance Based Navigation

Oct 17th 2013: First published
PBN procedure in Spain:
Santander RNP APCH



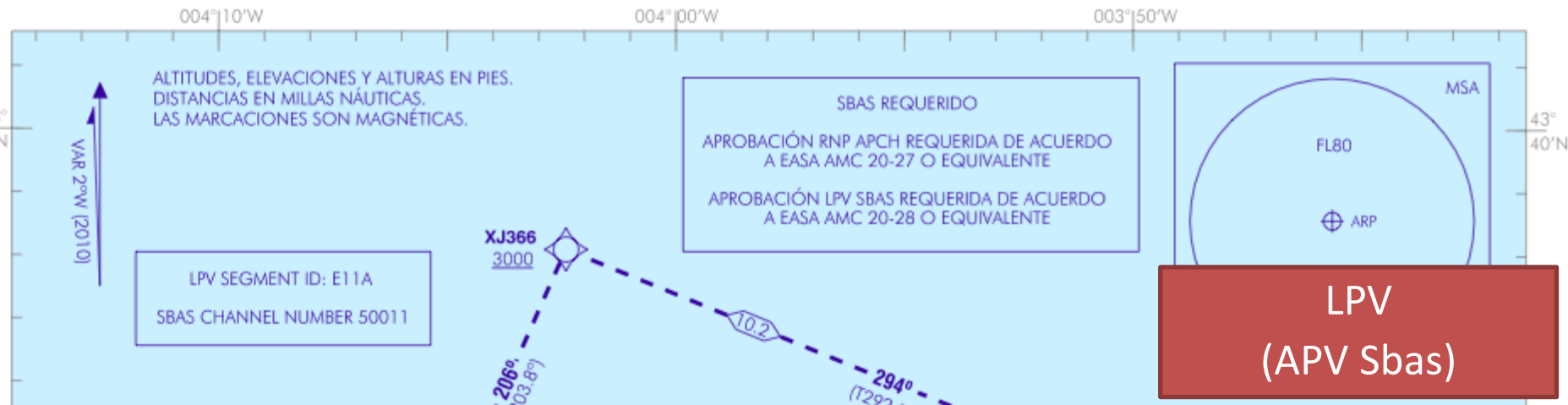
LNAV/VNAV
APV (Baro)

CARTA DE APROXIMACIÓN
POR INSTRUMENTOS-OACI

ELEV AD
16

APP 118.375
TWR 118.100
GMC 121.700

SANTANDER
RNAV (GNSS) Z
RWY 11



LPV
(APV Sbas)

May 2014: GBAS approach in malaga (4th operational GBAS station in the world)



Performance Based Navigation



Required
Navigation
Performance (RNP)

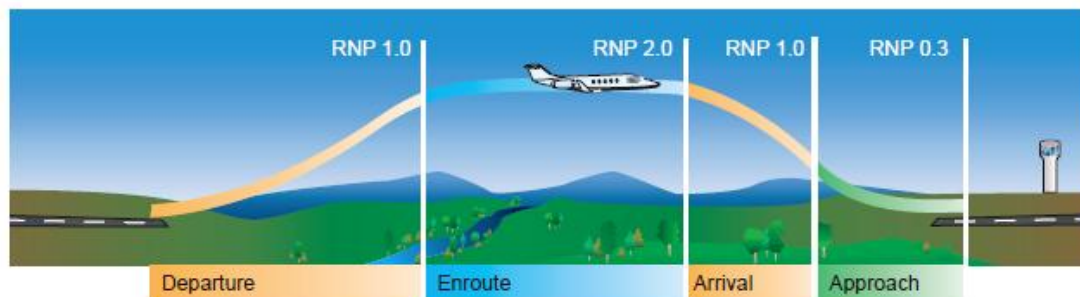


Figure 1-11. Required Navigation Performance.

Performance Based Navigation

Airbus FMS

PREDICTIVE

<GPS

REQUIRED

0.15 NM

ACCUR

LOW

ESTIMATED

0.32 NM

GPS PRIMARY LOST

PREDICTIVE

<GPS

REQUIRED

0.15 NM

ACCUR

HIGH

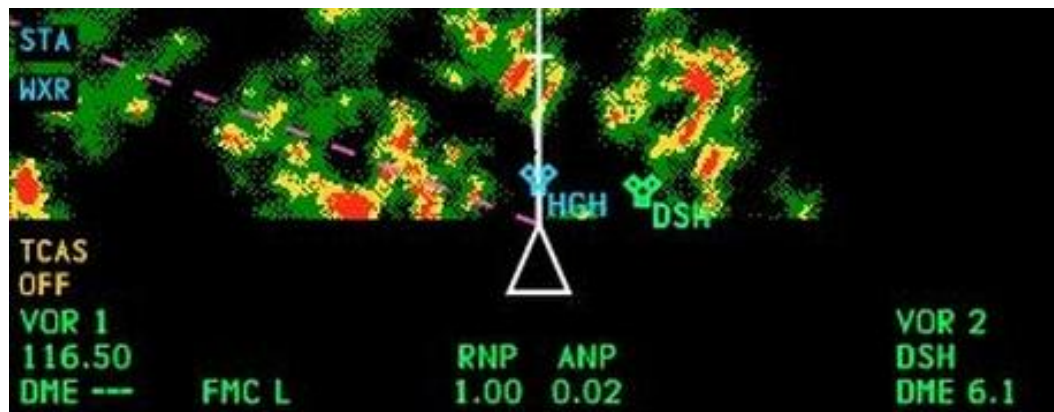
GPS

ESTIMATED

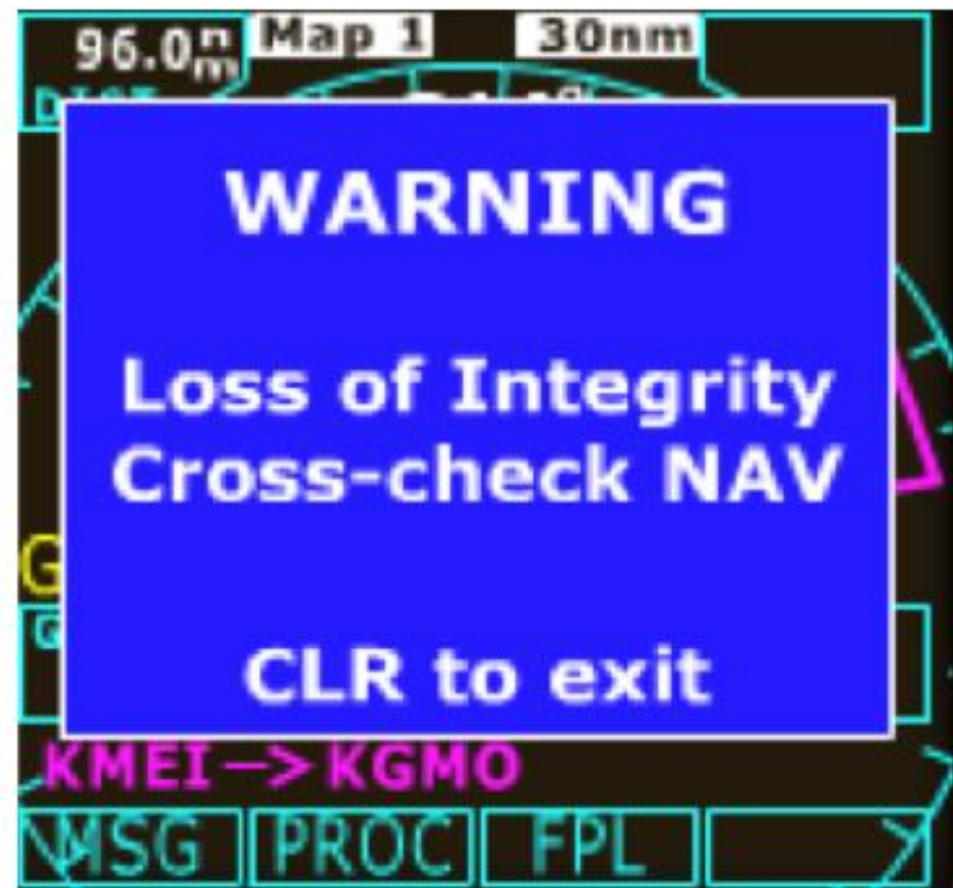
0.08NM

EPE

B737 Navigation Display



Performance Based Navigation



Approach minimas

Approach “Minima-Minima” (ICAO Annex 6)

Precision Approaches (PA)

	Decision Height (DH)	Visibility
CAT I:	DH \geq 200 ft	Visibility \geq 800m or RVR \geq 550m
CAT II*:	200 ft \geq DH \geq 100 ft	RVR \geq 350 m
CAT III-A*:	100 ft \geq DH \geq 0 ft	RVR \geq 200 m
CAT III-B*:	50 ft \geq DH \geq 0 ft	RVR \geq 50 m
CAT III-C*:	No DH limitation	No RVR limitation

Approaches with vertical guidance (APV)

APV I:	DH \geq 250 ft	RVR \geq 600m
APV II:	To be defined	To be defined

* Subject to operations and airworthiness evaluation
(aircraft equipment, crew training, maintenance
procedures, airport infrastructure, ATC training...)

RVR: Runway Visual Range



Thank you!!

Gràcies!!