Nav specifications

07-10 April 2015

PBN Concept Review

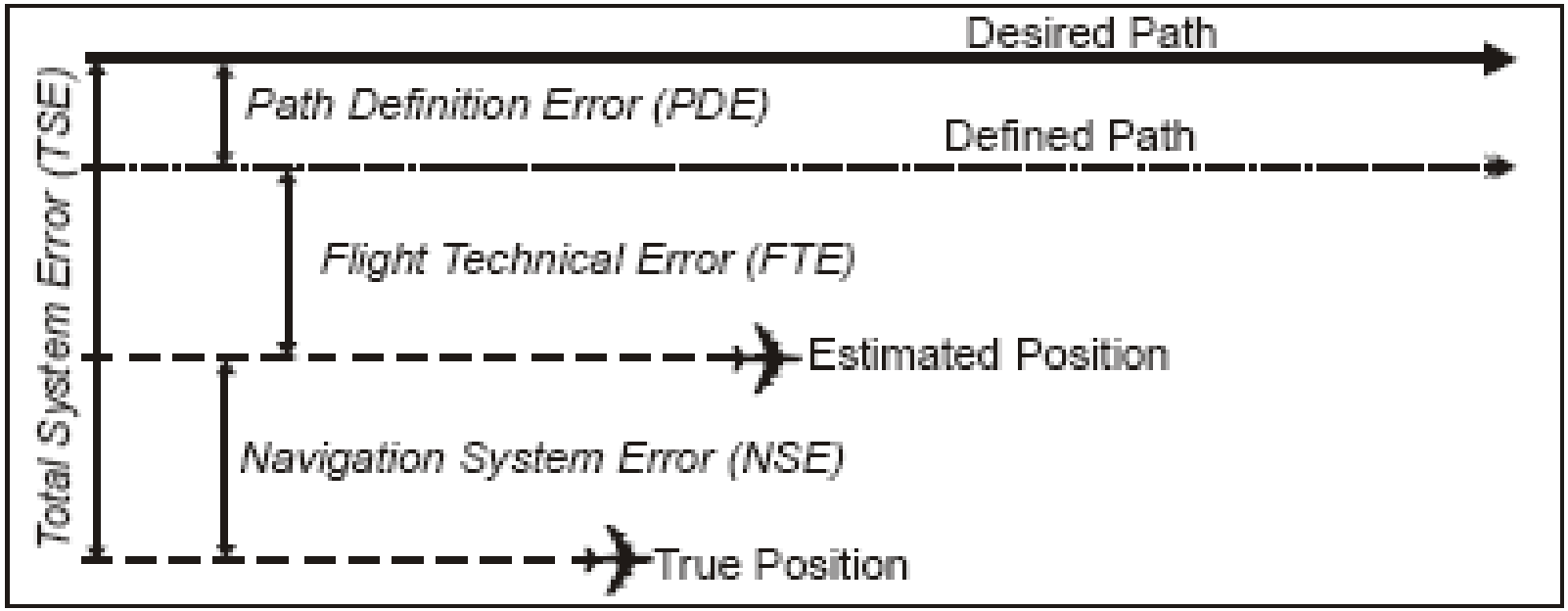
- **Requirements placed on the RNAV system**
  - Performance required for accuracy, integrity, continuity and availability
  - Functionalities necessary to achieve required performance
  - Navigation sensors to achieve required performance
  - Flight crew procedures to achieve required performance

- **RNP specifications require on-board performance monitoring and alerting…RNAV specifications do not**

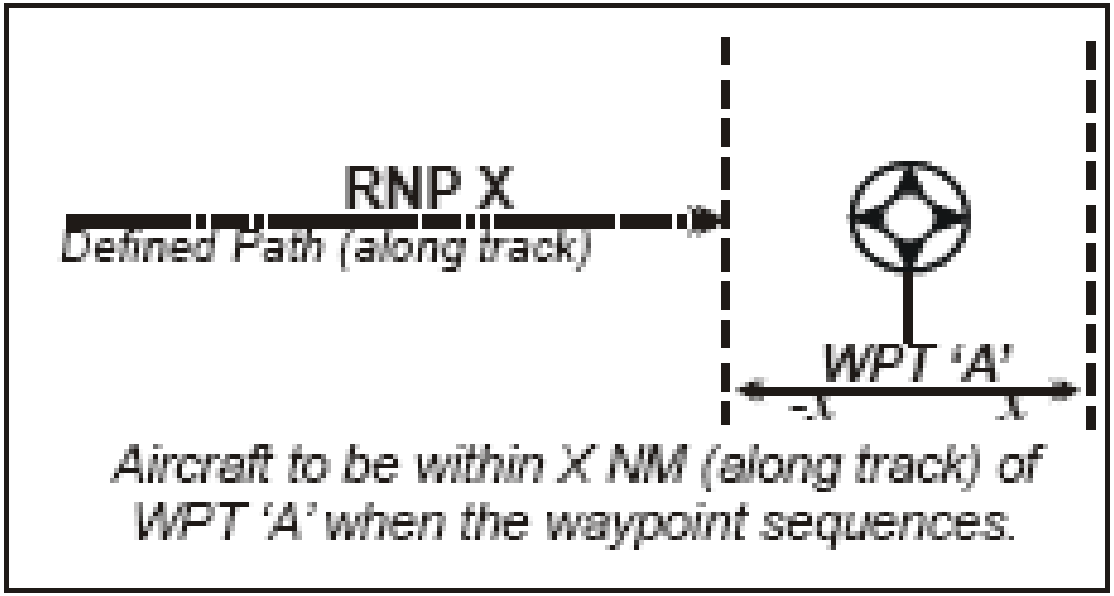
Navigation Performance

- **System performance error components**
  - Lateral navigation errors
  - Longitudinal navigation errors
- **On-board performance monitoring and alerting**
  - Role
  - Application

- **Lateral navigation errors (95%)**
  - Characterized by the Total System Error: TSE
  - TSE is the Root Sum Square (RSS) of 3 errors: PDE, NSE and FTE



- **Longitudinal navigation errors (95%)**
  - The TSE is characterized by the along-track navigation errors (NSE)
  - No FTE in longitudinal dimension
  - No current navigation specifications require 4-D control (time)



Role of On-board Performance Monitoring and Alerting

- **"On-board" means the performance monitoring and alerting is on-board the aircraft**
- **"Monitoring" relates to NSE and FTE**
  - PDE is constrained through database integrity and functional requirements on the defined path
  - "Monitoring" refers to the monitoring of the aircraft's performance; ability to determine positioning error (NSE) and/or to follow the desired path (PDE)
- **"Alerting" is related to monitoring**
  - Flight crew alerted if navigation system not performing to requirement

Application of On-board Performance Monitoring and Alerting

- **A performance monitoring function**
  - Aircraft (or aircraft and pilot in combination)
  - Required to monitor TSE
  - Provides an alert if :
    - TSE requirement is not met

    or if
    - probability that TSE exceeds 2x accuracy value is larger than 10^{-5}
- **Net effect of RNP navigation specifications is to bound TSE distribution**
  - PDE negligible (navigation data base integrity process)
  - FTE is known (manual flight or coupled flight)
  - NSE dynamically varies (propagation, geometry..)

Application of On-board Performance Monitoring and Alerting

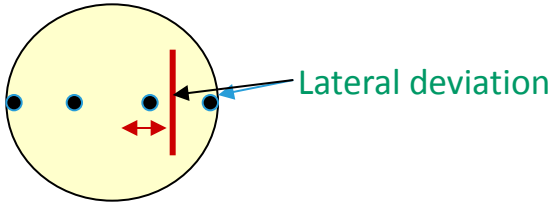
- **RNP navigation specifications provide assurance that TSE is suitable for the operation**
- **High confidence on aircraft position**
  - TSE remains ≤ required accuracy for 95% of flight time

    and
  - Probability TSE for each aircraft exceeds specified TSE (2xRNP) without annunciation is < 10^{-5}
- **Performance monitoring is not error monitoring**
  - Alert if detection of an error position or if it is not possible to determine if the position is accurate
    - An alert doesn't mean that the actual position is wrong

NSE Monitoring and Alerting

- **Alerting Threshold: (1x accuracy) Nm**
- **Pb missed alerting: 10-5/Fl Hr**

FTE Monitoring and Alerting



- **Crew procedure based on display scaling**
- **Effective threshold: ½ full scale deflection**
- **Pb missed alerting: not quantified. Crew procedure.**

PDE Monitoring and Alerting

- **Based on Data quality process**
  - LOA or equivalent
  - Gross error check: Crew procedure

TSE Monitoring and Alerting

All error components monitored or controlled

Application of On-board Performance Monitoring and Alerting

- **Safety assessment**
  - Performance monitoring and alerting required for RNP navigation specifications (RNP 4, Basic-RNP 1 and RNP APCH) does not obviate need for safety assessments
  - Cannot assume appropriate route spacing is 4xRNP
  - Navigation database errors not covered by nav specs
- **RNP AR APCH specificities**
  - Additional requirements to more tightly control each error source
  - Aircraft requirements and/or crew procedures

PBN Manual includes airworthiness, operational and training guidance

NAVIGATION SPECIFICATION	FLIGHT PHASE							
				APPROACH				
	En Route Oceanic / Remote	En Route Continental	ARR	Initial	Intermed	Final	Missed	DEP
RNAV 10 (RNP 10)	10							
RNAV 5		5	5					
RNAV 2		2	2					2
RNAV 1		1	1	1	1		1	1
RNP 2	2	2						
RNP 4	4							
RNP 1			1	1	1		1	1
A-RNP	2*	2 or 1	1	1	1	0.3	1	1
RNP APCH				1	1	0.3	1	
RNP AR APCH				1 - 0.1	1 - 0.1	0.3 - 0.1	1 - 0.1	
RNP 0.3		0.3	0.3	0.3	0.3		0.3	0.3

Use and Scope of Navigation Specifications

- **ICAO navigation specifications do not address all airspace requirements (e.g., comm, surv) necessary for operation in a particular airspace, route or area**
  - These will be listed in the AIP and ICAO Regional Supplementary Procedures
  - Incumbent upon States to undertake a safety assessment in accordance with provisions outlined in Annex 11 and PANS-ATM, Chapter 2
- **ICAO PBN Manual provides a standardized set of criteria, but is not a stand-alone certification document**

Navigation Specifications and the Approval Process

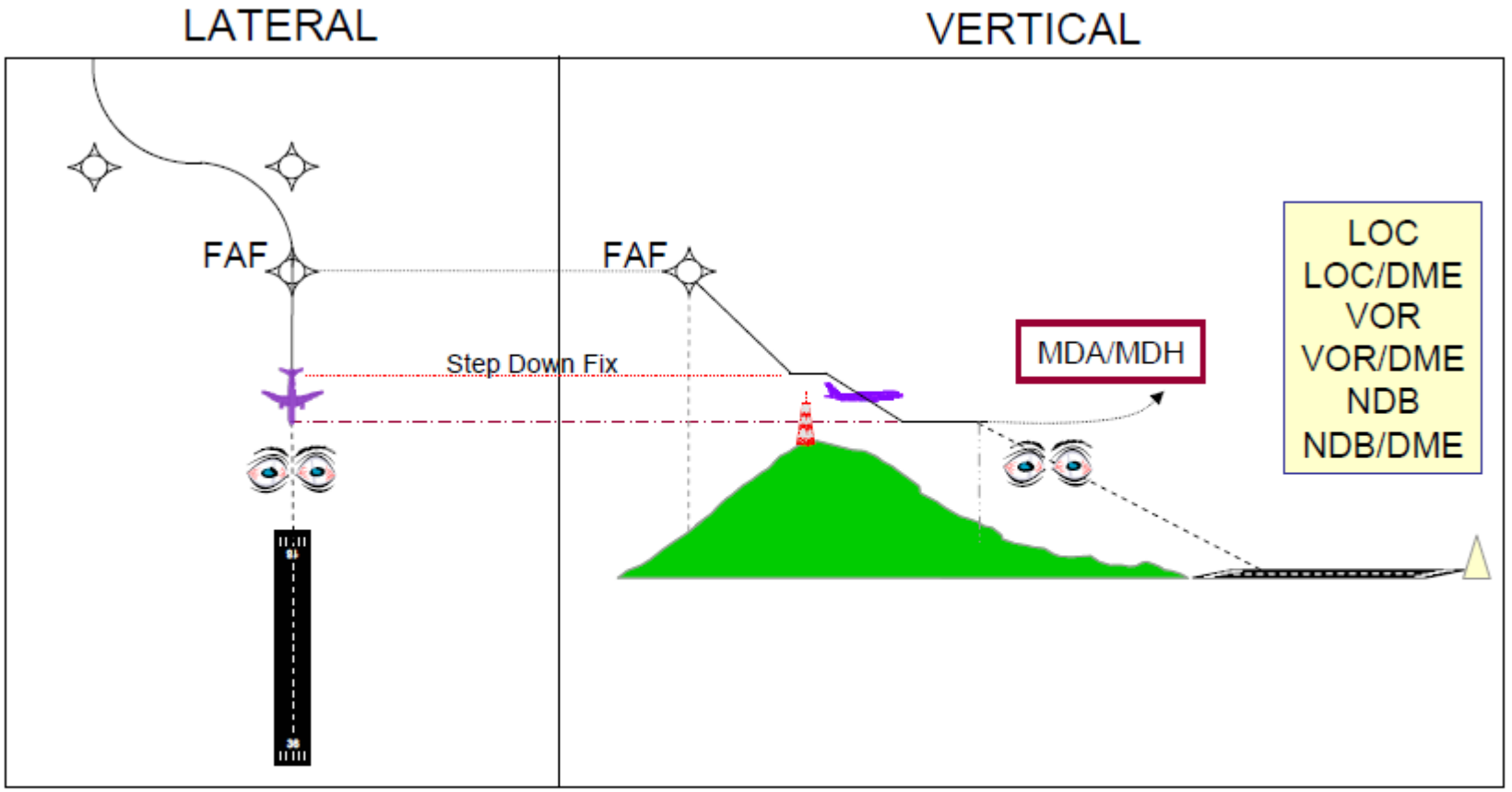
- **Navigation specifications are used by States as *basis* for aircraft certification and operational approval**
- **A navigation specification does not in itself constitute regulatory guidance material**
  - Aircraft approved by State of manufacture
  - Operators approved in accordance with their National Operating Rules
- **Compliance with one navigation specification does not guarantee compliance with another**

Overview of Specific Navigation Services

	Permitted Sensors					AFCS Requirement
	GNSS	IRU	DME/DME	DME/DME /IRU	DME/VOR	AP/FD
RNAV 10	✓	✓				FTE may be manually controlled by the pilot remaining within ½ full scale deflection of CDI with correct scaling for phase of flight
RNAV 5	✓	✓	✓	✓	✓	
RNAV 2/1	✓		✓	✓		
RNP 4	✓					
RNP 2 [2]	✓					
RNP 1	✓		✓ [3]			
A-RNP [2]	✓		✓ [3]			✓ [1]
RNP 0.3	✓					✓
RNP APCH	✓		✓ [3]	✓ [3]		✓
RNP AR APCH	✓					✓

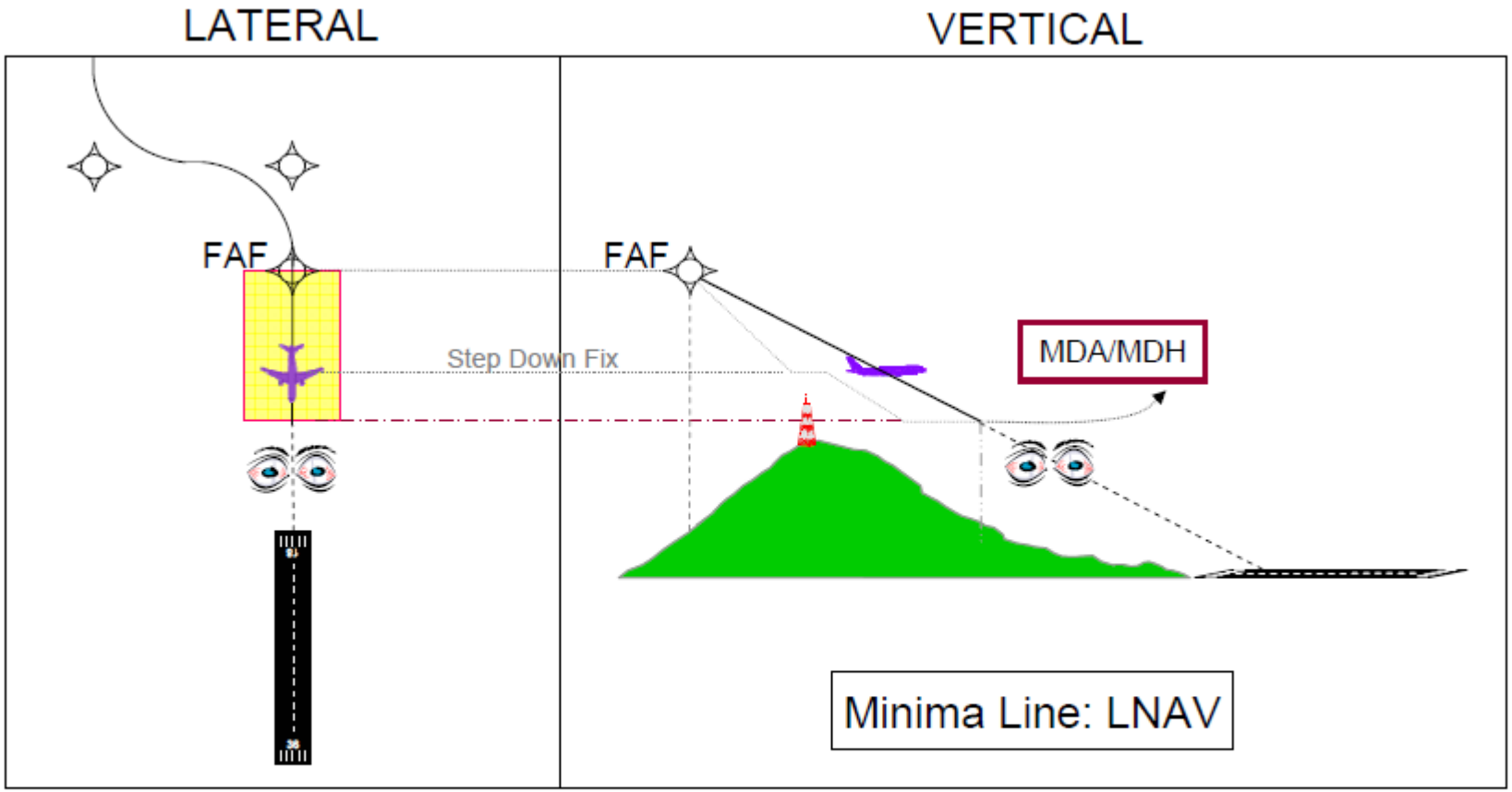
1. Although the A-RNP Nav Spec does not explicitly state FD/AP the RF appendix does and RF is a requirement for A-RNP
2. For Oceanic/Remote Continental operations dual independent LRNS (providing Higher Continuity) are required
3. Only when authorised by a specific State. Based on an available DME infrastructure and appropriate aircraft capability

NPA conventional



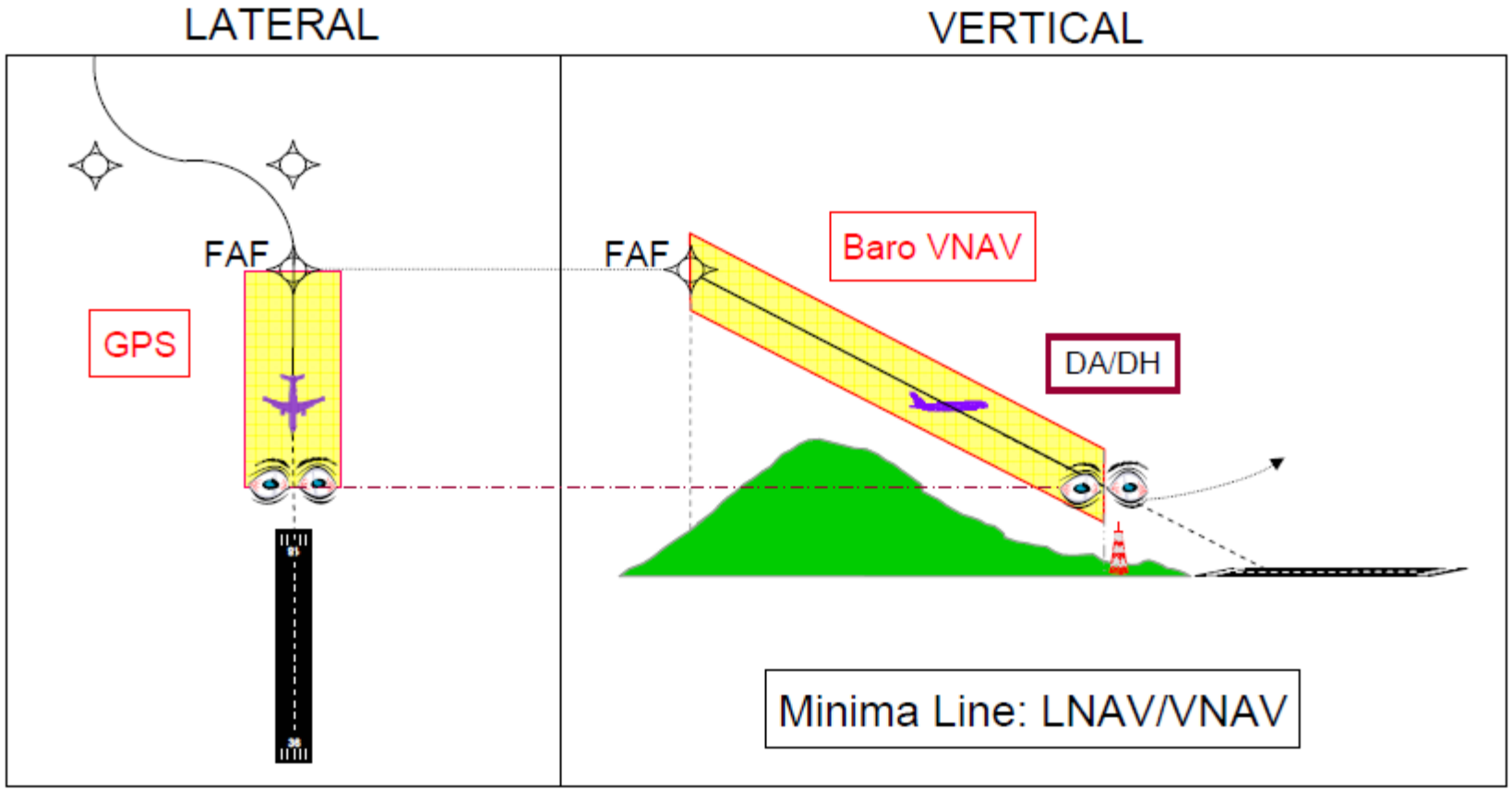
Description	System	Performance
▪ Approach conducted to a MDA/MDH ▪ Lateral Guidance based on ground based NAVAIDS	As Displayed	/

RNP APCH with CDFA



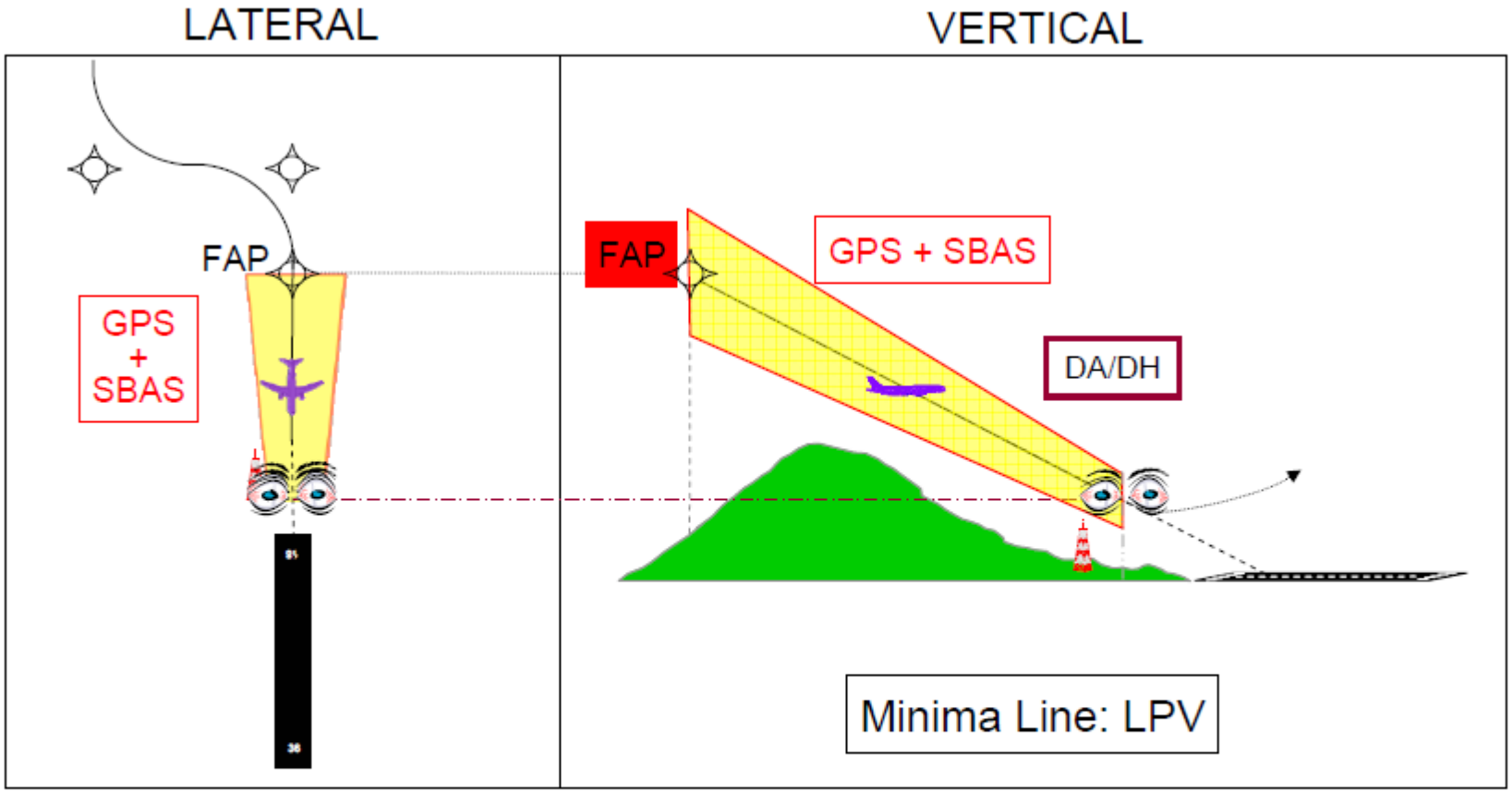
Description	System	Performance
▪ Approach conducted to a MDA/MDH ▪ Lateral Guidance only based on GPS (with RAIM)	GPS (RAIM)	0.3NM (95%)

RNP APCH B-VNAV

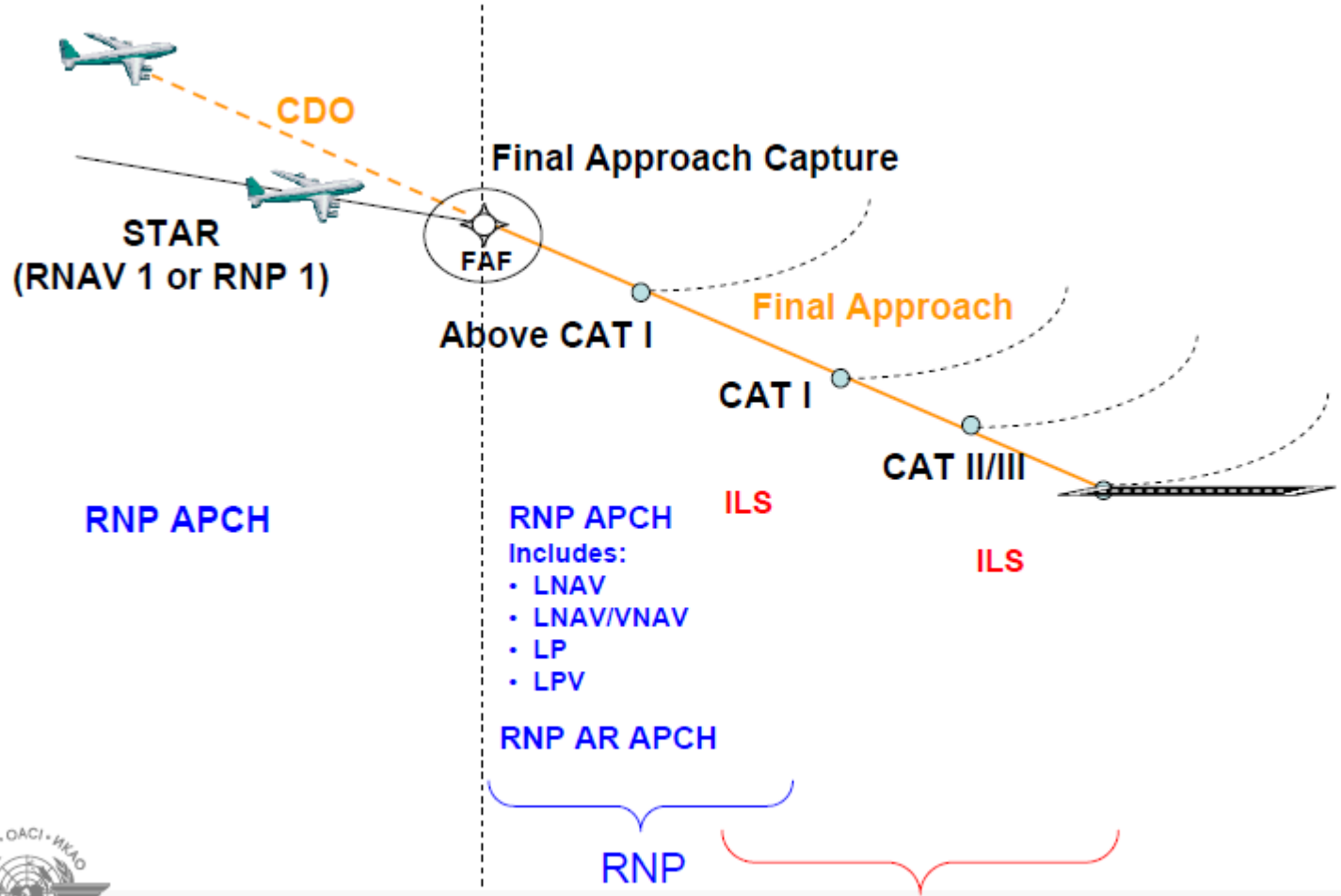


Description	System	Performance
▪ Approach conducted to Decision Altitude / Height ▪ Lateral guidance based on GPS (with RAIM) and vertical guidance based on Baro	GPS (RAIM) and Barometric altimetry	0.3NM (95%) VNAV: 20-27

RNP APCH SBAS



Description	System	Performance
▪ Approach conducted to a Decision Altitude / Height ▪ Lateral and vertical guidance based SBAS	GPS + SBAS	HAL: 40m VAL: 50m


CDO
Final Approach Capture
STAR
(RNAV 1 or RNP 1)
FAF
Final Approach
Above CAT I
CAT I
CAT II/III
ILS
ILS
RNP APCH
RNP APCH
Includes:
• LNAV
• LNAV/VNAV
• LP
• LPV
RNP AR APCH
RNP
Precision Approach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ICAO

THANK YOU