PBN Flight Procedure Design Workshop for NON-DESIGNERS (online)

The Concepts of PBN

(4-5/Feb/2026)

CONTENTS

- PBN basic concepts;
- PBN regulations
- PBN Navigation facilities
- PBN Navigation specifications;
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- PBN benefits;

What is flight procedure design

Flight procedure design. Like the route design in the sky, you should design a specific route for the aircraft with the following parameters: gradient, speed limitation, altitude, heading…, to make sure the aircraft can safely avoid all the obstacles and can efficiency operation.

Flight procedure design

- **IFR**
  - **Conventional (VOR NDB DME ILS …)**
  - **Performance based navigation (PBN)**
    - **GNSS**
    - **DME/DME**
    - **VOR/DME**
    - **IRS**
- **VFR**

Instrument approach procedure (IAP). A series of predetermined manoeuvres by reference to flight instruments with specified protection from obstacles from the initial approach fix, or where applicable, from the beginning of a defined arrival route to a point from which a landing can be completed and thereafter, if a landing is not completed, to a position at which holding or en-route obstacle clearance criteria apply. Instrument approach procedures are classified as follows:

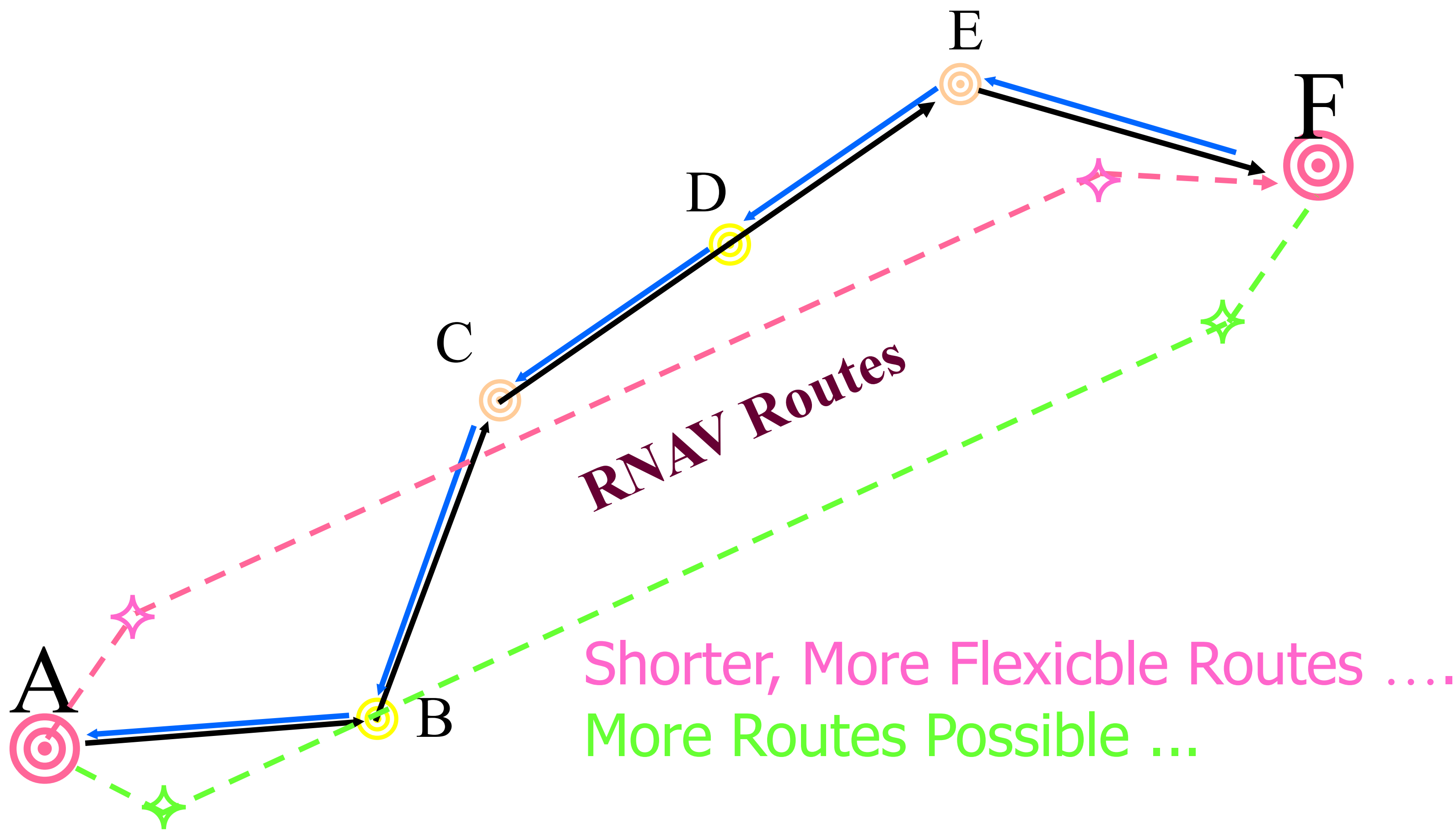
Non-precision approach (NPA) procedure. An instrument approach procedure designed for 2D instrument approach operations.

Approach procedure with vertical guidance (APV). A performance-based navigation (PBN) instrument approach procedure designed for 3D instrument approach operations.

Precision approach (PA) procedure. An instrument approach procedure based on navigation systems (ILS, MLS, GLS and SBAS Cat I) designed for 3D instrument approach operations.

PBN flight procedure

Efficiency and Flexibility - Improve efficiency and flexibility by *reducing reliance on the locations of ground-based navigation aids*



PBN Basic Concepts

PBN Basic Concepts

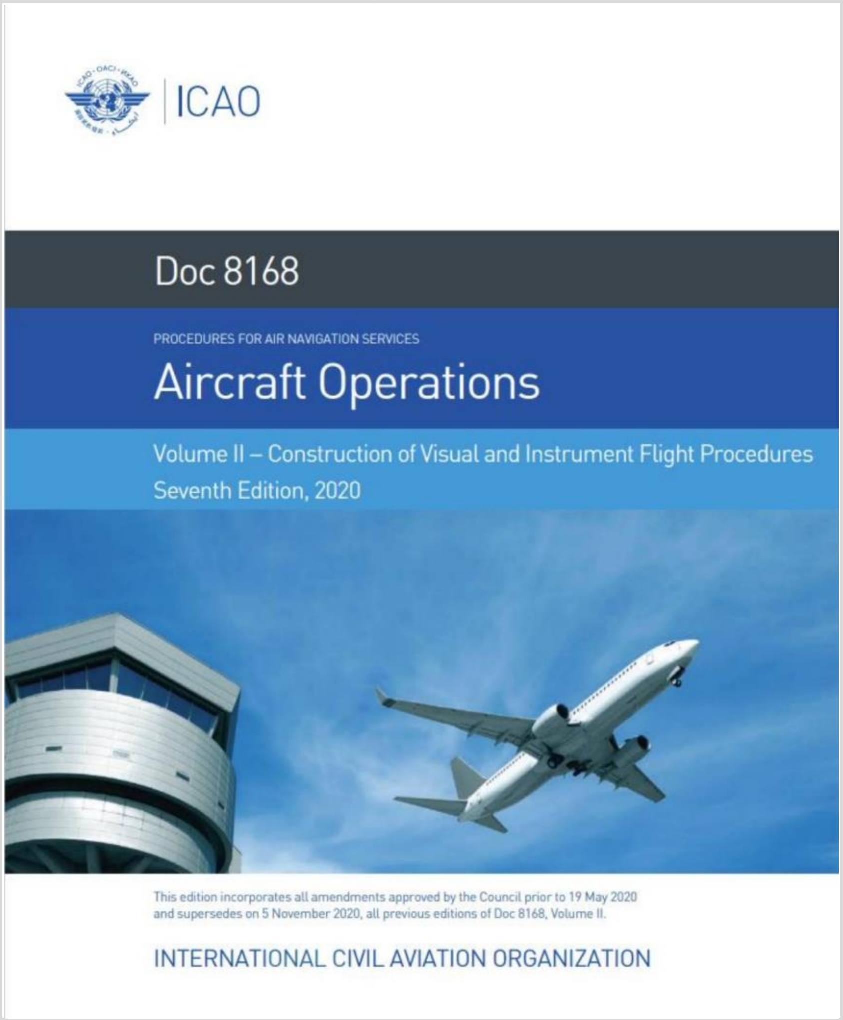
- PBN -**Performance-based navigation** is defined as a type of area navigation in which the navigation performance requirements are prescribed in **navigation specifications**.
- The PBN concept specifies that aircraft RNAV and RNP system performance requirements be defined in terms of the **accuracy**, **integrity**, **continuity** and **functionality**, which are needed for the proposed operation in the context of a particular airspace concept.

PBN Basic Concepts

- Performance requirements are identified in navigation specifications, which also identify the choice of navigation sensors and equipment that may be used to meet the performance requirements.
- A navigation specification is defined as a set of **aircraft** and **aircrew requirements** needed to support PBN operations within a defined airspace.

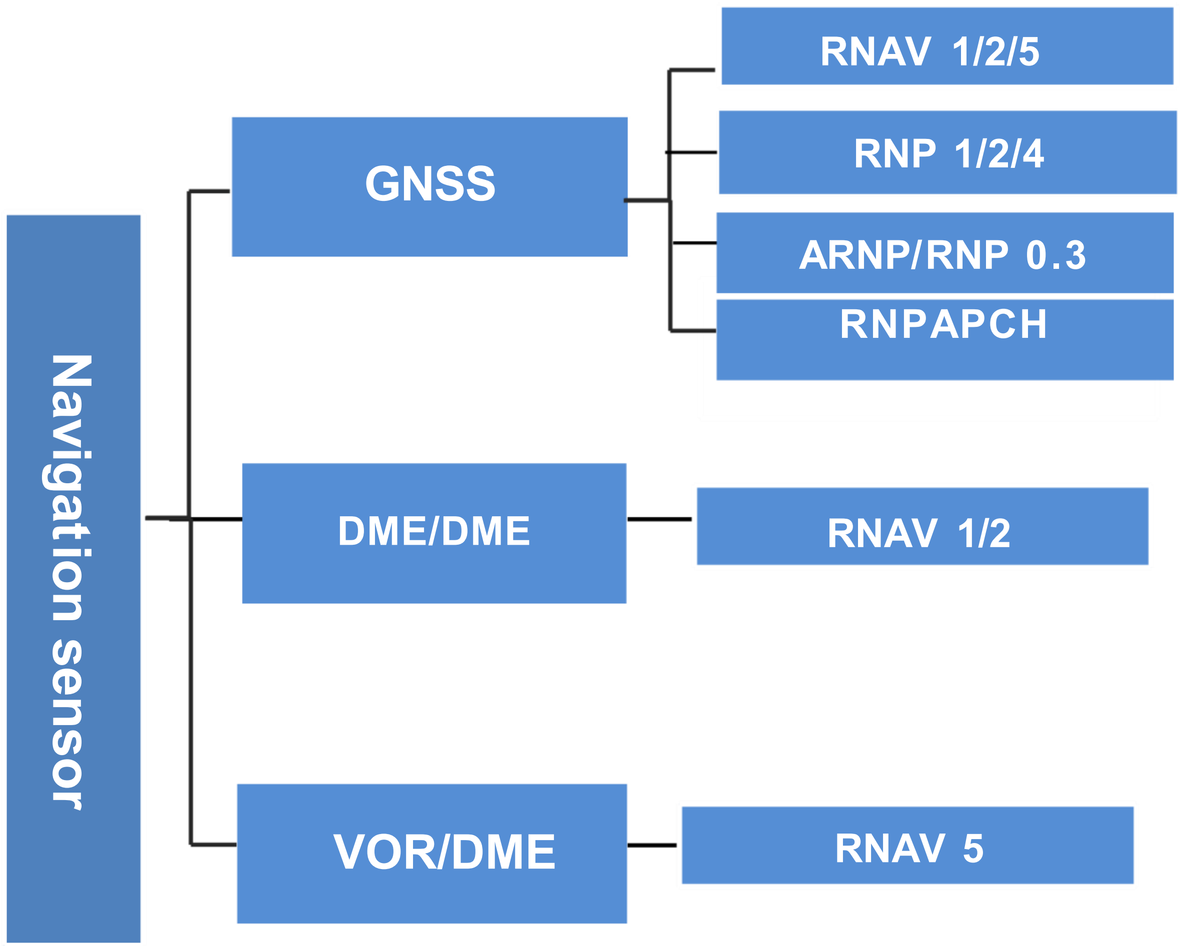
PBN Regulations

PBN Regulations

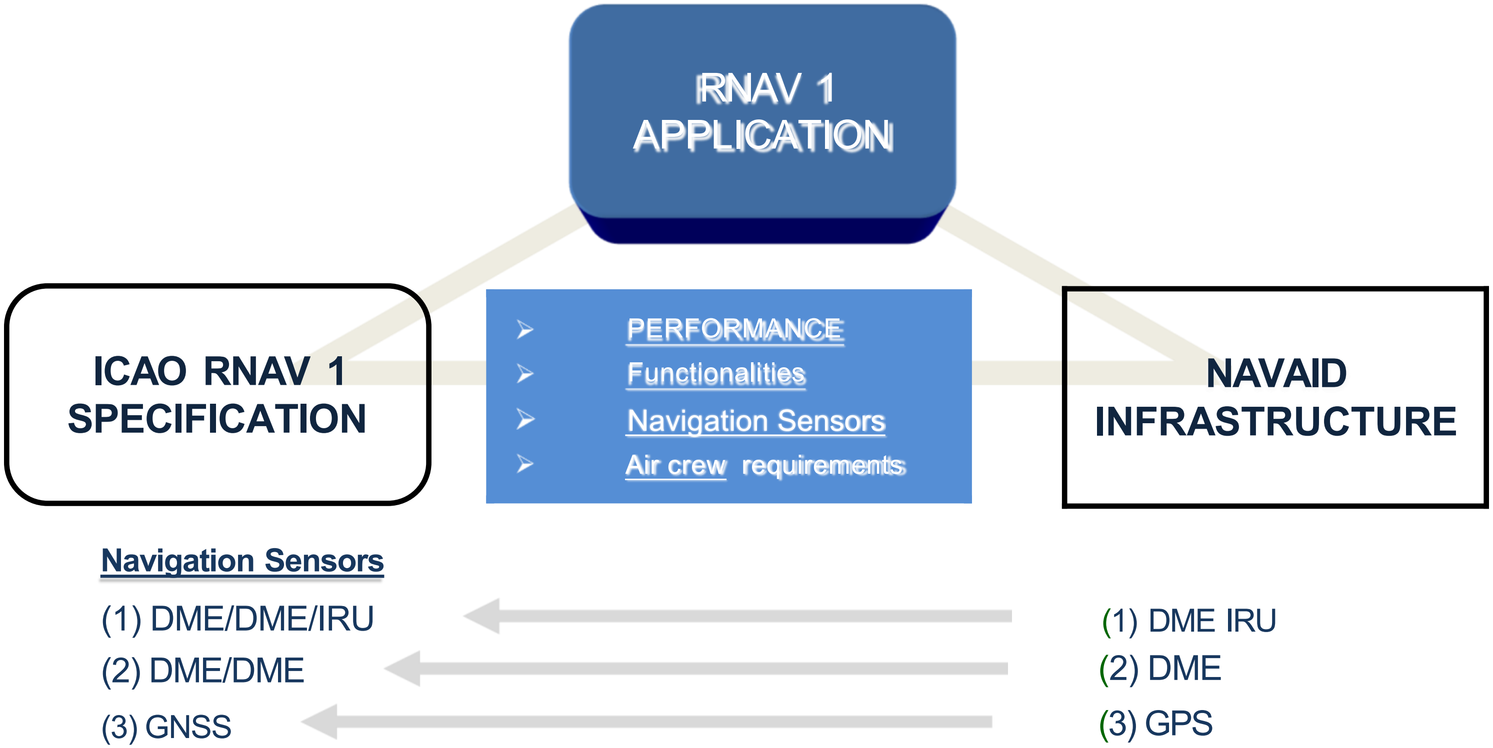


PBN Navigation Facilities

Navigation Specification



PBN Basic Concepts



PBN Navigation Specifications

Navigation Specification

Table III-1-1-1. Navigation specification per flight phase

	Flight Phase							
	Oceanic/Remote	*En-route*	*Arrival*	*Approach: Initial*	*Approach: Intermediate*	*Approach: Final*	*Approach: Missed*[1]	*Departure*
RNAV 10	10							
RNAV 5		5	5[2]					
RNP 4	4							
RNP 2	2	2						
RNAV 2		2	2					2
Advanced RNP[3]	2	2 or 1	1 – 0.3	1 - 0.3	1 - 0.3	0.3	1 - 0.3	1 - 0.3
RNP 1			1	1	1		1	1
RNAV 1		1	1	1	1		1	1
RNP 0.3 (Cat H)		0.3	0.3	0.3	0.3		0.3	0.3
RNP APCH (Part A)[4]				1	1	0.3	1	
RNP APCH (Part B)[4]				1	1	Angular	1 or 0.3 (initial straight MISAP)	
RNP AR APCH				1-0.1	1-0.1	0.3-0.1	1-0.1	

Navigation Specification Application（RNAV）

- ***RNAV10***: used to support RNAV operations in the ***en-route*** phase of flight to support longitudinal distance-based separation minima in oceanic or remote area airspace. Procedure design criteria have not been developed.

- ***RNAV5***: used to support RNAV operations in the ***en-route*** phase of flight continental airspace.

- ***RNAV1 & 2***: used to support RNAV operations in the ***en-route*** phase of flight, on ***SIDs***, on ***STARs*** and on approaches up to FAF/FAP.

Navigation Specification Application（RNP）

- ***RNP4***: used to support RNP operations in the ***en-route*** phase of flight to support longitudinal distance-based separation minima in oceanic or remote area airspace.

- ***RNP2***: used to support RNNP operations in the ***en-route*** phase of flight inoceanic， remote area and continental airspace.

- ***RNP1*** : used to support RNP operations on ***SIDs,*** on ***STARs*** and on approaches up to the FAF/FAP with no or limited, ATS surveillance and with low to medium density traffic.

Navigation Specification Application（RNP）

- ***Advanced RNP(ARNP):*** used to support RNP operations in the ***en-route*** continental airspace and on SIDs, STARs and approach procedures.

- ***RNP 0.3***: used to support ***helicopter*** RNP operations in all phases of flight except final approach.

- ***RNPAPCH*** : used to support ***RNP approach*** to LNAV, LNAV/VNAV, LP and LPV minima.

- ***RNPAR APCH***： used to support ***RNP approach operations***, including the final approach segment, which consist of straight and/or fixed radius segments, with navigation accuracies equal to or less then 0.3NM on final and 1NM on the other approach segments.

Navigation Specification Value

Table III-1-1-1. Navigation specification per flight phase

	Flight Phase							
				Approach				
	Oceanic/Remote	*En-route*	*Arrival*	*Initial*	*Intermediate*	*Final*	*Missed*[1]	*Departure*
RNAV 10	10							
RNAV 5		5	5[2]					
RNP 4	4							
RNP 2	2	2						
RNAV 2		2	2					2
Advanced RNP[3]	2	2 or 1	1 – 0.3	1 - 0.3	1 - 0.3	0.3	1 - 0.3	1 - 0.3
RNP 1			1	1	1		1	1
RNAV 1		1	1	1	1		1	1
RNP 0.3 (Cat H)		0.3	0.3	0.3	0.3		0.3	0.3
RNP APCH (Part A)[4]				1	1	0.3	1	
RNP APCH (Part B)[4]				1	1	Angular	1 or 0.3 (initial straight MISAP)	
RNP AR APCH				1-0.1	1-0.1	0.3-0.1	1-0.1	

The RNP value X NM means the lateral TSE and the along track error will not exceed X for at least 95% of the total flight time.

PBN Total System Errors

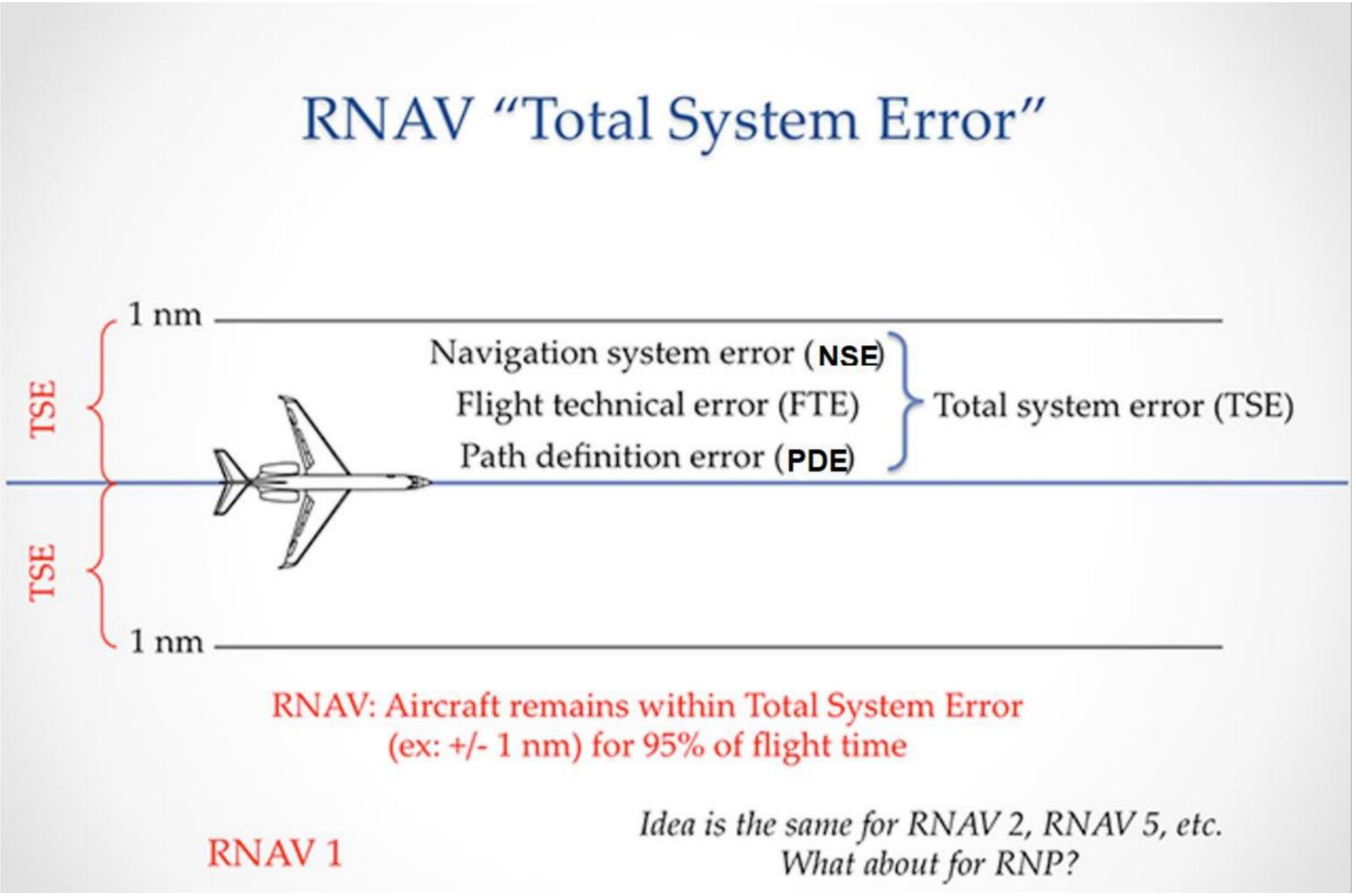
Errors always exist in navigation system both for PBN and ground-based navigation stations. Only if the error is acceptable.

- For PBN navigation, the RNAV and RNP cross-track tolerance values are derived from the following errors:
- ***NSE***(navigational system error) ;
- ***FTE***(flight technical error);
- ***PDE***(path definition error);

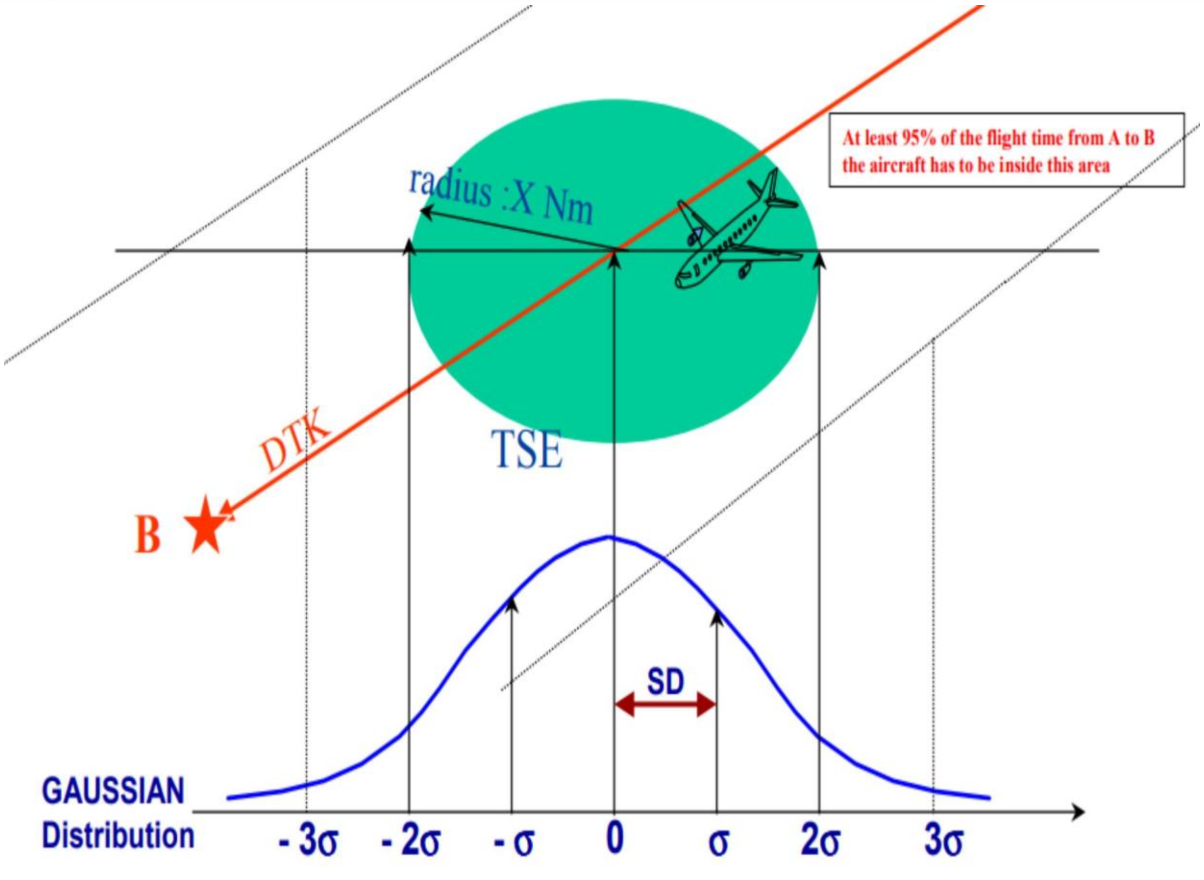
TSE=NSE+FTE+PDE

NSE and FTE are both treated as though they are Gaussian and are determined by the RSS(room sum square) of these two errors. PDE value is small, so the ***NSE and FTE are the dominant component***.

PBN Total System Errors



Navigation Specification Value



The RNP value X NM means the lateral TSE and the along track error will ***not exceed*** X for at least ***95%*** of the total flight time.

Navigation Specification Value

Table III-1-1-1. Navigation specification per flight phase

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	Oceanic/Remote	*En-route*	*Arrival*	*Initial*	*Intermediate*	*Final*	*Missed*[1]	*Departure*
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RNAV 1		1	1	1	1		1	1
RNP 0.3 (Cat H)		0.3	0.3	0.3	0.3		0.3	0.3
RNP APCH (Part A)[4]				1	1	0.3	1	
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RNP AR APCH				1-0.1	1-0.1	0.3-0.1	1-0.1	

The RNP value X NM means the lateral TSE and the along track error will not exceed X for at least 95% of the total flight time.

RNAV & RNP

Navigation specifications

RNP specifications include a requirement for OPMA(on-board performance monitoring and alerting)

Designation RNP X

RNAV specifications do not include a requirement for OPMA(on-board performance monitoring and alerting)

Designation RNAV X

RNAV & RNP

- RNP=RNAV + OPMA.
- For RNAV procedures, it's air traffic controllers' responsibility to monitor whether the aircrafts' location meet the corresponding requirements;
- For RNP procedures, it's the flight crew's duty to surveil whether the aircrafts' location meet the corresponding requirements through monitoring and alerting.

OPMA Brief Introduction

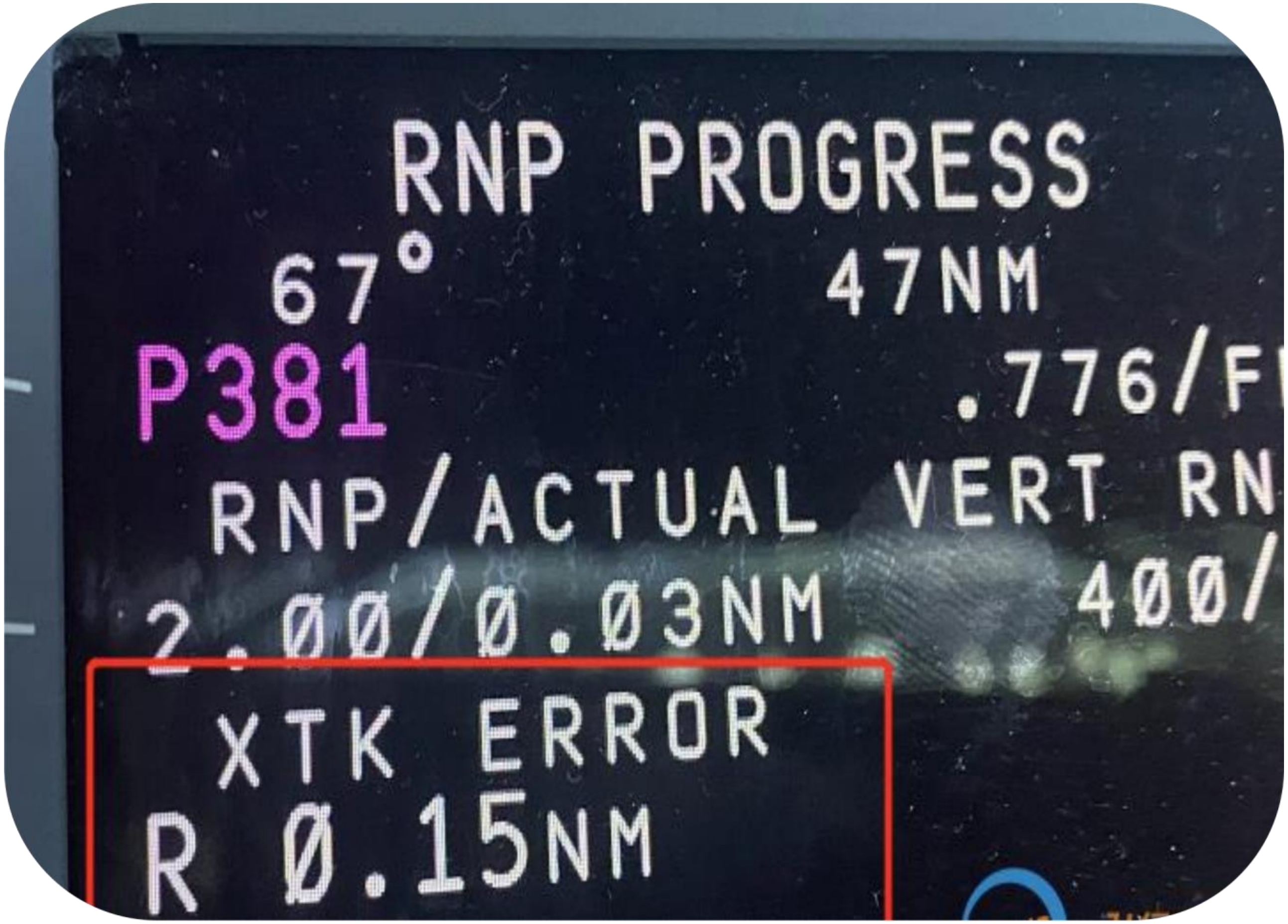
- ***OPMA*** is onboard facility to help pilots to detect whether the TSE could meet the required navigation performance.
- OPMA will monitor the TSE(NSE and FTE)(total system error), when the TSE does not meet the requirement, the FMC will alert.

NSE monitoring

OPMA Brief Introduction

- Once the ANP value exceeds the RNP value, the FMC will alert.

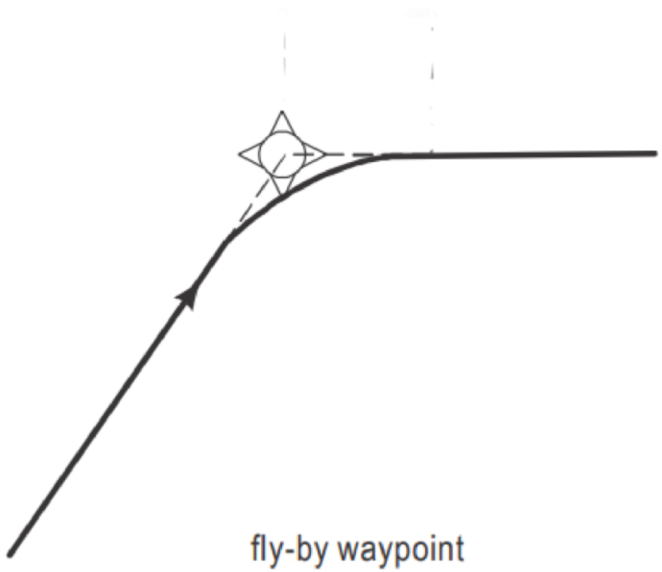
OPMA Brief Introduction

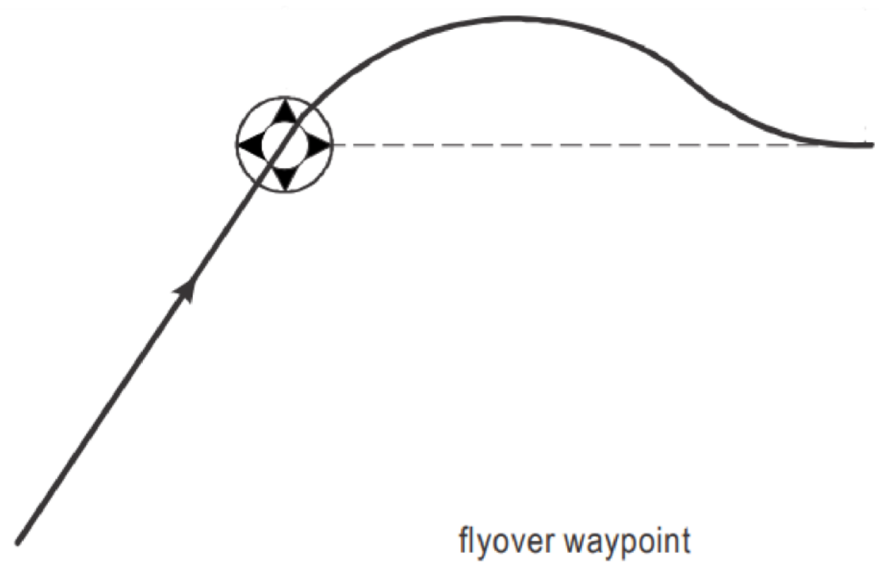


- FTE monitoring

PBN WAY POINTS

- Turn
  - Fly by turn
  - Fly over turn





Turn parameters

R = (6 355 tan *a*)/πV, where V is the TAS in km/h; and

r = V/(20 π R) where V is the TAS.

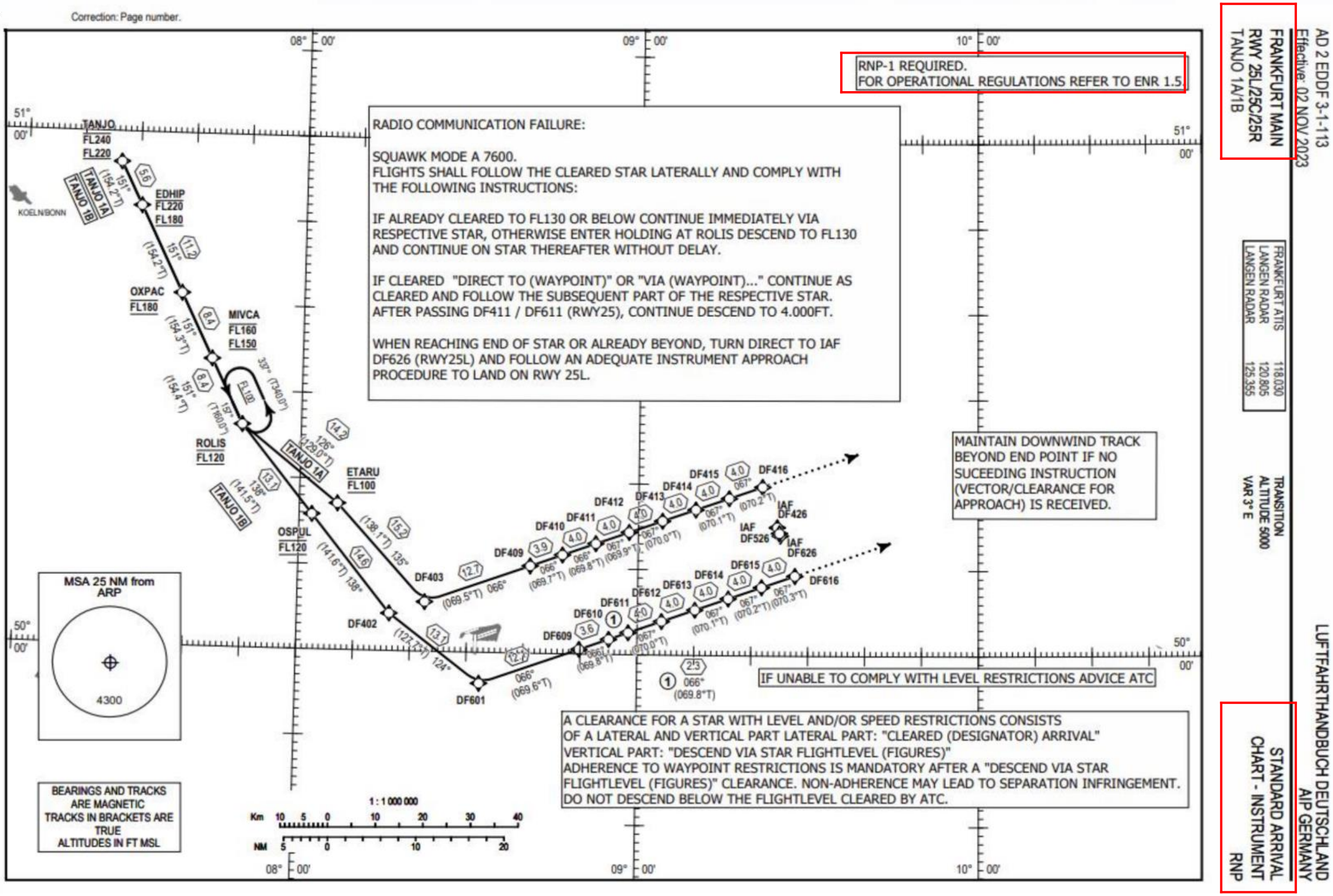
R represents the rate of turn;

r represents the radius of turn;

a represents the bank angle.

PBN Application

Navigation Specifications Application（Charts）



Navigation Specifications Application（Charts）

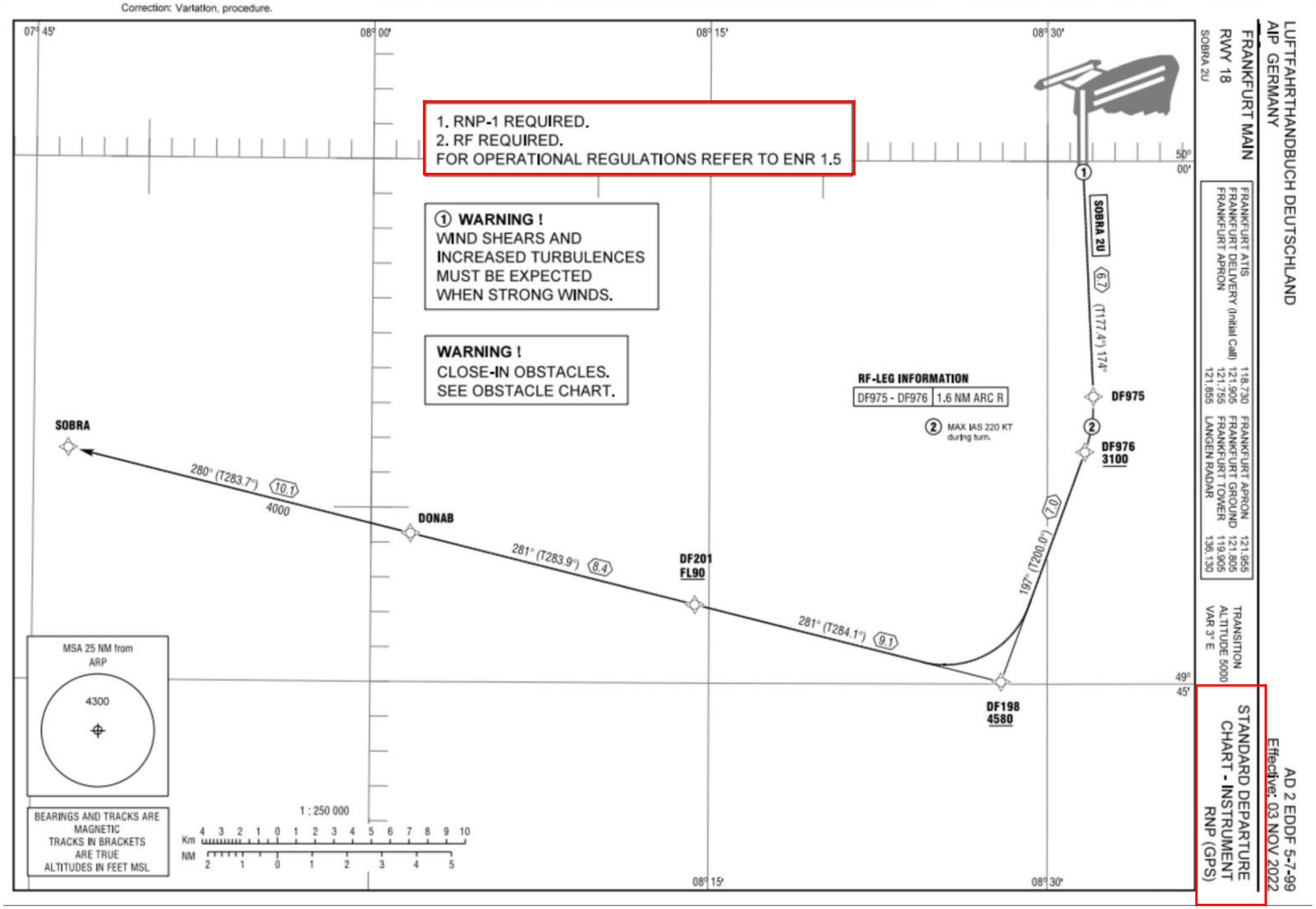
AD 2 EDDF 3-1-116 LUFTFAHRTHANDBUCH DEUTSCHLAND
Effective: 02 NOV 2023 AIP GERMANY

FRANKFURT MAIN STANDARD INSTRUMENT ARRIVAL ROUTES
RNP RWY 25L/25C/25R (STAR)

Designator	TANJO 1A
	TANJO ONE ALPHA
Procedure Remark	-

Route Type	Path Terminator	Waypoint Identifier	Coordinates	Fly-over	(True Track) MAG Track (°)	Distance (NM)	Turn Direction	Altitude (ft) Flight Level	Speed Limit (kt IAS)	Vertical Path Angle (°)	NAV Specification	Remark
Common	IF	TANJO	N 50 56 25.00 E 007 26 34.00	N	-	-	-	FL240- FL220+	-	-	RNP 1	-
Common	TF	EDHIP	N 50 51 22.29 E 007 30 25.43	N	(T154.2) 151	5.6	-	FL220- FL180+	-	-	RNP 1	-
Common	TF	OXPAC	N 50 41 16.40 E 007 38 05.87	N	(T154.2) 151	11.2	-	@FL180	-	-	RNP 1	-
Common	TF	MIVCA	N 50 33 41.56 E 007 43 49.10	N	(T154.3) 151	8.4	-	FL160- FL150+	-	-	RNP 1	-
Common	TF	ROLIS	N 50 26 06.37 E 007 49 30.55	N	(T154.4) 151	8.4	-	@FL120	-	-	RNP 1	-
Common	TF	ETARU	N 50 17 08.00 E 008 06 44.00	N	(T129.0) 126	14.2	-	@FL100	-	-	RNP 1	-
Common	TF	DF403	N 50 05 48.13 E 008 22 30.06	N	(T138.1) 135	15.2	-	-	-	-	RNP 1	-
Common	TF	DF409	N 50 10 13.28 E 008 40 59.94	N	(T069.5) 066	12.7	-	-	-	-	RNP 1	-
Common	TF	DF410	N 50 11 33.83 E 008 46 39.57	N	(T069.7) 066	3.9	-	-	-	-	RNP 1	-
Common	TF	DF411	N 50 12 56.53 E 008 52 30.83	N	(T069.8) 066	4.0	-	-	-	-	RNP 1	-
Common	TF	DF412	N 50 14 18.94 E 008 58 22.44	N	(T069.9) 067	4.0	-	-	-	-	RNP 1	-
Common	TF	DF413	N 50 15 41.04 E 009 04 14.39	N	(T070.0) 067	4.0	-	-	-	-	RNP 1	-
Common	TF	DF414	N 50 17 02.83 E 009 10 06.68	N	(T070.0) 067	4.0	-	-	-	-	RNP 1	-
Common	TF	DF415	N 50 18 24.33 E 009 15 59.31	N	(T070.1) 067	4.0	-	-	-	-	RNP 1	-
Common	TF	DF416	N 50 19 45.52 E 009 21 52.29	N	(T070.2) 067	4.0	-	-	-	-	RNP 1	-
Runway	IF	DF416	N 50 19 45.52 E 009 21 52.29	N	-	-	-	-	-	-	RNP 1	-
Runway	FM	DF416	N 50 19 45.52 E 009 21 52.29	N	(T070.2) 067	-	-	-	-	-	RNP 1	-
Runway	CF	DF426	N 50 15 03.04 E 009 24 30.17	N	(T250.3) 247	-	-	-	-	-	RNP 1	IAF RWY 25R
Runway	IF	DF416	N 50 19 45.52 E 009 21 52.29	N	-	-	-	-	-	-	RNP 1	-
Runway	FM	DF416	N 50 19 45.52 E 009 21 52.29	N	(T070.2) 067	-	-	-	-	-	RNP 1	-
Runway	CF	DF526	N 50 14 21.68 E 009 24 53.24	N	(T250.3) 247	-	-	-	-	-	RNP 1	IAF RWY 25C
Runway	IF	DF416	N 50 19 45.52 E 009 21 52.29	N	-	-	-	-	-	-	RNP 1	-
Runway	FM	DF416	N 50 19 45.52 E 009 21 52.29	N	(T070.2) 067	-	-	-	-	-	RNP 1	-
Runway	CF	DF626	N 50 14 04.23 E 009 25 02.97	N	(T250.3) 247	-	-	-	-	-	RNP 1	IAF RWY 25L

Navigation Specification Application（Charts）



Navigation Specification Application（Charts）

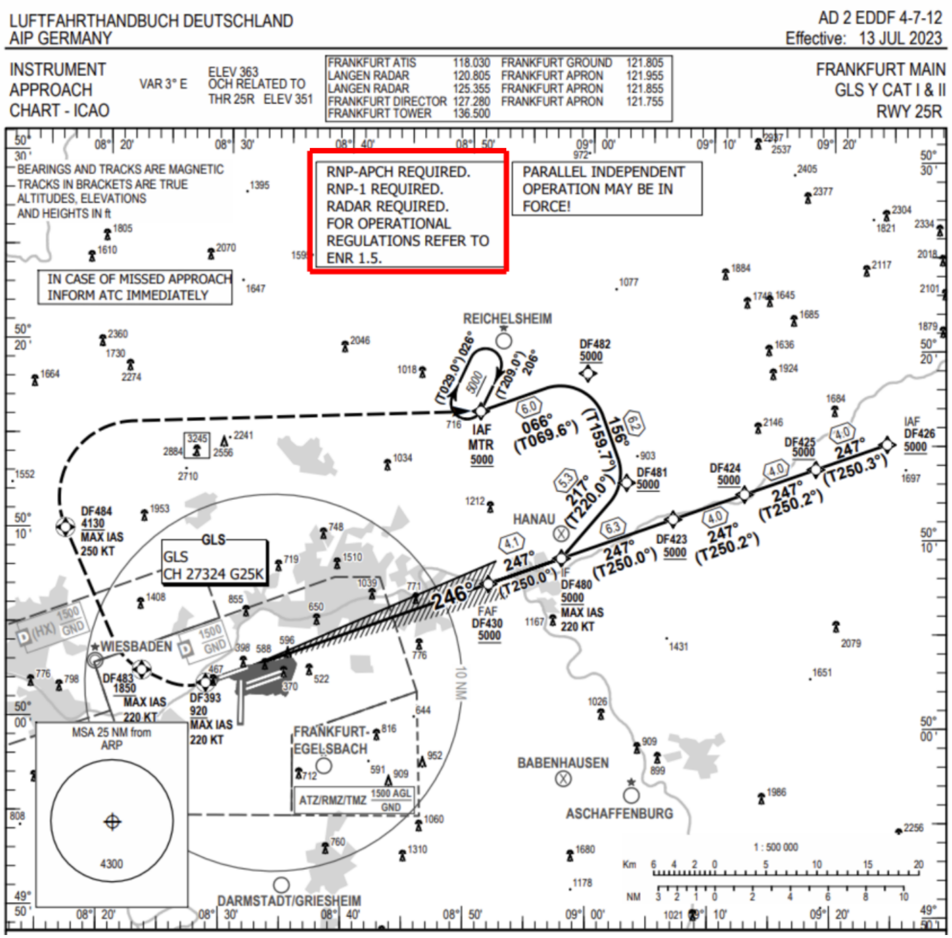
FRANKFURT MAIN
RWY 18
UNIFORM

STANDARD DEPARTURE
ROUTES - INSTRUMENT (SID)
RNP (GPS)

Designator	Route	After Take-Off		Remarks Text Page
		Climb to	Contact	
SOBRA 2U	**SOBRA TWO UNIFORM** To DF975 on course 174°. Turn right with 4.15 NM radius to DF976, at or above 3100, maximum speed 220 kts. To DF198, at or above 4580. To DF201 at or above FL90. To DONAB. To SOBRA.	4000 ft	Langen Radar 136.130 Contact Langen Radar when advised by Tower! (Departure frequency may deviate from the frequency published. Check ATIS for current departure frequency.)	1. If unable to pass DF201 at or above FL90, advise EDDF DELIVERY prior to start-up and expect routing via SID ULKIG L. 2. For flights intending to proceed at or above FL 250 via Y180/Y181. Flights have to be able to cross RUDOT at or above FL 240. If unable to comply, flight plan shall read RUDOT FL 220 - Y180 - NISIV - UY180 - DIK RFL. 3. Do not turn before DER.

Recommended Path Terminator	Waypoint Identifier	Coordinates	Fly Over	(True Track°) Mag Track°	Distance (NM)	Turn Direction	Altitude (ft) / Flight Level	Speed Limit (kt IAS)	NAV-Specification	Remarks
CF	DF975	N 49 53 14.87 E 008 32 02.38	-	(T177.4) 174	6.7	-	-	-		-
RF	DF976	N 49 51 39.29 E 008 31 39.92	-	-	1.6	R	A3100+	220-		ARC Center: DF977 N 49 53 03.56 E 008 25 37.60 ARC Radius: 4.15 NM
TF	DF198	N 49 45 03.68 E 008 27 57.13	-	(T200.1) 197	7.0	-	A4580+	-	RNP-1 RF required	-
TF	DF201	N 49 47 15.18 E 008 14 22.30	-	(T284.1) 281	9.1	-	FL90+	-		-
TF	DONAB	N 49 49 15.89 E 008 01 44.83	-	(T283.9) 281	8.4	-	-	-		-
TF	SOBRA	N 49 51 39.00 E 007 46 32.00	-	(T283.7) 280	10.1	-	-	-		-

Navigation Specification Application（Charts）



AD 2 EDDF 4-7-24 Effective: 13 JUL 2023										LUFTFAHRTHANDBUCH DEUTSCHLAND AIP GERMANY		

FRANKFURT MAIN — INSTRUMENT APPROACH PROCEDURE

GLS Y CAT I & II RWY 25R — TABULAR DESCRIPTION

Procedure Remark:	-											
Approach Segment	**Path Terminator**	**Waypoint Identifier**	**Coordinates**	**Fly Over**	**(True Track°) Mag Track°**	**Distance (NM)**	**Turn Direction**	**Altitude (ft) / FL**	**Speed Limit / (kt IAS)**	**Vertical Path Angle (°) / TCH (ft)**	**NAV - Specification**	**Remarks**
Initial APCH from DF426	IF	DF426	N 50 15 03.04 E 009 24 30.17	N	-	-	-	A5000+	-	-	RNP 1	-
	TF	DF425	N 50 13 41.98 E 009 18 37.71	N	(T250.3) 247	4.0	-	A5000+	-	-	RNP 1	-
	TF	DF424	N 50 12 20.62 E 009 12 45.59	N	(T250.2) 247	4.0	-	A5000+	-	-	RNP 1	-
	TF	DF423	N 50 10 58.96 E 009 06 53.81	N	(T250.2) 247	4.0	-	A5000+	-	-	RNP APCH	-
	TF	DF480	N 50 08 50.34 E 008 57 44.06	N	(T250.0) 247	6.3	-	A5000+	220-	-	RNP APCH	-
Initial APCH from MTR	IF	MTR	N 50 16 34.59 E 008 50 55.05	N	-	-	-	A5000+	-	-	RNP APCH	-
	TF	DF482	N 50 18 39.81 E 008 59 42.89	N	(T069.6) 066	6.0	-	A5000+	-	-	RNP APCH	-
	TF	DF481	N 50 12 53.75 E 009 03 01.97	N	(T159.7) 156	6.2	-	A5000+	-	-	RNP APCH	-
	TF	DF480	N 50 08 50.34 E 008 57 44.06	N	(T220.0) 217	5.3	-	A5000+	220-	-	RNP APCH	-
APCH	TF	DF430	N 50 07 25.85 E 008 51 44.59	N	(T250.0) 247	4.1	-	A5000+	-	-	RNP APCH	FAF for coding
	TF	RW25R	N 50 02 44.97 E 008 32 01.38	Y	(T249.9) 246	13.5	-	-	-	-3.2/50	RNP APCH	-
Missed APCH	DF	DF393	N 50 01 56.38 E 008 28 38.44	Y	-	-	-	A920+	220-	-	RNP APCH	-
	DF	DF483	N 50 02 33.35 E 008 23 22.48	Y	-	-	R	A1850+	220-	-	RNP APCH	-
	DF	DF484	N 50 10 00.65 E 008 16 50.49	Y	-	-	R	A4130+	250-	-	RNP APCH	-
	DF	MTR	N 50 16 34.59 E 008 50 55.05	N	-	-	R	@A5000	250-	-	RNP APCH	-

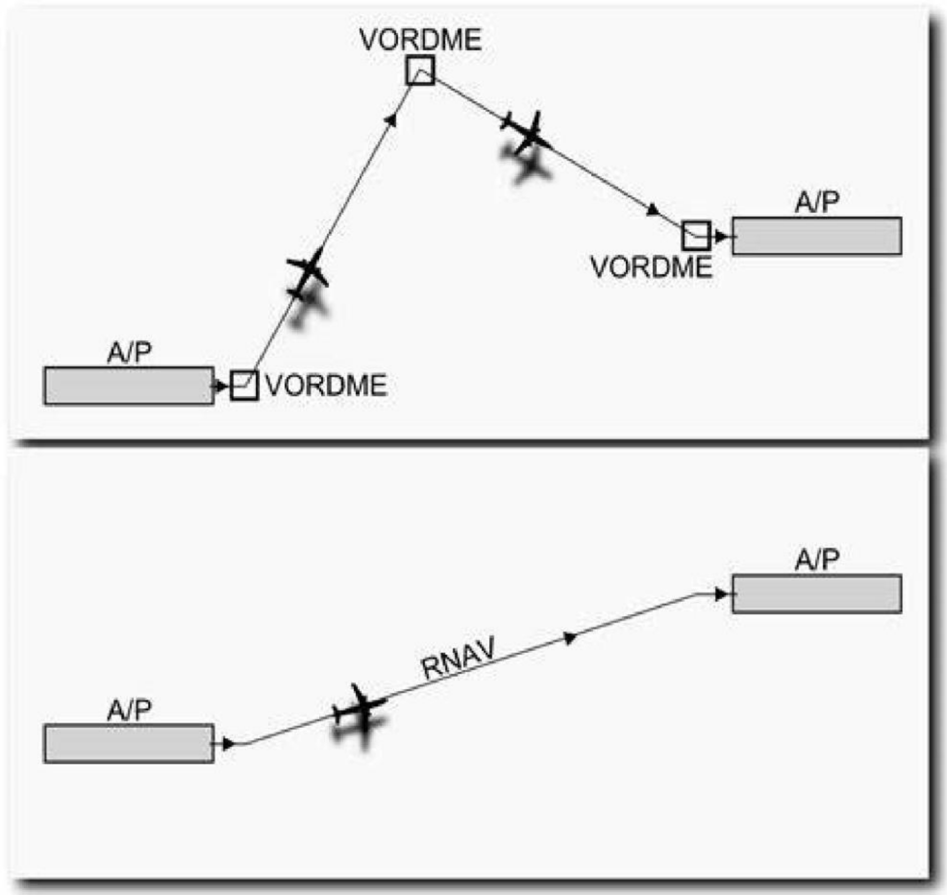
RNAV HOLDING IDENTIFICATION

Path Terminator	Holding Fix	Coordinates	(True Track°) Mag Track°	Time (MIN) / Distance outbound	Turn Direction	Altitude (ft) / FL	Speed Limit (kt IAS)	Remarks
HM	MTR	N 50 16 34.59 E 008 50 55.05	(T209.0) 206	1	R	A5000+	230-	-

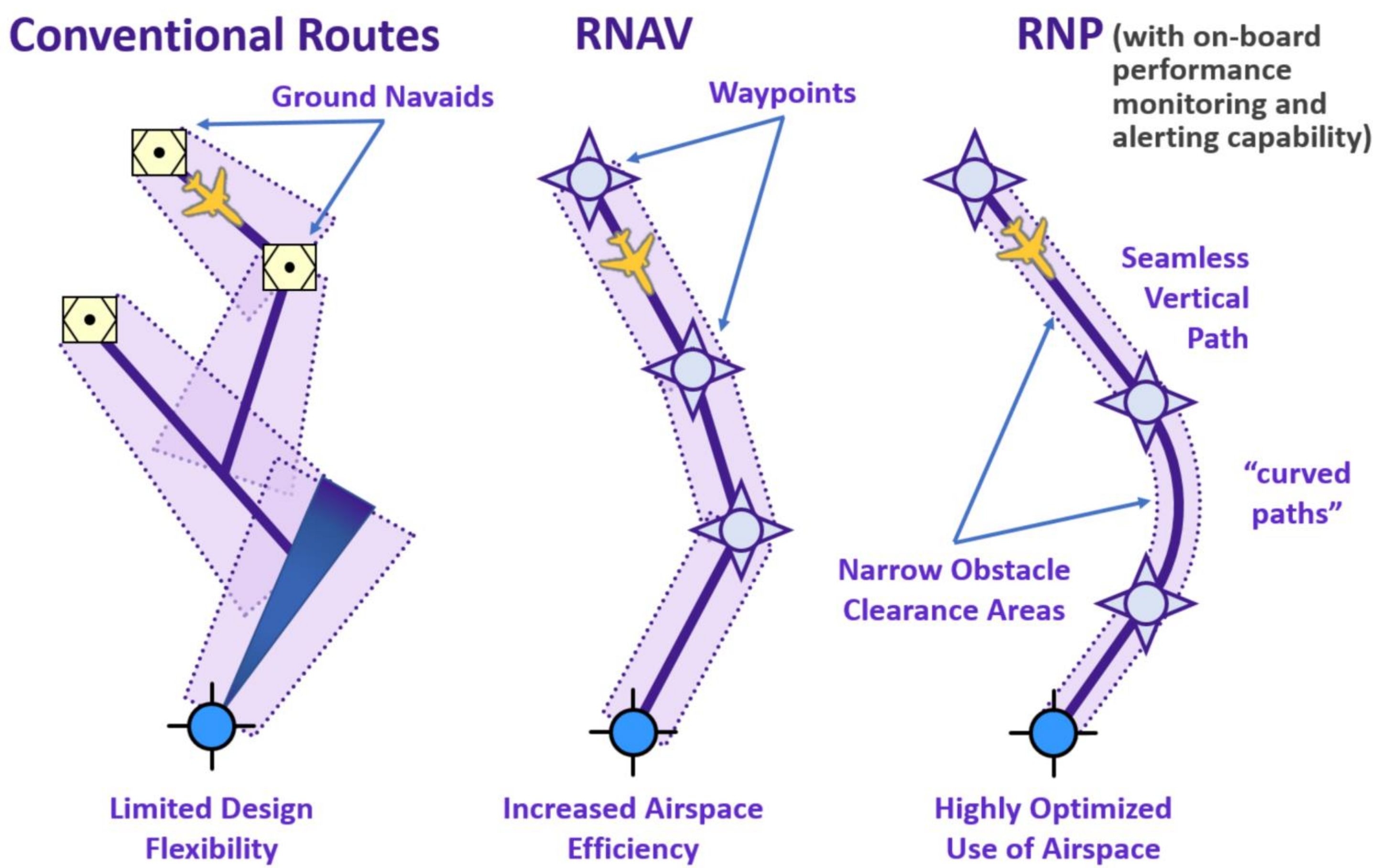
PBN Benefits

PBN Benefits

- Conventional procedures: Aircrafts receive signals from ground navigation stations. Aircrafts usually fly ***towards*** or ***away*** from the stations. The routes planning and terminal flight procedures would be limited by the layout and types of ground navigation stations.
- Aircrafts could fly any desired paths with PBN procedures. The path are defined by waypoints. Comparing to conventional procedures, PBN procedures are more flexible and accurate.



PBN Benefits



PBN Benefits

- PBN offers a number of advantages over the of ground-based navigation flight procedure on obstacle clearance criteria. For instance, PBN:
- ➢ 1.Reduces the need to maintain sensor-specific routes and procedures, and their associated costs.
- ➢ 2. Avoids the need to develop sensor-specific operations with each evolution of navigation systems, which would be cost-prohibitive.
- ➢ 3. Allows for more efficient use of airspace;

Case Study

(source: BEA)

The crew of the Airbus A320, performing flight NSZ4311 (call sign Red Nose 4311), took off on 23 May at around 09:30 from Stockholm Arlanda airport (Sweden) bound for Paris-Charles de Gaulle airport (CDG).

Before the descent, the flight crew prepared for a satellite approach procedure with barometric vertical guidance, in this case a RNP APCH operation down to LNAV/VNAV minima, to runway 27R at CDG because the ILS was out of service.

Case Study

(source: BEA)

The meteorological information indicated in the ATIS Q (Automatic Terminal Information Service) used by the flight crew to prepare the approach was the following:

Transition level 70, wind 280/10 kt, visibility 10 km, broken clouds at 1,500 ft, temperature 19°C, dew point 14°C, QNH 1001 hPa.

The crew indicated in their statements that they remained in clouds, without visual references, for all of the approach. They experienced moderate turbulence and flew through heavy rain, which led them to use the windshield wipers at high speed.

Case Study

(source: BEA)

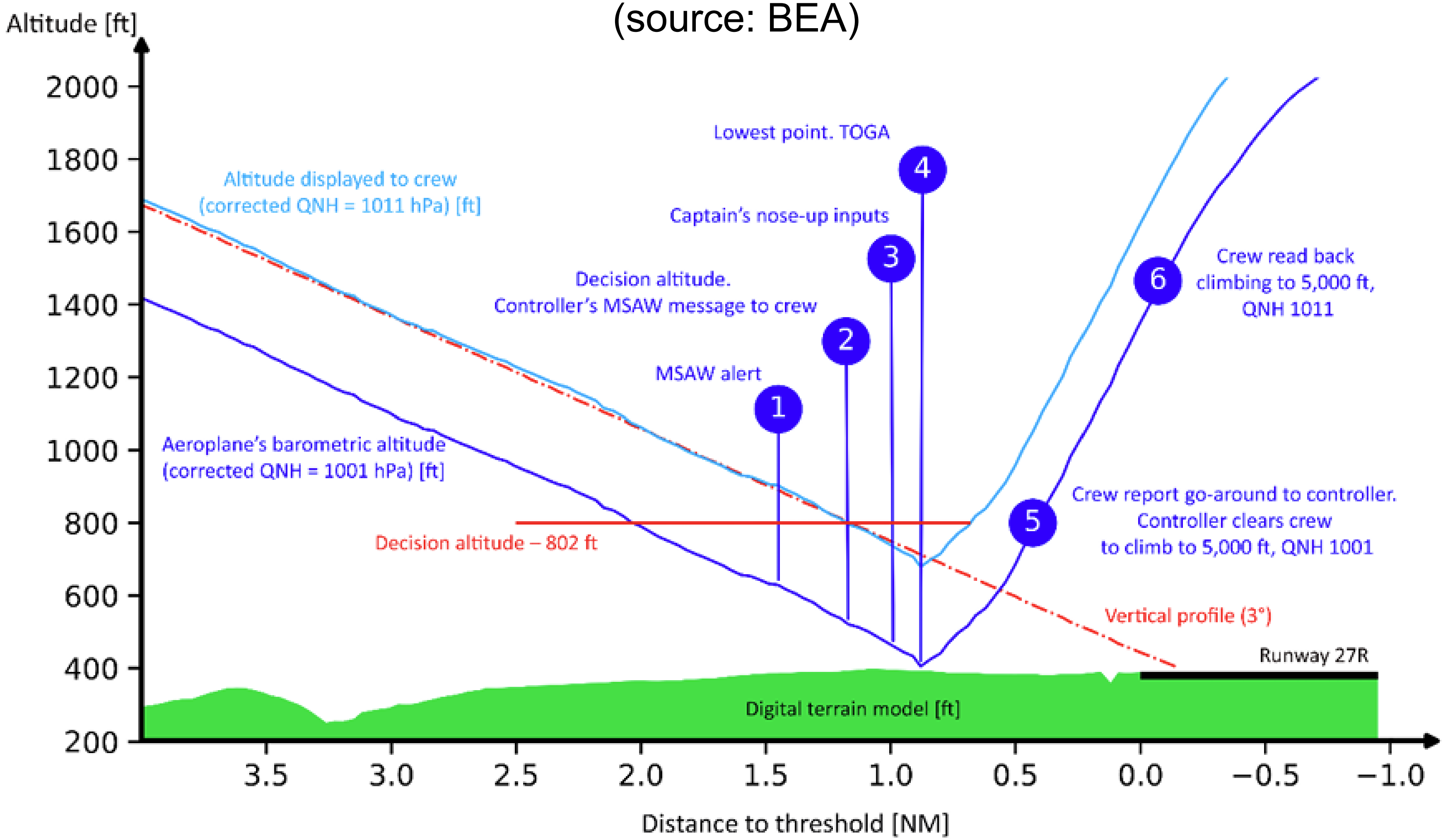
At 11:32:24, when the aeroplane was on approach to CDG, the intermediate controller cleared the crew to descend to 6,000 ft and gave them an incorrect QNH value of 1011 hPa instead of 1001 hPa in force at the time3: “Red Nose 4 3 1 1 descend ... descend … 6,000 feet 1 0 1 1.” The PM read back the QNH provided: “6,000 feet 1 0 1 1 ... 1 ... 0 1 1 … Red Nose 4 3 1 1.”

At 11:34:28, she cleared the crew to descend to 5,000 ft, repeating the incorrect QNH, and clearing them for the RNP approach. “Red Nose 4 3 1 1 descend 5,000 feet 1 0 1 1 cleared full R N P 2 7 right.” The PM read back the information and the incorrect QNH: “Descend 5,000 feet Q N H 1 0 1 1 cleared full R N P approach 2 7 right Red Nose 4 3 1 1.”

At 11:35:37, the ITM controller cleared an easyJet crew to descend to 5,000 ft and gave them the same incorrect QNH: “Easy 7 5 Mike Alpha direct Papa Golf 6 5 0 … and descend 5,000 ft 1 0 1 1 cleared RNP approach 2 7 right.” The easyJet crew did not correctly read back the message as they read back the valid QNH of 1001 hPa: “Direct to Papa Golf 6 5 0 descend 5,000 ft QNH 1 0 0 1 Easy 7 5 Victor Alpha.” This was not picked up by the controller.

Case Study

(source: BEA)



Case Study

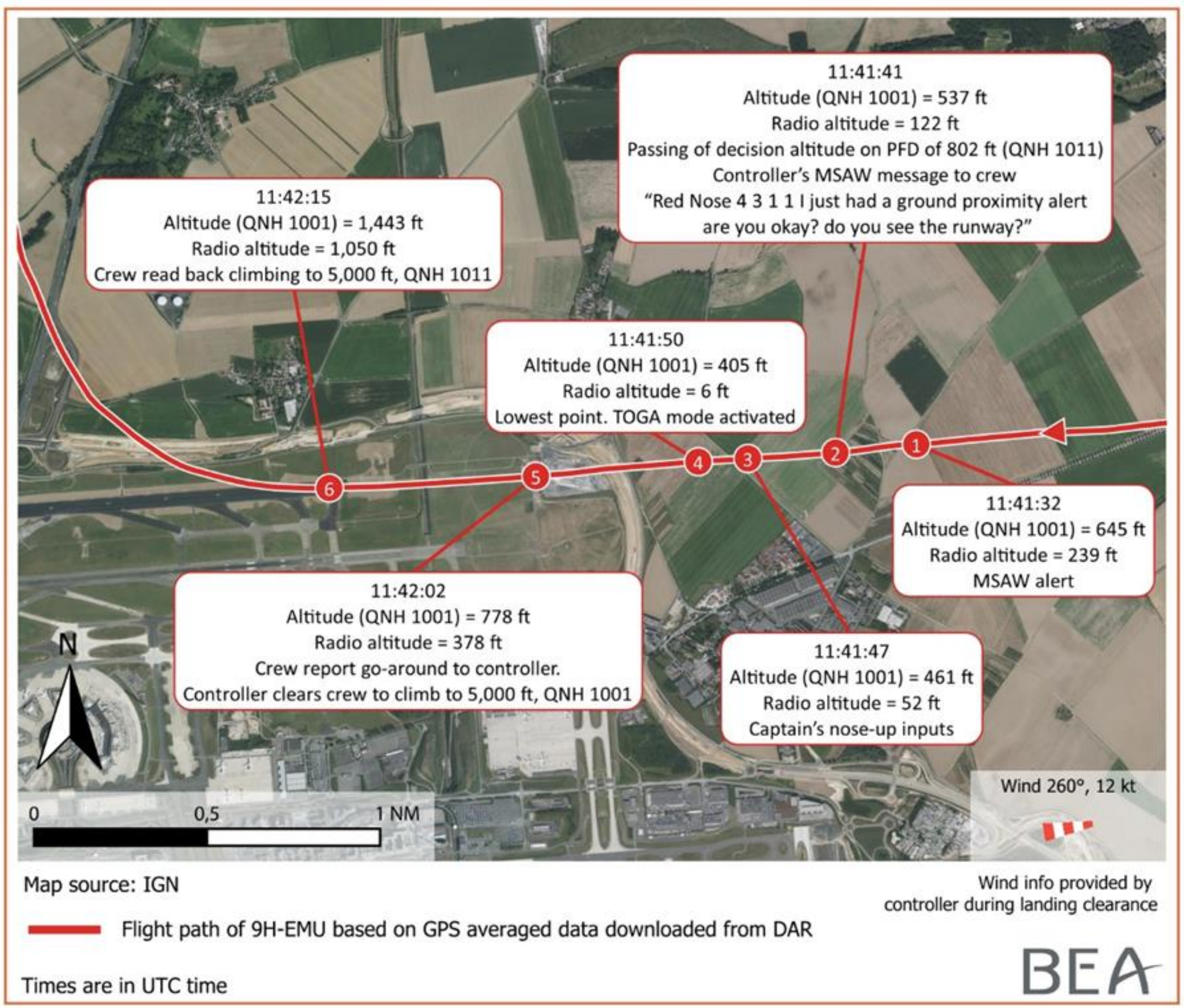


Figure 2: horizontal profile of first approach (source: BEA)

Case Study

The main decision is the following :

On aerodromes open to public air traffic:
*- the decision heights (DH) of the **LNAV/VNAV operational minima** associated with the RNP APCH procedures determined in accordance **are increased by 100 feet**, but not more than the minimum descent height (MDH) value of the LNAV minima associated with the same RNP APCH procedure;*

*- the minimum value of the DHs associated with the RNP **AR** APCH procedures is not less than 350 feet;*

- the runway visual range (RVR) values of the LNAV/VNAV minima associated with the RNP APCH procedures and the RNP AR APCH procedures shall be increased by applying the rules in ...

Q&A?

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Thank You


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South American (SAM) Office Lima
ICAO Headquarter Montreal
Western and Central African (WACAF) Office Dakar
European and North Atlantic (EUR/NAT) Office Paris
Middle East (MID) Office Cairo
Eastern and Southern African (ESAF) Office Nairobi
Asia and Pacific (APAC) Office Bangkok
ICAO Asia Pacific Flight Procedure Programme (APAC FPP)