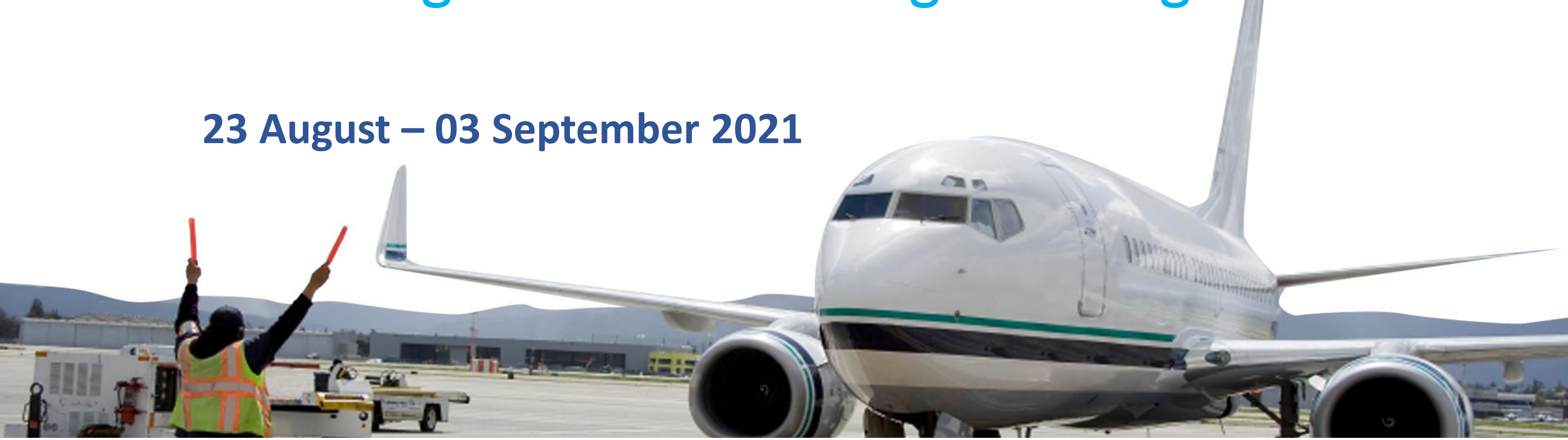
PANS-OPS Flight Procedure Design Training for CAAs

23 August – 03 September 2021



04 – Tolerance and protection area

(GNSS sensor only)

(Doc. 8168, vol. 2, Part III, Section 1, Chap. 1 & 2)

Content

1. General
2. Waypoint tolerances
3. The Total System Error (TSE)
4. Protection area width

Objectives:

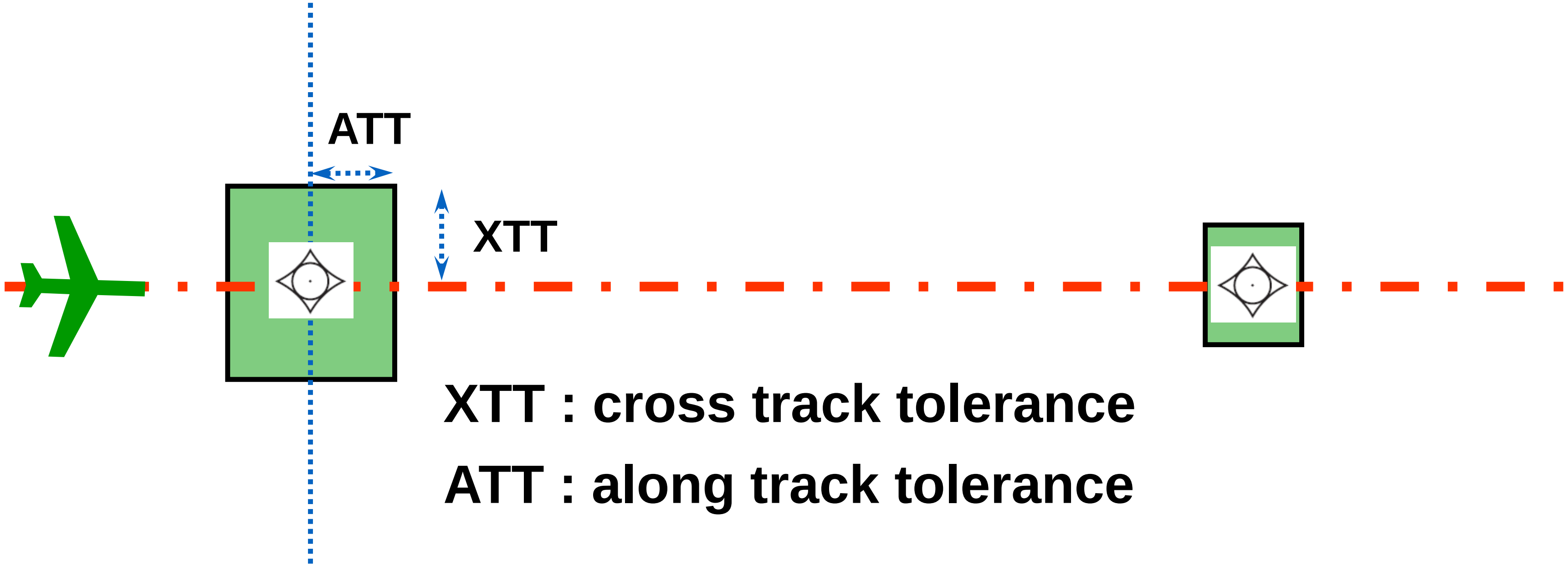
- Know how :
  - to calculate RNAV and RNP tolerances;
  - To protect the PBN segments for all navigation specifications.

PBN performance criteria:

- Accuracy (TSE);
- Integrity;
- Continuity.

Fix tolerances

- The fix tolerance represents where A/C is assumed to be regarding the fix position and the **ACCEPTABLE PROBABILITY;**
- The **tolerance** addresses a 2 SD (standard deviation) value.



XTT : cross track tolerance

ATT : along track tolerance

The Total System Error (TSE)

PDE : Path Definition Error

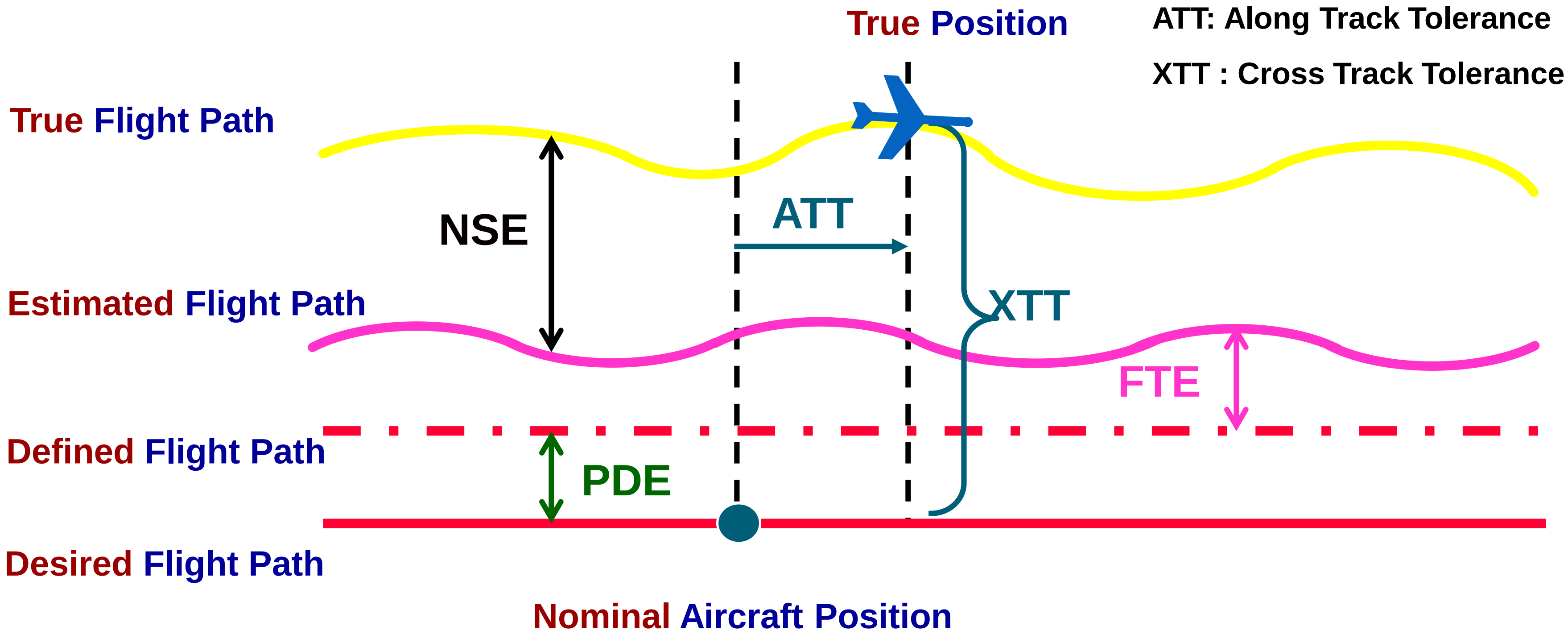
FTE : Flight Technical Error

NSE : Navigation System Error

ATT: Along Track Tolerance

XTT : Cross Track Tolerance

Lateral deviation



XTT = TSE

Calculating the TSE

- TSE = Root Sum Square (RSS) of different errors (NSA, FTE, PDE, etc.).
- TSE defined for each navspec:
  - ☞ NSE depends on the system performance:
    - NSE= 0.08 NM for GNSS
    - NSE for VORDME or DME/DME vary
  - ☞ FTE is a fixed value per navigation specification:
    - For RNAV, FTE = ½ required navigation accuracy
    - For RNP ≥ 0.5, FTE = ½ RNP
    - For RNP ≤ 0.5, FTE = 463 m (0.25 NM)
  - ☞ PDE corresponds to the system computation tolerance ST and is a fixed value 0.25 NM

Flight Technical Error (FTE)

- ❑ Ability to follow the defined path
  - ☞ FTE in manual mode (Pilot follows the deviation from the CDI)
  - ☞ FTE with the FD
  - ☞ FTE of the Autopilot
- ❑ Error depends on the flight phase (sensibility of the deviation indicator, AP ....)

Flight phase	Manual (NM)	Coupled	
		Flight Director (NM)	Autopilot (NM)
Oceanic	2.0	0.5	0.25
En-route	1.0	0.5	0.25
Terminal	1.0	0.5	0.25
Approach	0.5	0.25	0.125

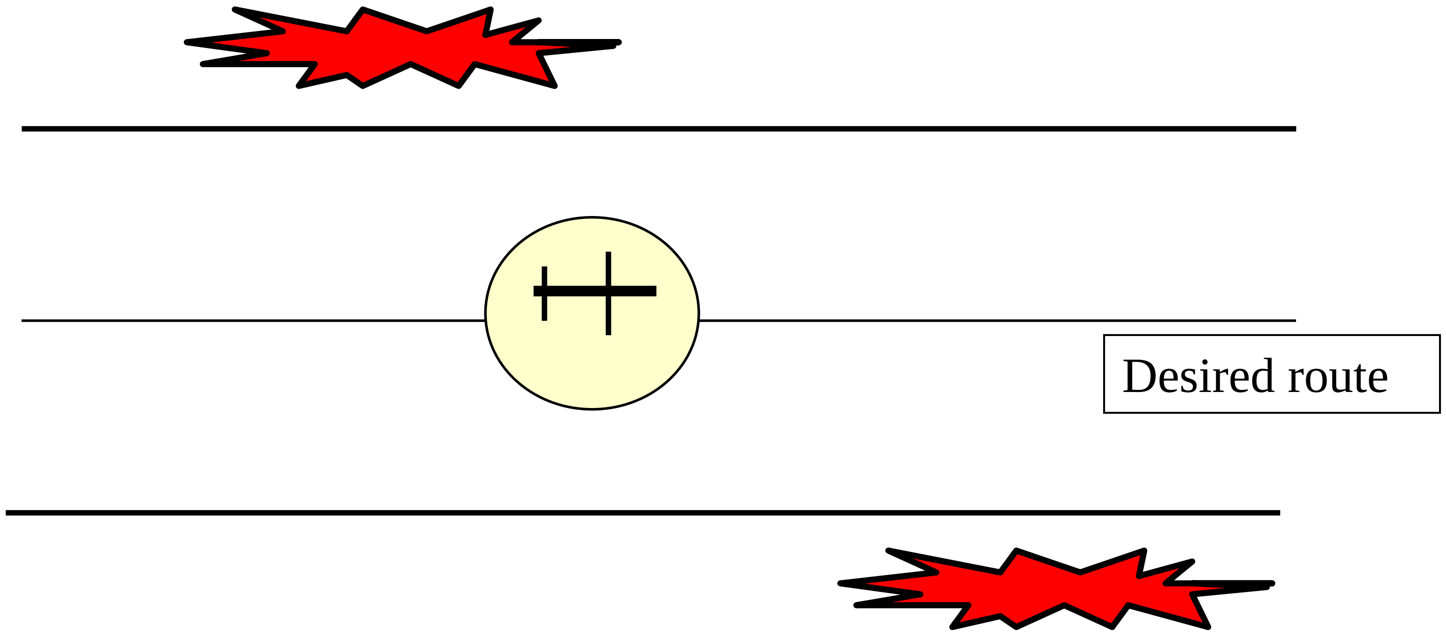
Navigation System Error (NSE)

- ❑ Difference between the estimated position and the real position;
- ❑ Takes into account:
  - ☞Transmitted Signal error;
  - ☞Position calculation error.

Path Definition Error (PDE)

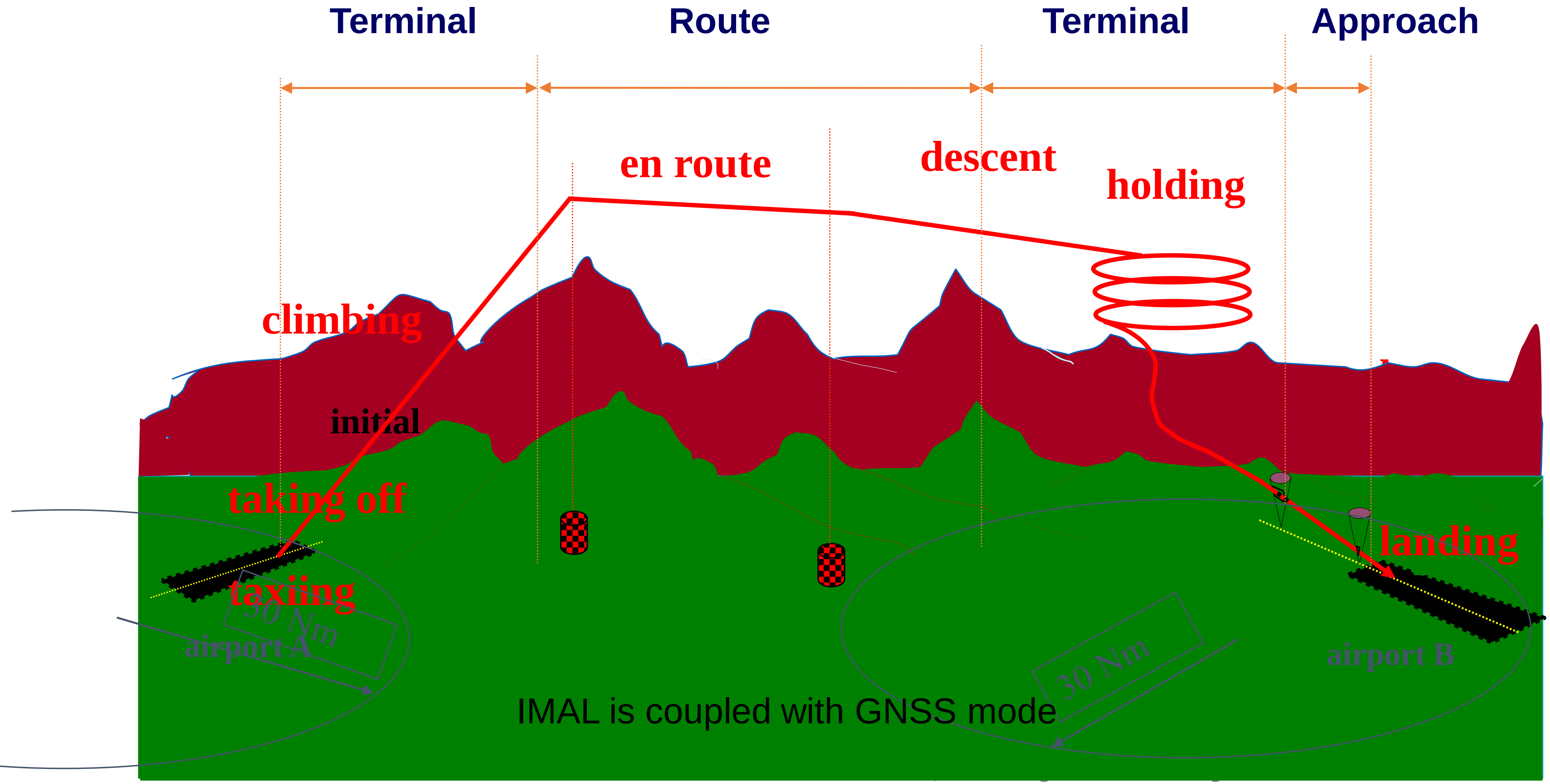
- Errors between the desired path and the defined path;
- Waypoint coordinates in WGS 84;
- Possible Error Source:
  - Errors in the defined coordinates of the WPt;
  - Misinterpretation of the source by the data base encoder;
  - Errors induced by data resolution must also be considered.
- PDE is managed through a quality process and development methodology in data processing (coding process):
  - DO 200A
  - LOA Type 1 and 2
- The end user is the operator:
  - He has to assess that adequate development methodology has been applied;
  - Crew procedures to check that what is encoded is what is published.

IMAL : Integrity Monitoring Alarm Limit



- IMAL allows AIRCREW to DETECT that the SIGNAL IN SPACE (NSE) is not achieving the navigation PERFORMANCE REQUIRED
- IMAL value depends on the GNSS MODE which corresponds to the PHASE OF FLIGHT

GNSS mode


Terminal
Route
Terminal
Approach
en route
descent
holding
climbing
initial
taking off
taxiing
landing
30 Nm
airport A
30 Nm
airport B
IMAL is coupled with GNSS mode

XTT and ATT calculations

RNP APPLICATION → ATT = 0.8 XTT; XTT = TSE = RNP

GROUND BASED SENSOR → ATT = $\sqrt{NSE^2 + ST^2}$; XTT = $\sqrt{NSE^2 + FTE^2 + ST^2}$

RNAV APPLICATION

GNSS SENSOR → ATT = 0.8 x XTT; XTT = IMAL or $\sqrt{NSE^2 + FTE^2 + ST^2}$

Buffer Values (BV)

Phase of flight	BV for Cat. A to E (NM)	BV for Cat. H (NM)
En-route (> 30 NM from departure or destination ARP)	2.0	1.0
Terminal (STARs, Initial and intermediate Approaches within 30 NM to ARP; SIDs and missed approaches within 30 NM from ARP but more than 15 Nmfrom ARP)	1.0	0.7
Final Approach	0.5	0.35
Missed Approach and SIDs ≤ 15 NM ARP	0.5	0.35

Area Width (AW) calculations

- Semi area width is based on 3σ standard deviation
  - ☞ 2 σ value corresponds to XTT;
  - ☞ 3 σ value corresponds to 1/2 A/W:

$$^{1/2}\ A/W = 1.5\ XTT + BV$$

- Why Buffer Value (BV)?
  - ☞ to cater for BLUNDER ERRORS
  - ☞ to cater for TAIL OF DISTRIBUTION
- Buffer Value depends on:
  - ☞ PHASE OF FLIGHT
  - ☞ AIRCRAFT characteristic (helicopter or airplane)

Protection area width

Navigation specification		RNP	FTE	IMAL	ATT	XTT	BV	1/2AW
RNP4	En route	4	2		3.2	4	2	**8**
RNP1	More than 30 Nm from ARP	1	0.5		0.8	1	2	**3.5**
	< 30 Nm ARP	1	0.5		0.8	1	1	**2.5**
	SID<15 NM ARP	1	0.5		0.8	1	0.5	**2**
RNP APCH	< 30 Nm ARP	1	0.5		0.8	1	1	**2.5**
	FAF	0.3	0.25		0.24	0.3	1	**1.45**
	MAPT	0.3	0.25		0.24	0.3	0.5	**0.95**
	MA <15 NM	1	0.5		0.8	1	0.5	**2**

RNP APPLICATION → ½ AW= 1.5 x XTT + BV

ion area width

ight Procedure Programme (AFPP)

Navigation specification		RNP	FTE	IMAL	ATT	XTT	BV	1/2AW
RNAV5	En route		2.5	2	2.01	2.51	2	5.77
RNAV2	Plus de 30 Nm ARP		1	2	1.6	2	2	5
	< 30 Nm ARP		1	1	0.8	1	1	2.5
	SID <15 NM ARP		1	1	0.8	1	0.5	2
RNAV1	greater than 30 Nm ARP		0.5	2	1	2	2	5
	< 30 Nm ARP		0.5	1	0.8	1	1	2.5
	SID<15 NM ARP		0.5	1	0.8	1	0.5	2

RNAV APPLICATION
With GNSS sensor

$\frac{1}{2}$ AW= 1.5 x XTT + BV

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Navigation specification		RNP	FTE	IMAL	ATT	XTT	BV	1/2AW
RNP4	En route	4	2		3.2	4	2	8
RNAV5	En route		2.5	2	2.01	2.51	2	5.77
RNP1	More than 30 Nm from ARP	1	0.5		0.8	1	2	3.5
	< 30 Nm ARP	1	0.5		0.8	1	1	2.5
	SID<15 NM ARP	1	0.5		0.8	1	0.5	2
RNAV2	Plus de 30 Nm ARP		1	2	1.6	2	2	5
	< 30 Nm ARP		1	1	0.8	1	1	2.5
	SID <15 NM ARP		1	1	0.8	1	0.5	2
RNAV1	greater than 30 Nm ARP		0.5	2	1.6	2	2	5
	< 30 Nm ARP		0.5	1	0.8	1	1	2.5
	SID<15 NM ARP		0.5	1	0.8	1	0.5	2
RNP APCH	< 30 Nm ARP	1	0.5		0.8	1	1	2.5
	FAF	0.3	0.25		0.24	0.3	1	1.45
	MAPT	0.3	0.25		0.24	0.3	0.5	0.95
	MA <15 NM	1	0.5		0.8	1	0.5	2

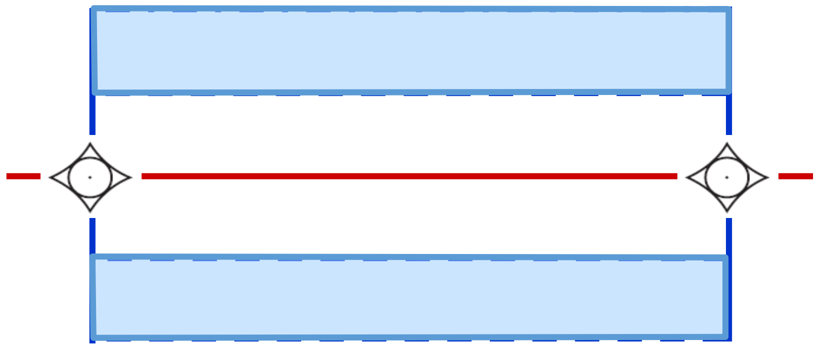
For RNAV NAVIGATION SPECIFICATION ,values in the table are applicable for airplane and for GNSS sensor only

Protection area width

- Area Width global methodology:
  - ☞Whatever the navigation application is, area width depends on two elements:
    - XTT
    - BV
  - ☞Where NEITHER XTT NOR BV are changing:
    - Area width is a CORRIDOR
  - ☞Where at least one of the two elements changes, to calculate the area width, three questions are to be answered:
    - Question 1 : AT THE LOCATION where XTT is changing which value is taken into account for area width calculation ?
    - Question 2 : AT THE LOCATION where BV is changing which value is taken into account for area width calculation ?
    - Question 3 : How to CONNECT the two areas ?

Area Width global methodology: Straight area

- Primary & secondary area apply:
  - Where no no change of flight phase nor XTT:
    - Area is a corridor



Area Width at the location where XTT changes:

- AT THE LOCATION where XTT is changing which value is taken into account for area width calculation?
  - First case :
    - When PRECEDING area width is LARGER than the SUBSEQUENT one.
  - Second case :
    - When PRECEDING area width is SMALLER than the SUBSEQUENT one.
  - What are the conditions that induce the change of XTT?
    - Change of value of RNP;
    - Change of accuracy for RNAV application.

Area Width at the location where XTT changes:

- First case: When PRECEDING accuracy value is LARGER than the SUBSEQUENT one :
  - Assumption:
    - At the point where the change of RNP / accuracy is required, the RNP/ accuracy is achieved.
    - Conclusion and answer to the question :

AT the LOCATION where ACCURACY is changing, take the MOST ACCURATE so the SMALLEST XTT

- Example:
  - At FAF RNP changes from 1 to 0.3 NM
  - For RNP application : XTT= RNP
    - **XTT_{FAF} = 0.3 NM**

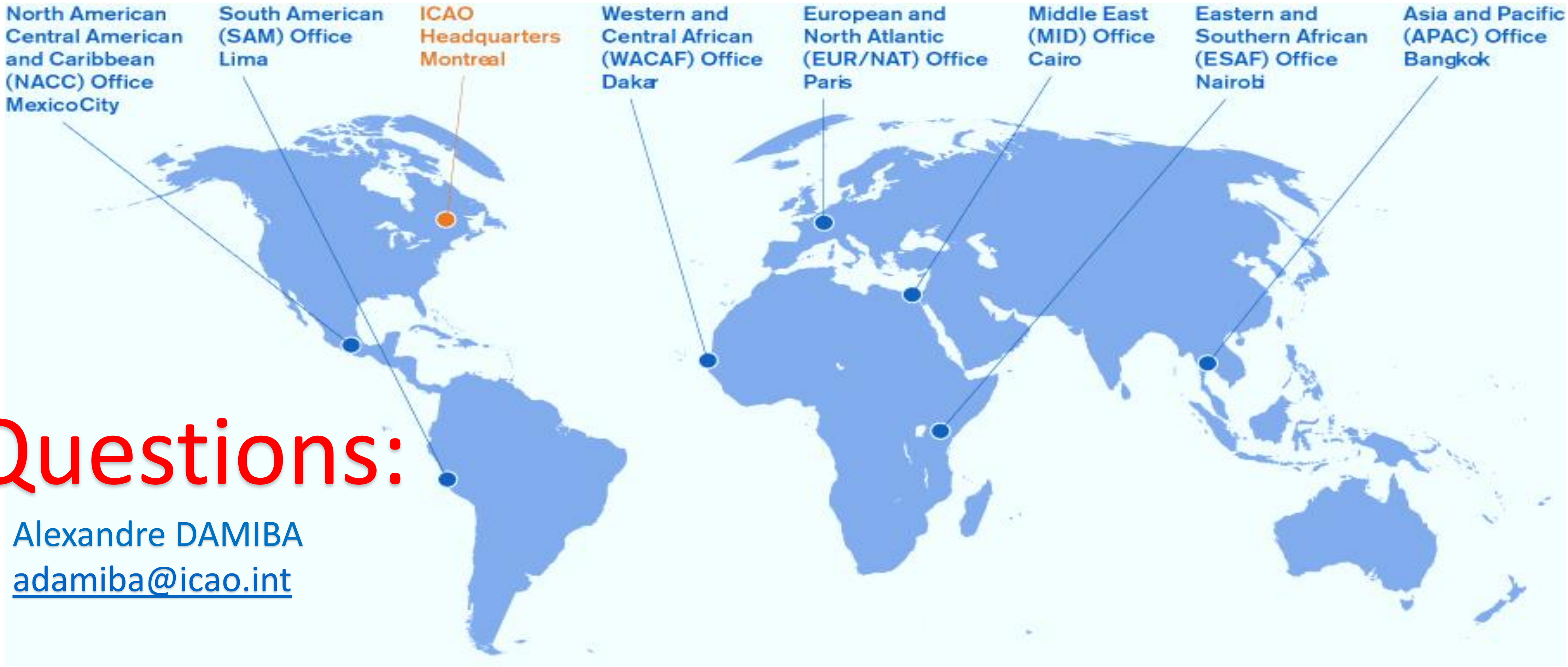
Area Width at the location where BV changes:

- Calculation for the FAF :
  - At the FAF, BV id changing from 1 to 0.5 NM

AT THE LOCATION where BV is changing, take the BV of the PRECEDING phase.

BV = 1 NM

$^{1/2}$AW = 1.5*0.3+1 = 1.45



Questions:

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