PANS-OPS Flight Procedure Design Training for CAAs

23 August – 03 September 2021

10 – APV Baro-VNAV

(Doc. 8168, Vol. 2, Part III, Section 3, Chap. 4)

Outlines

1. General
2. Standard conditions
3. APV segment
4. APV OAS
5. Obstacles Assessment
6. Promulgation

General

- APV baro-VNAV procedure:
  - An Approach Procedure with Vertical guidance in support of Type A 3D approach operations;
  - FAP instead of FAF (but FAF needed for other purposes);
  - DA/H not an MDA/H
  - No MAPt (but MAPt needed for other purposes);
  - Use THR coordinates system;
  - Used in association with LNAV only procedures;
  - HL instead of MOC for the APV segment;
  - Not allow with a Remote Altimeter Setting Source.

General

- Baro-VNAV key features:
  - Includes cold temperature correction;
  - Has a minimum promulgated temperature;
  - Can have a maximum promulgated temperature;
  - Cannot be used with remote altimeter setting;
  - Area defined by underlying LNAV area;
  - Identified in the minimum box by:
    - "LNAV/VNAV".
  - The final approach segment should be aligned with the extended centre line of the runway.

Standard conditions

- Vertical Path Angle (VPA):
  - Effective VPA deepends on temperature and aerodrome elevation;
    - Published VPA may differ from Effective VPA;
    - Effective VPA tabulated as a function of aerodrome elevation and temperature.
  - Effective VPA :
    - Minimum ≥ 2.5° at the lowest prevailing temperature;
    - Maximum ≤ 3.5° at the highest prevailing temperature.
- A procedure with a promulgated VPA >3.5° is a non-standard procedure:
  - Subject to an aeronautical study;
  - Require special approval by competent authority.

Standard conditions

- FAP should not be located more than 10 NM before THR;
- VPA between 2.5° and 3.5°;
- RDH: 15 m;
- Final axis = RWY axis (max turn at FAF 15°).

Table III-3-4-1. Effective vs promulgated VPA as a function of aerodrome elevation and temperature (Green = optimum; Yellow = non-standard; Orange = prohibited)

Temp (C°)	*Promulgated VPA 2.8°*			*Promulgated VPA 3.0°*			*Promulgated VPA 3.2°*		
	Aerodrome elevation			*Aerodrome elevation*			*Aerodrome elevation*		
	MSL	*3 000 ft*	*6 000 ft*	*MSL*	*3 000 ft*	*6 000 ft*	*MSL*	*3 000 ft*	*6 000 ft*
50	3.14	3.21	3.28	3.37	3.44	3.51	3.59	3.67	3.75
40	3.05	3.11	3.18	3.26	3.33	3.40	3.48	3.55	3.63
30	2.95	3.01	3.07	3.16	3.22	3.29	3.37	3.44	3.51
20	2.85	2.91	2.97	3.05	3.12	3.18	3.26	3.32	3.40
10	2.75	2.81	2.87	2.95	3.01	3.07	3.14	3.21	3.28
0	2.65	2.71	2.77	2.84	2.90	2.96	3.03	3.10	3.16
-10	2.55	2.61	2.66	2.74	2.79	2.85	2.92	2.98	3.04

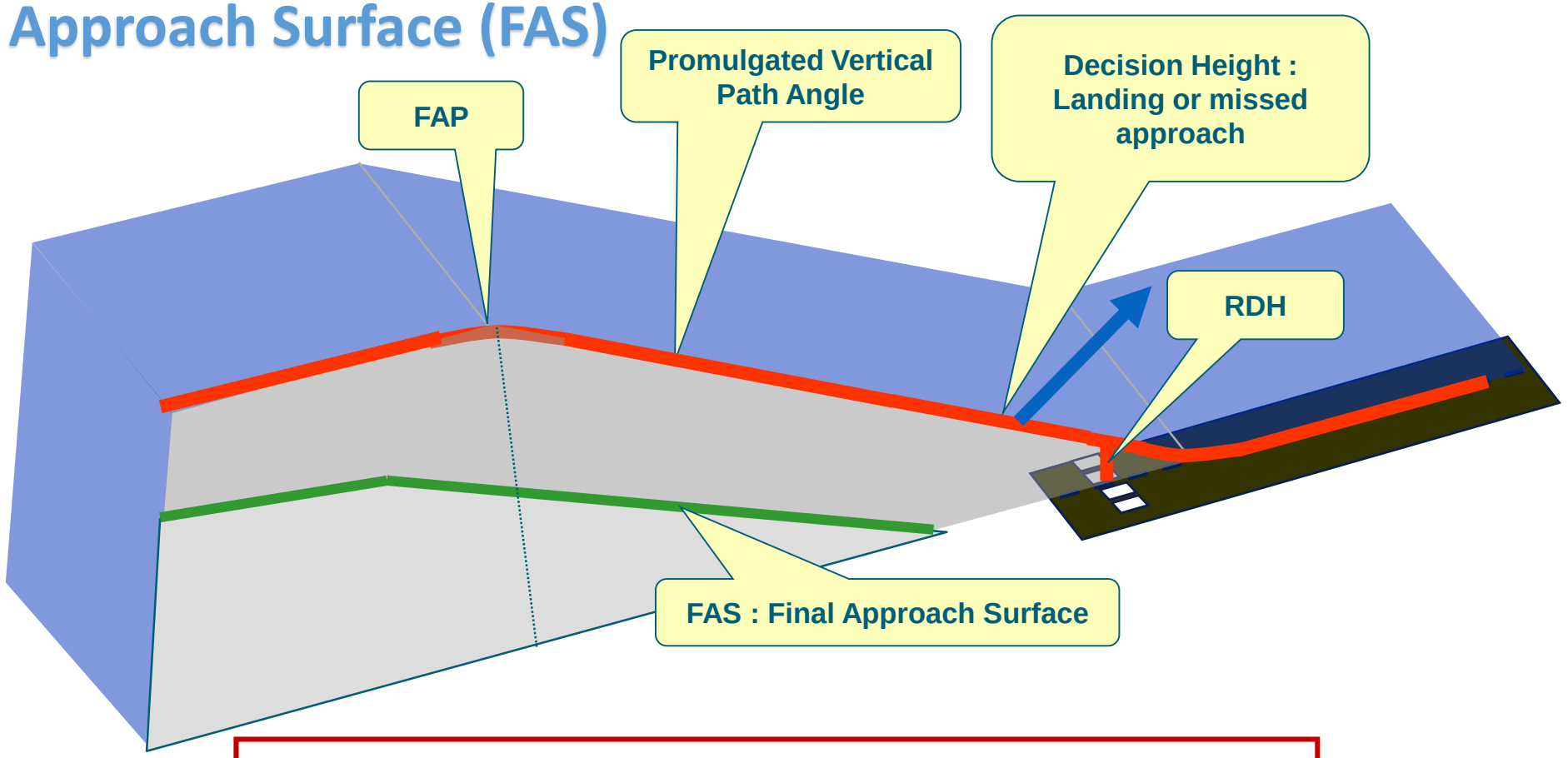
APV segment

- The APV segment for baro-VNAV:
  - Starts at FAP (intersection intermediate altitude and VPA);
  - Ends at MATF, MAHF or the turn altitude.
- The APV segment contains:
  - The final approach segment;
  - The initial and intermediate missed approach segments.
- APV Obstacles Assessment Surfaces (OAS) to be defined for obstacles assessment;
- The LNAV missed approach criteria apply in final missed approach.

APV OAS

- APV segment has 3 surfaces:
  - Final Approach Surface (FAS);
  - Horizontal/ Ground Plane;
  - Missed approach surface (Z).
- Each surface split in :
  - Central surface bounded laterally by the LNAV primary area;
  - Side surfaces bounded laterally by the LNAV secondary area.

Final Approach Surface (FAS)



FAS depends on : Hi, VPA, Temperature correction

FAS parameters

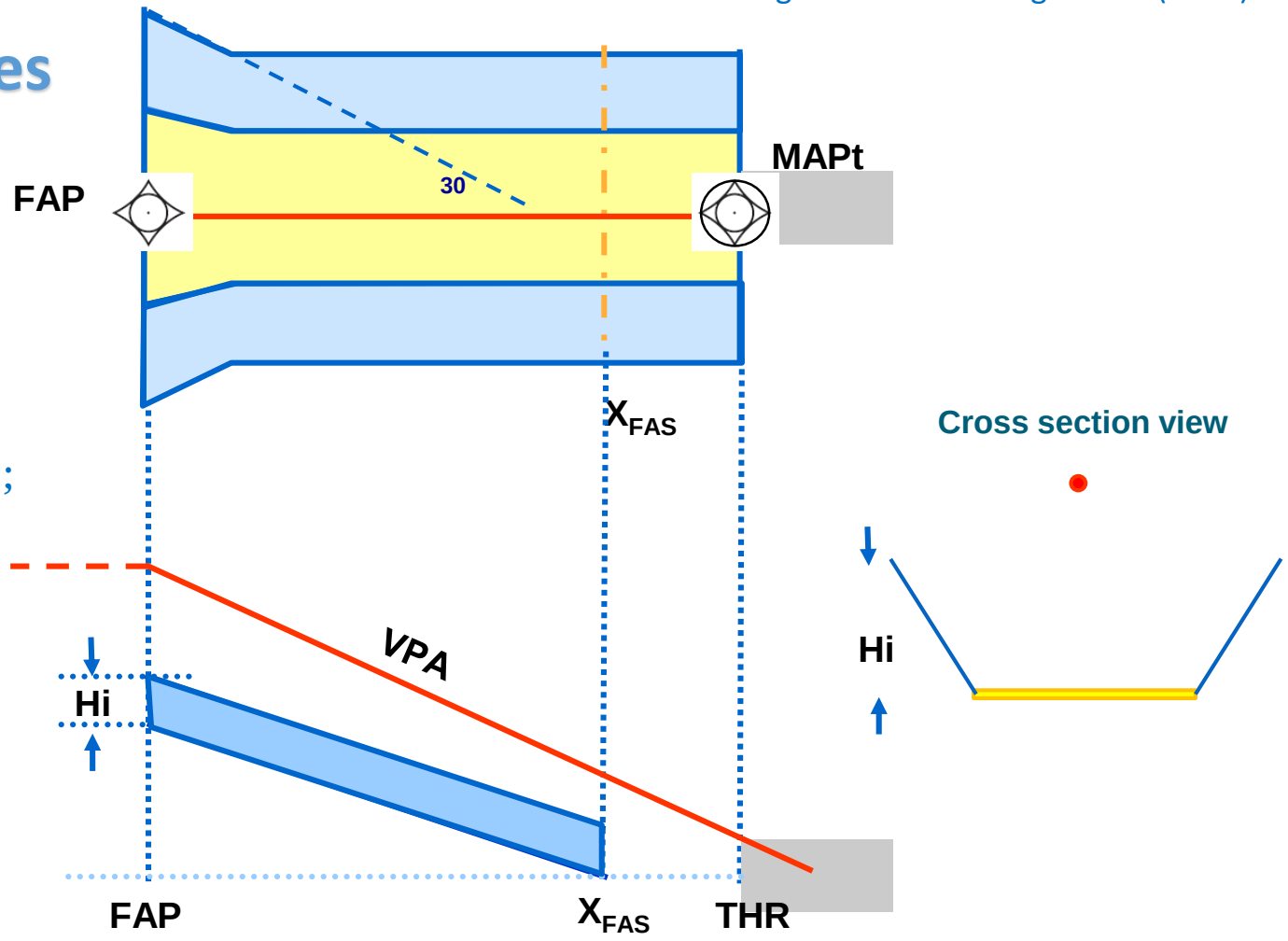
- Lateral : LNAV surface:
  - MAPt at threshold;
  - FAF at FAP;
  - The secondary area of LNAV surfaces become OAS side surfaces.
- Vertical :
  - VPA;
  - Temperature correction : Δh
  - Hi;
  - ATT = 0.8 x RNP(NM)= 444 m

XFAS : Origin of surface at the threshold level
αFAS : Angle of the FAS

FAS central and side surfaces

The value of H_i is as follows:

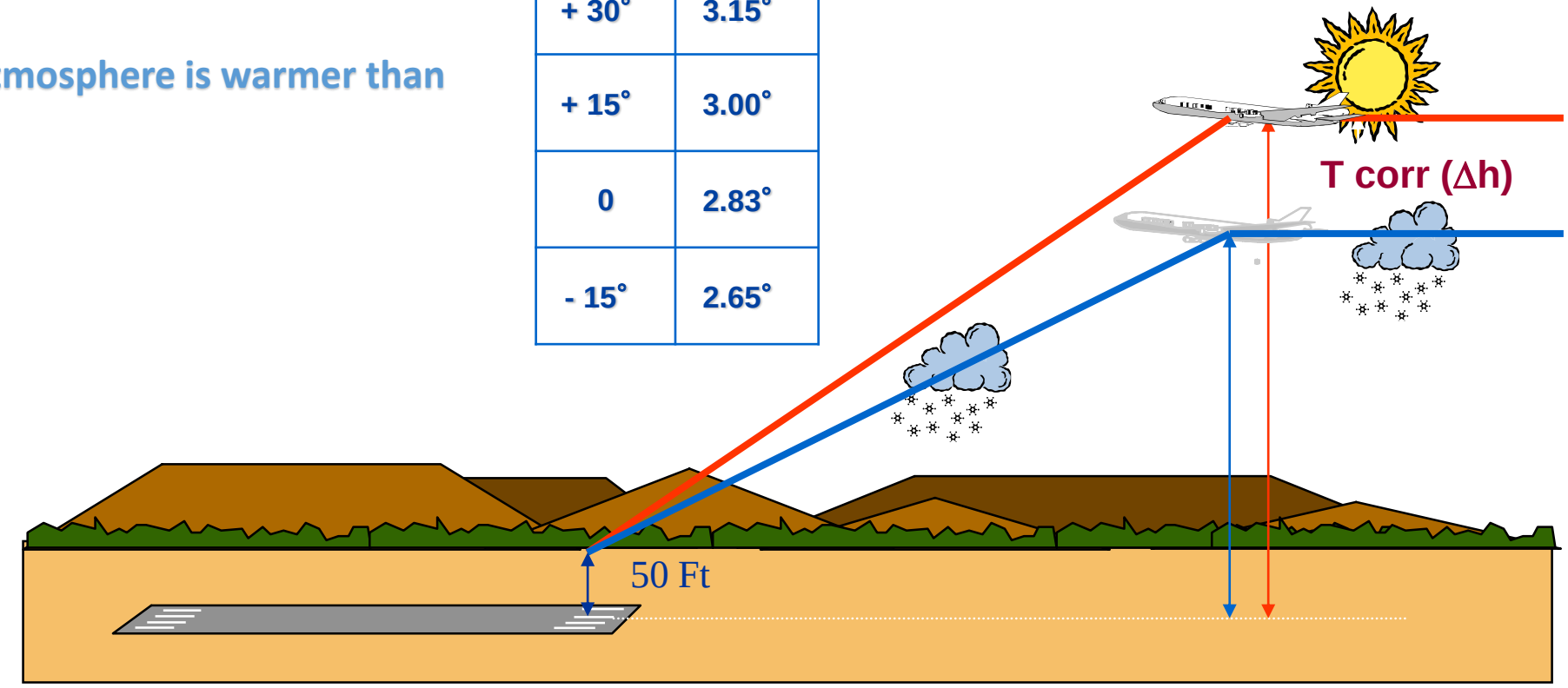
- H_0 = 75 m below 5 000' AMSL;
- $H_{5\,000}$ = 105 m between 5 000' and 10 000' AMSL;
- $H_{10\,000}$ = 120 m at or above 10 000' AMSL.



Temperature impact on the VPA

- Δh is positive when the atmosphere is colder than the standard one;
- Δh is negative when the atmosphere is warmer than the standard one.

A/D TEMP	VPA
+ 30°	3.15°
+ 15°	3.00°
0	2.83°
- 15°	2.65°



Calculation of the temperature correction

$$\Delta h = -\left(\frac{\Delta T_{STD}}{2a}\right) * \ln\left(1 + \frac{Lo * hFAP}{To + Lo * HTHR}\right)$$

ΔT_{STD}	=	temperature deviation from the standard day (ISA) temperature
L_o	=	standard temperature lapse rate with pressure altitude in the first layer (sea level to tropopause) of the ISA (-0.0065°/m)
h_{FAP}	=	procedure height above the threshold at the FAP
T_o	=	standard temperature at sea level (288.15K)
h_{THR}	=	threshold elevation above mean sea level

Δh tabulated in the PANS-OPS

Ex: h_{FAP}= 900m, h_{THR}=300m, Tmin = -20° C

$$\Delta T_{STD} = (273{,}15 - 20) - (-0{,}0065 \times 300)\ -288{,}15 = -33{,}05$$

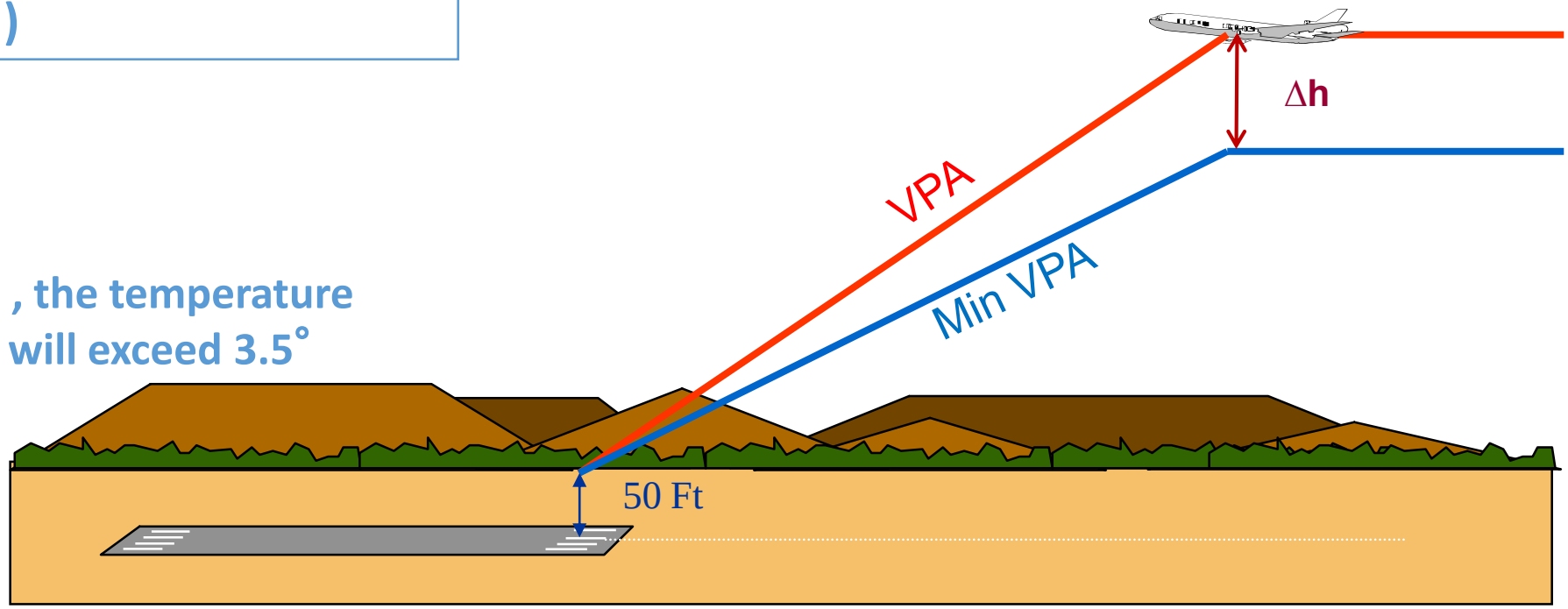
$$\Delta h = -\left(\frac{-33{,}05}{-0{,}0065}\right) \times \ln\left[1 + \frac{-0{,}0065 \times 900}{288{,}15 - 0{,}0065 \times 300}\right] = 105{,}01\text{m}$$

APV OAS: Minimum and maximum VPA checks

If tan(minVPA) < 2.5° :
- Increase VPA (max is 3.5°)

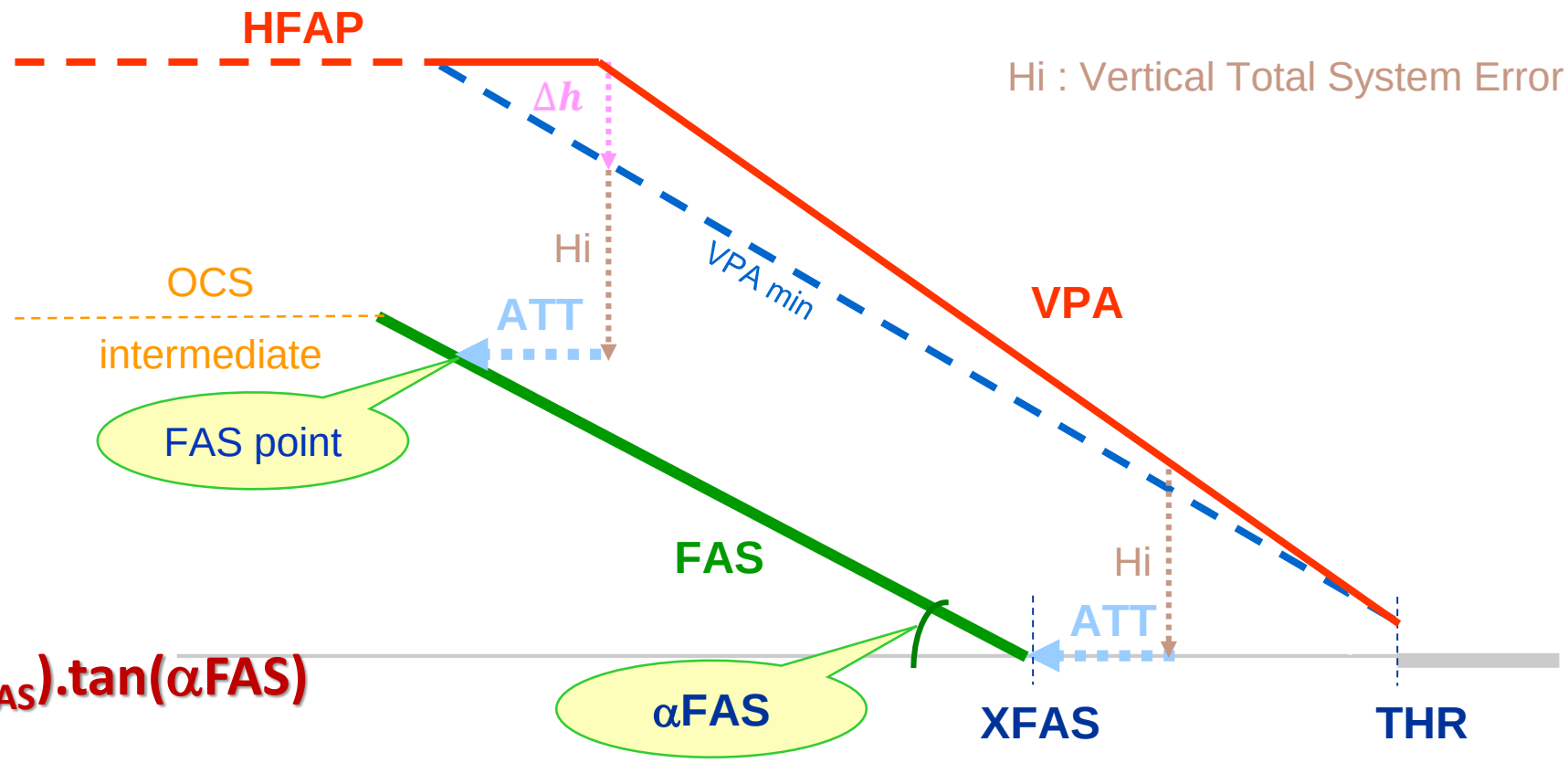
Tan (min VPA) = (Height FAP- Δh - RDH) / D $_{FAP/THR}$

- Define maximal temperature
- Compute Δh (negative value)
- Compute max VPA
- If max VPA is higher than 3.5° , the temperature above which the effective VPA will exceed 3.5° shall be promulgated



Tan (max VPA) = (Height FAP- Δh - RDH) / D $_{FAP/THR}$

FAS calculations



Hi : Vertical Total System Error

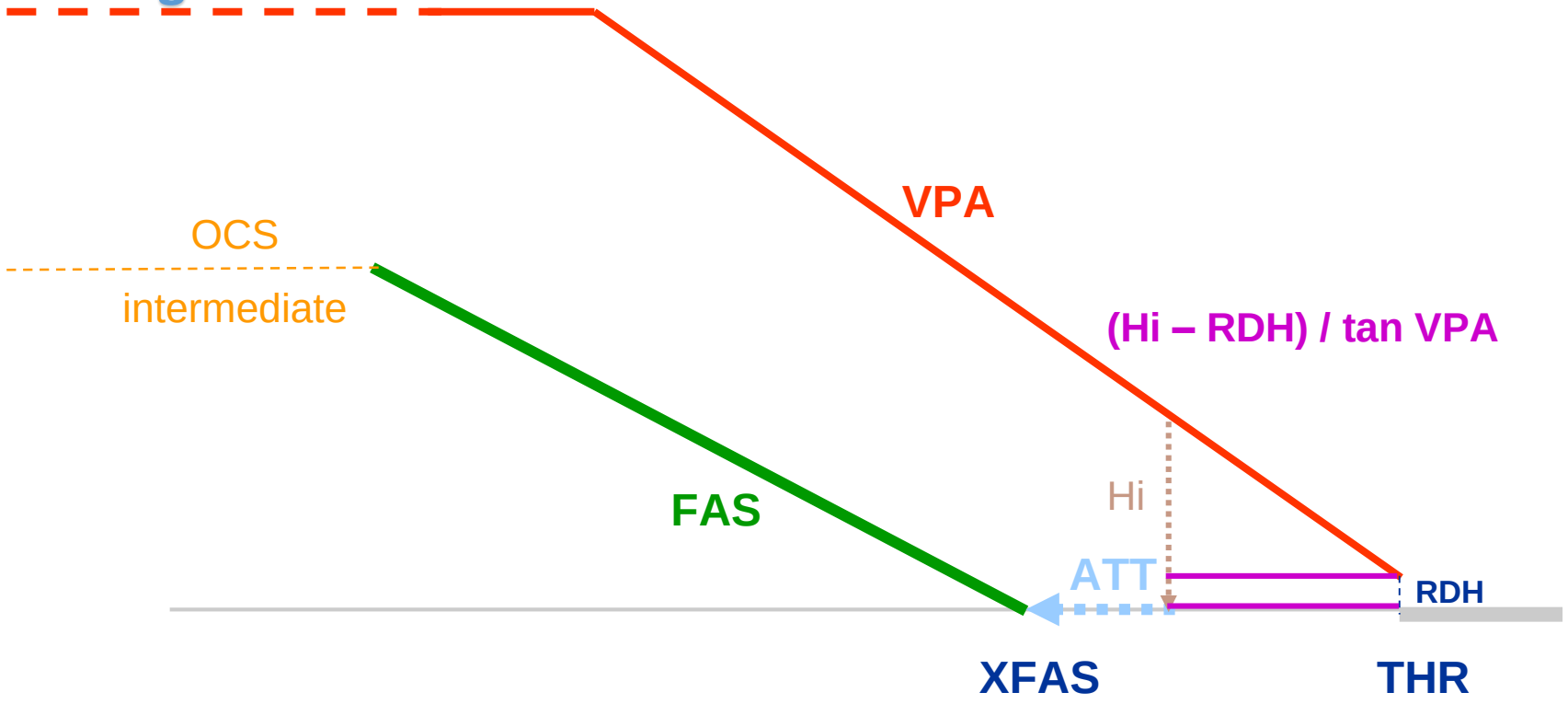
Calculate origin : XFAS

Calculate gradient : αFAS

FAS equation :

$$h(FAS) = (X-X_{FAS}).\tan(\alpha FAS)$$

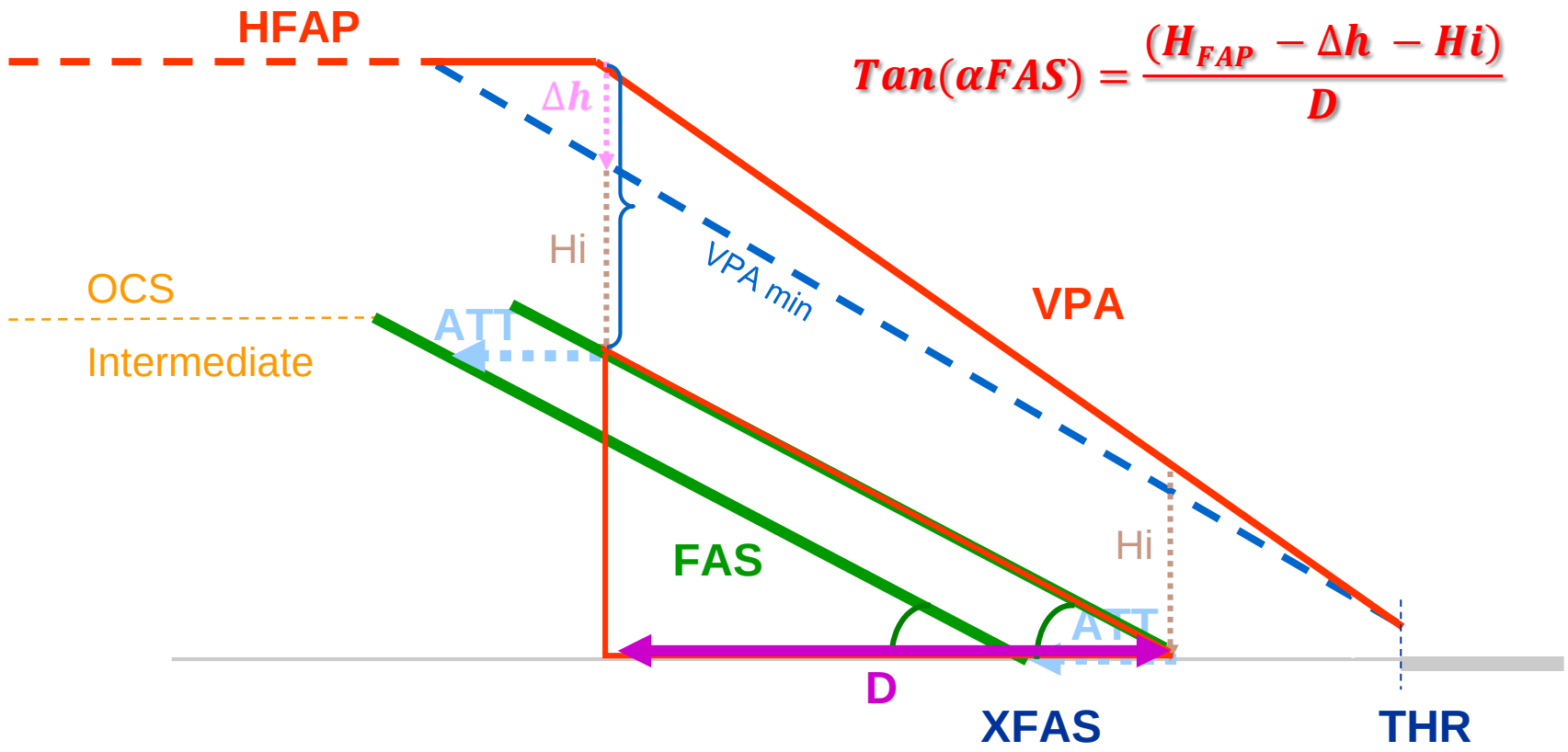
FAS calculations: FAS origin



$$X_{FAS} = [(Hi - RDH) / \tan VPA] + ATT$$

FAS calculations: FAS gradient (αFAS)

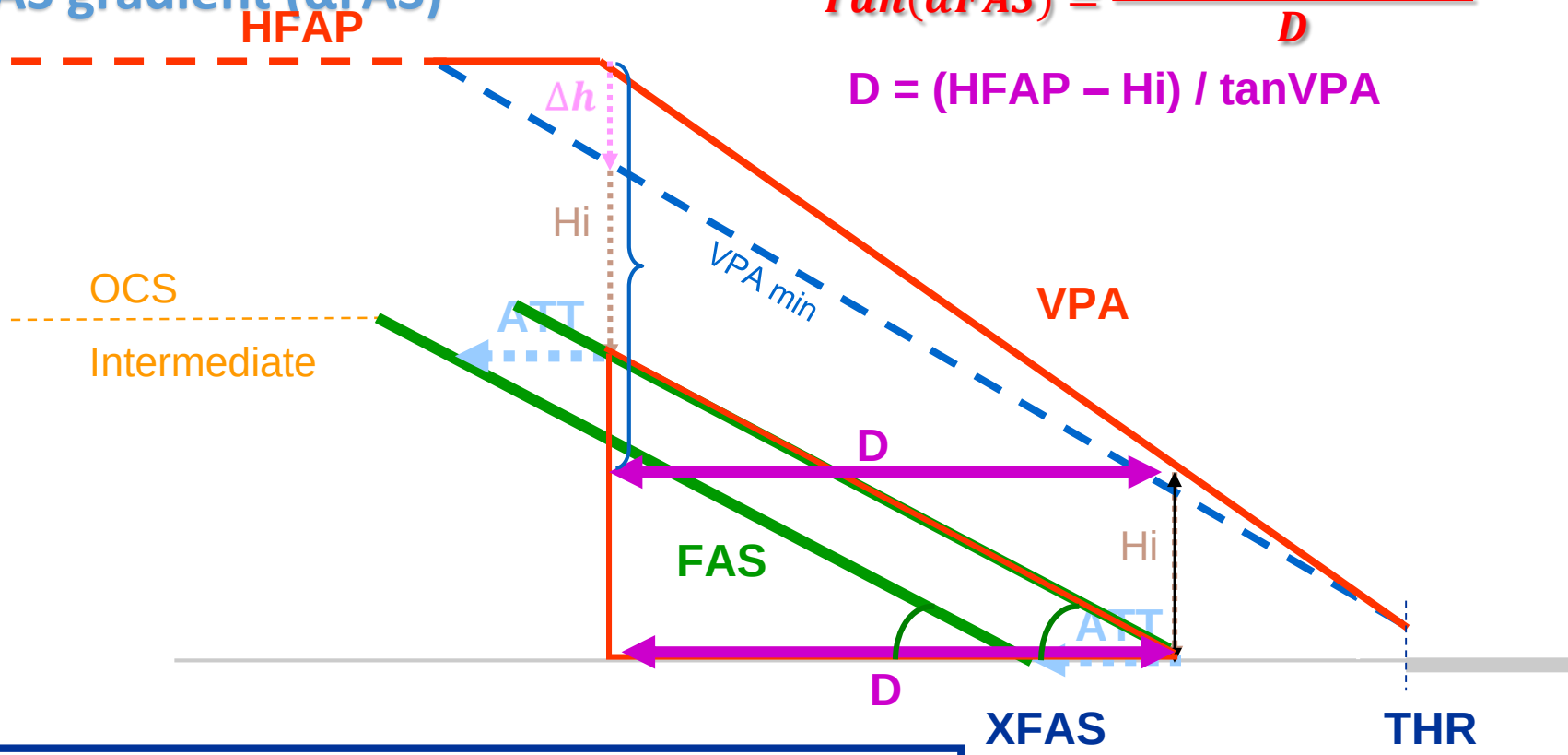
$$Tan(\alpha FAS) = \frac{(H_{FAP} - \Delta h - Hi)}{D}$$



FAS calculations: FAS gradient (αFAS)

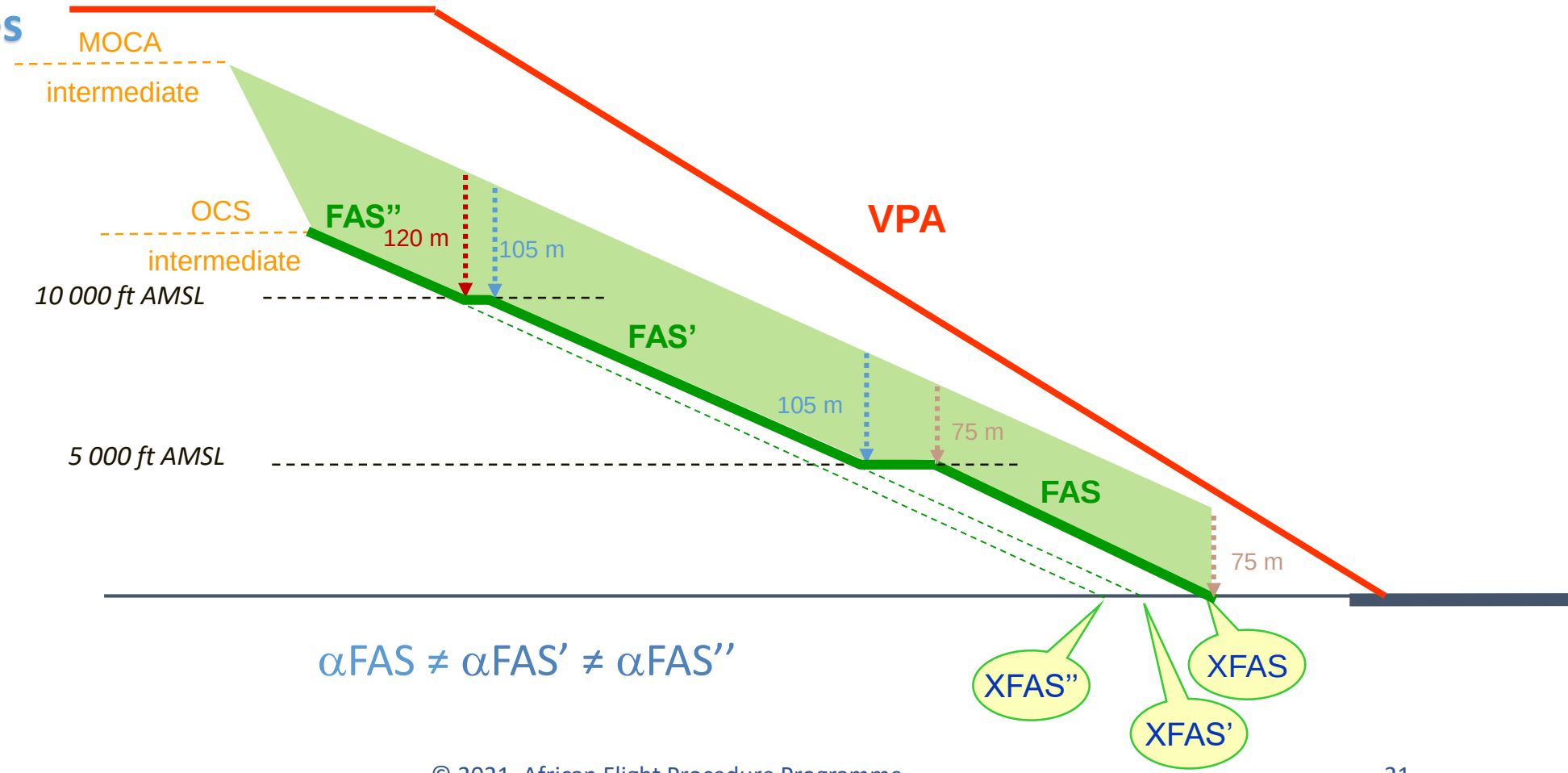
$$Tan(\alpha FAS) = \frac{(H_{FAP} - \Delta h - Hi)}{D}$$

D = (HFAP – Hi) / tanVPA

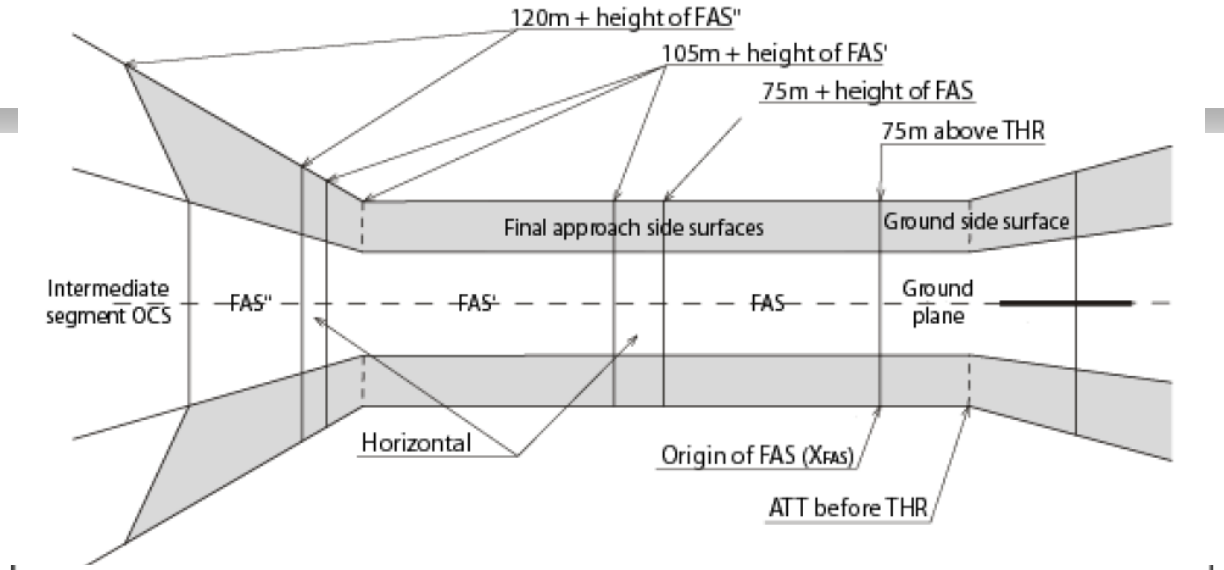


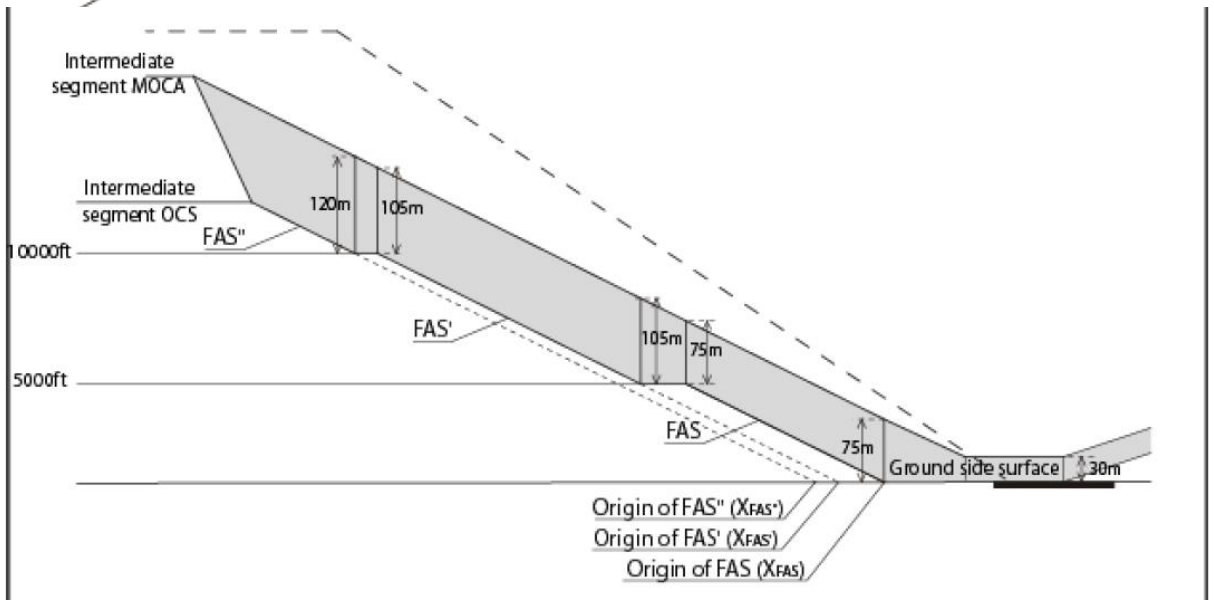
Tan(αFAS) = (HFAP – Δh – Hi) x tanVPA / (HFAP – Hi)

FAS side surfaces



APV OAS





FAS Summary

- Data :
  - ALT FAP
  - ALT THR
  - MIN TEMPERATURE
  - MAX TEMPERATURE
  - VPA
  - CAT Aircraft
  - RDH
- Calculations:
  - Calculate Δh
  - Check VPA min
  - Check VPA max
  - Calculate FAS Origin :
  - Xfas (Xfas' and Xfas'' if needed)
  - Calculate FAS gradient :
  - αFAS (αFAS' and αFAS'' if needed)

Height of FAS surface at range X : $h_{FAS} = (X - X_{FAS}).\tan \alpha_{FAS}$

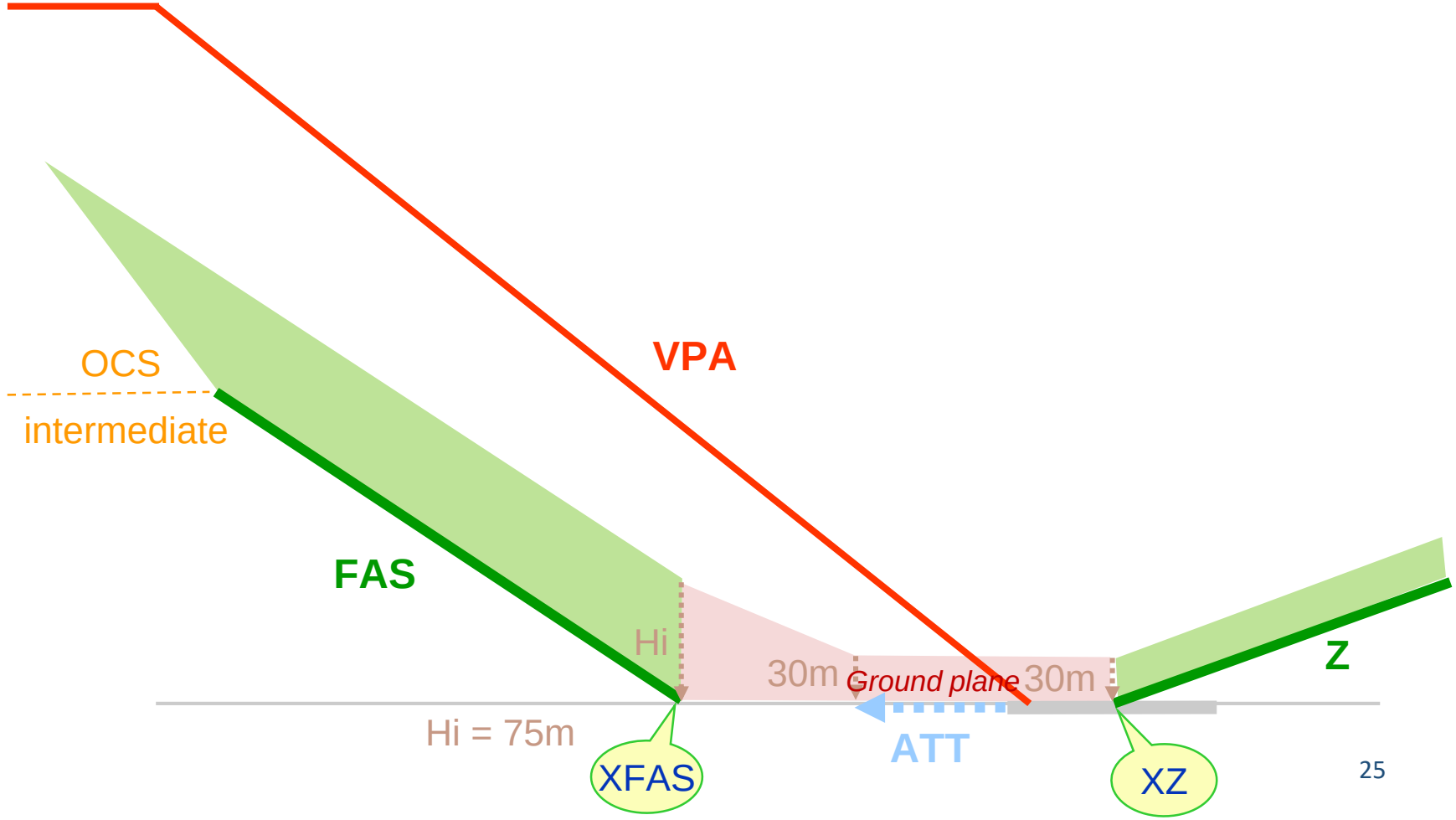
Height of FAS Side surface at range X,Y : $h_{side(x,y)} = h_{FAS(x)} + (\%\ of\ Hi)$

If $H_{obst} > h_{OAS}$ => consider this obstacle for OCH computation

Horizontal plane or Ground plane

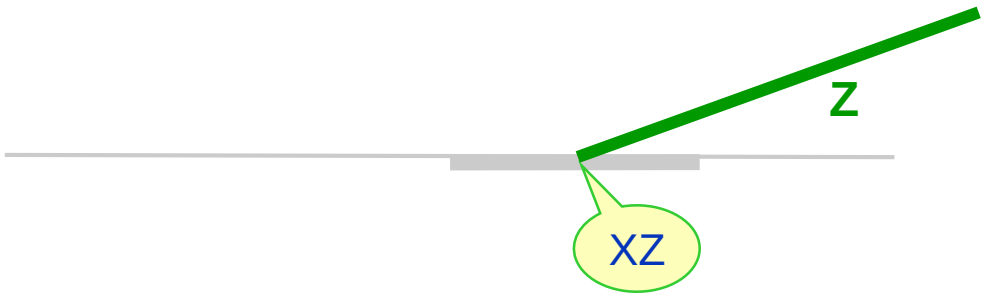
- Starts at XFAS;
- Ends at Xz*:
  - ☞Xz = - 900 m for Cat A and B;
  - ☞Xz = - 1 100 m for Cat C ;
  - ☞Xz = - 1 400 m for Cat D.
- *Note: Adjusted values for airfield elevation > 900 m or promulgated VPA>3.2°

Horizontal plane or Ground plane



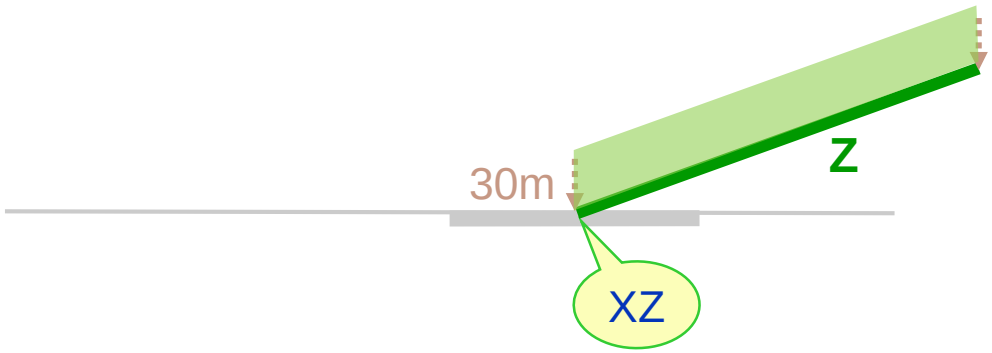
Missed approach surface (Z)

- Intermediate missed approach surface
  - Starts at X_z
  - Ends at earliest TP or XTH
- Climb gradient : 2.5 %
  - *Could be adjusted up to 5%*
- Hz = -(x - Xz) * 0.025

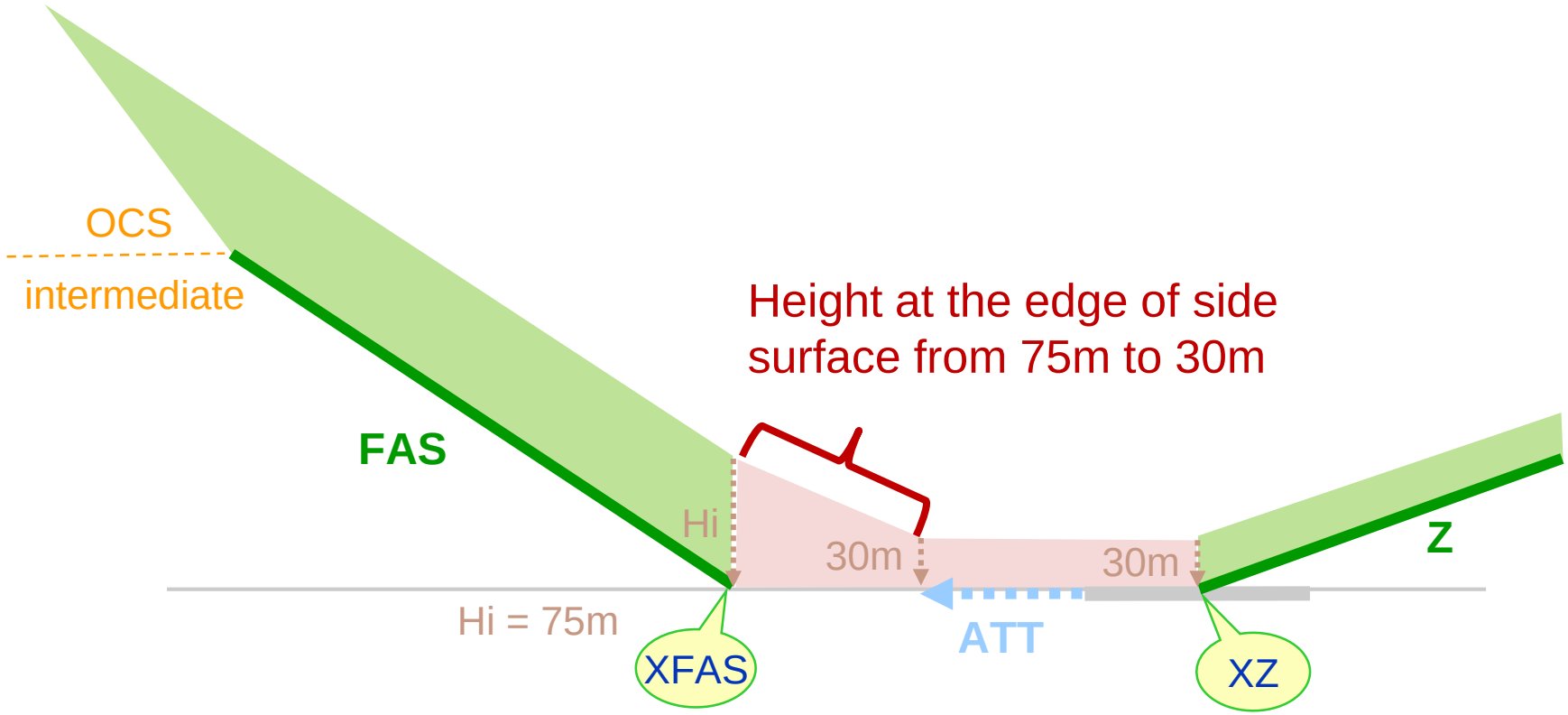


Missed approach side surface

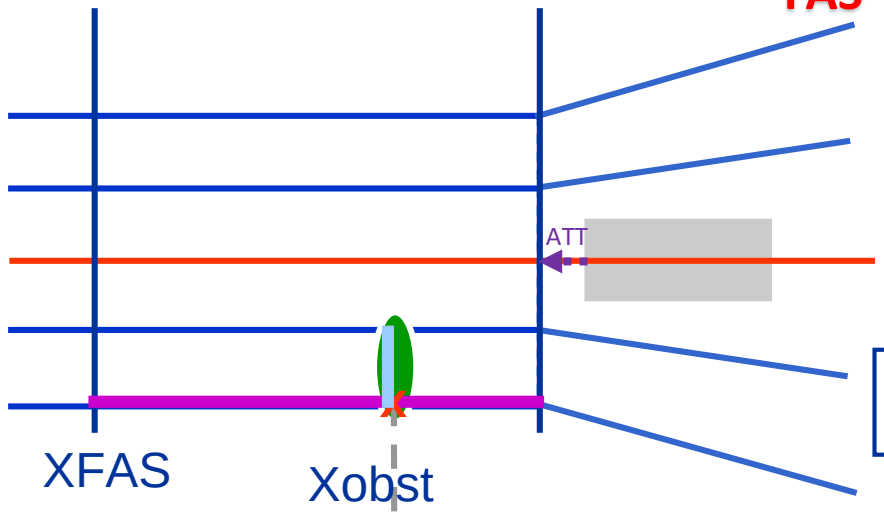
- After Xz :
  - ☞Height of edge of secondary area 30m higher than height of primary area



Side surfaces

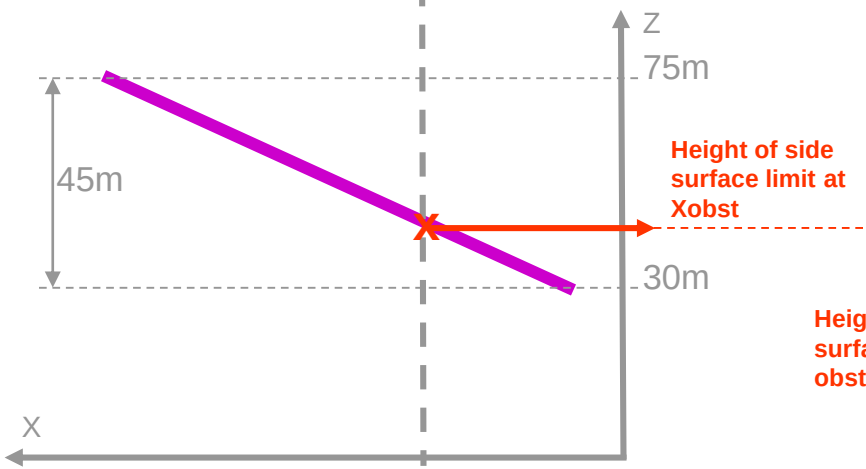


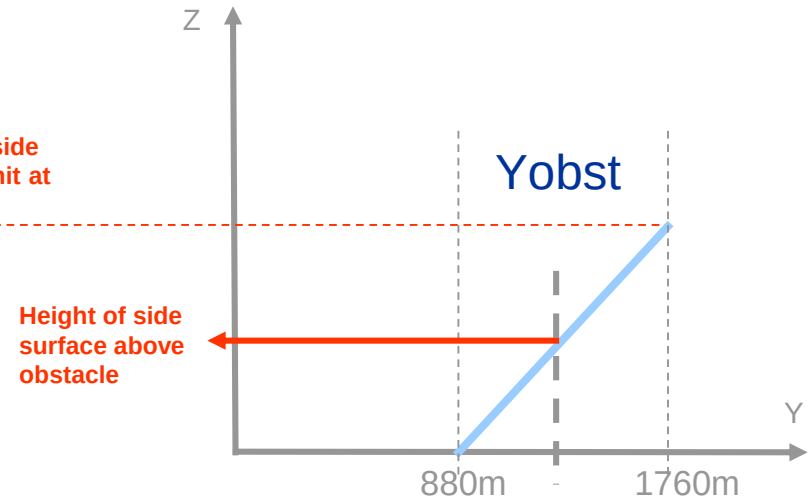
Height in Side surface between X_{FAS} and ATT before THR



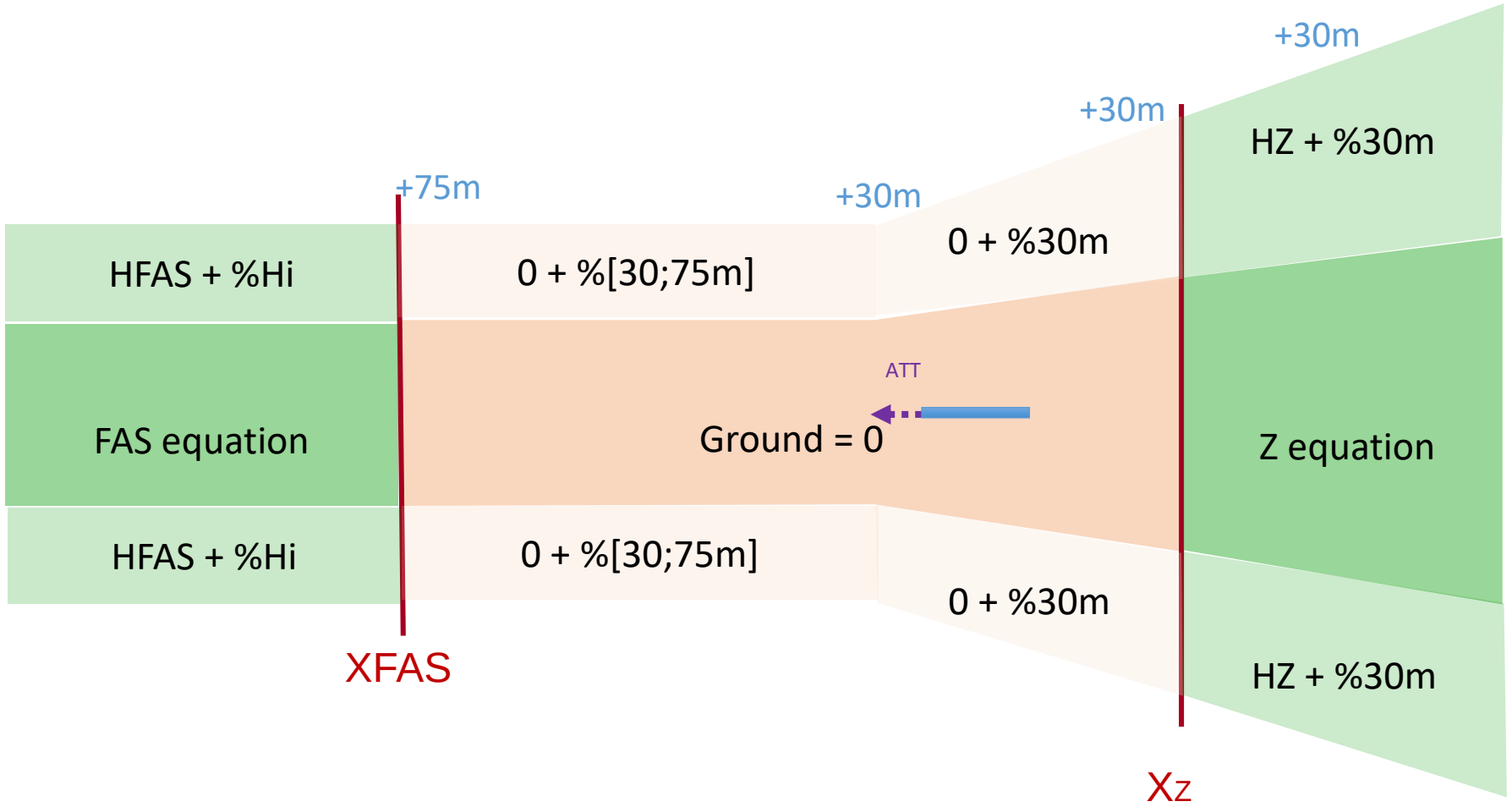
Height of side surface limit at Xobst = [(Xobst – ATT)/(XFAS – ATT)] x 45 + 30

Height of side surface above obstacle = [(Yobst – 880)/880] x **Height of side surface limit at Xobst**





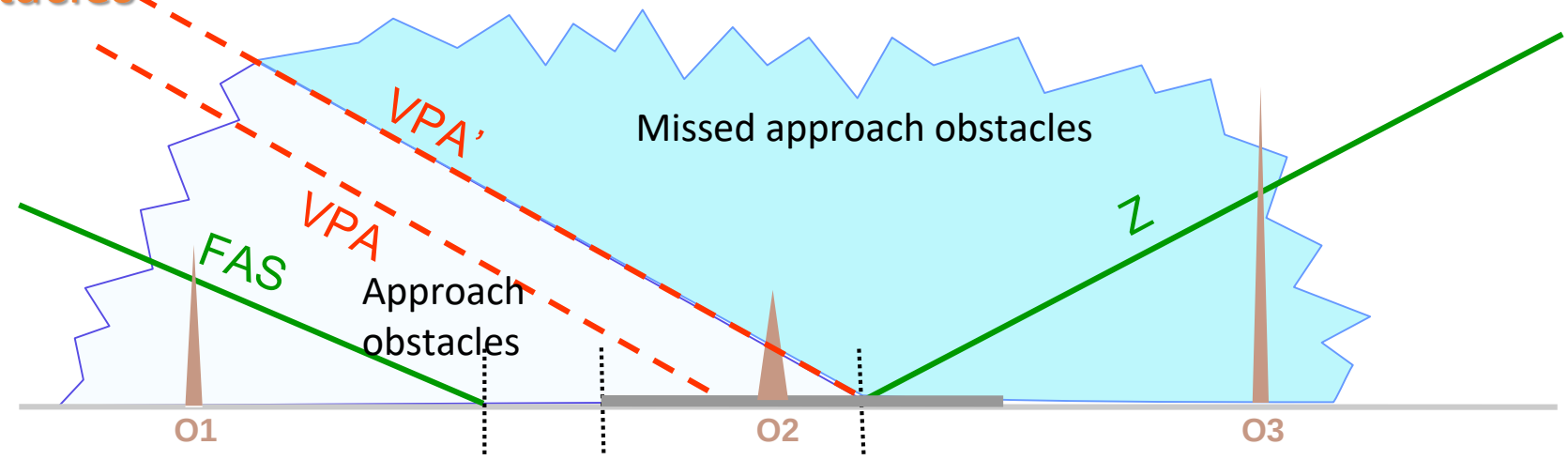
APV OAS summary



Obstacles Assessment

- As in ILS, obstacles classified in:
  - Approach obstacles and
  - Missed approach obstacles

$$VPA' : H_{VPA'} = (x - X_Z) \tan VPA$$



Approach Obstacle if

$h_{obst} \leq (x - X_Z) \tan VPA$

Missed approach Obstacles if

$h_{obst} > (x - X_Z) \tan VPA$

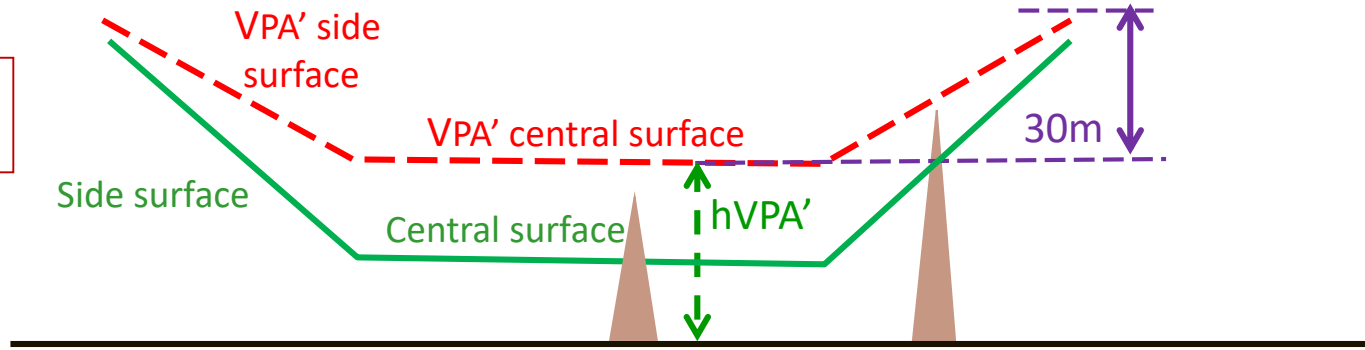
Obstacles Assessment

Obstacles before Xz & not penetrating VPA’

Approach obstacles because lower than VPA’

Obstacle penetrating FAS or ground central surface :

OCH = hobst + HL

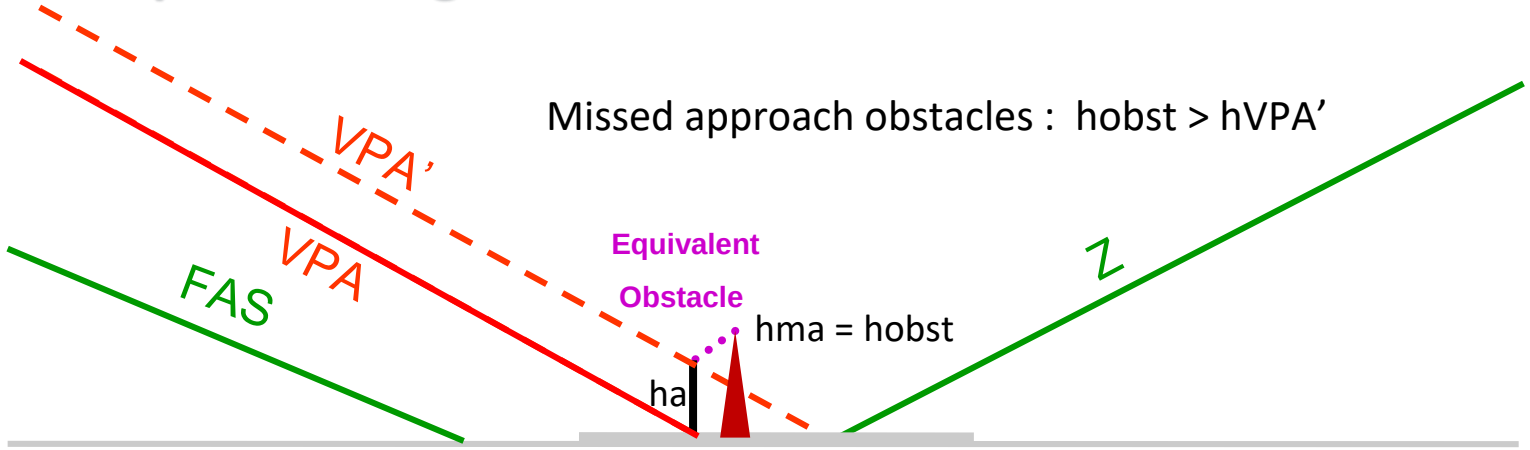


Obstacle penetrating FAS or ground plane **side surfaces** :

OCH = hobst + %HL

Side surfaces :
hVPA’= hVPA’ central +[(ABS(Yobst) - Yprimary) / Yprimary] x 30

Obstacles before Xz & penetrating VPA' central surface



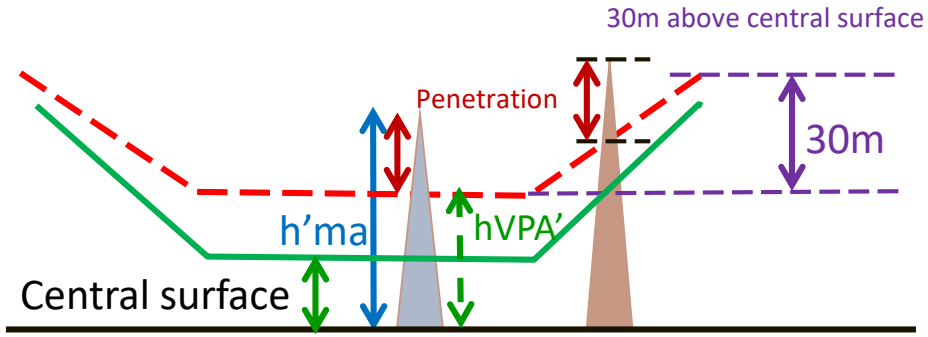
Central surface : hVPA' central =[(Xobst-Xz) tanVPA]

Computation of ha : height in approach (Equivalent height of the obstacle in approach: Same OCH)

$$ha = [(hma / \tan Z) + (Xobst - Xz)] / [(1/\tan Z) + (1/\tan VPA)]$$

OCH = ha + HL

Obstacles before Xz & penetrating VPA' side surface



Missed approach obstacles because higher than VPA' side surfaces

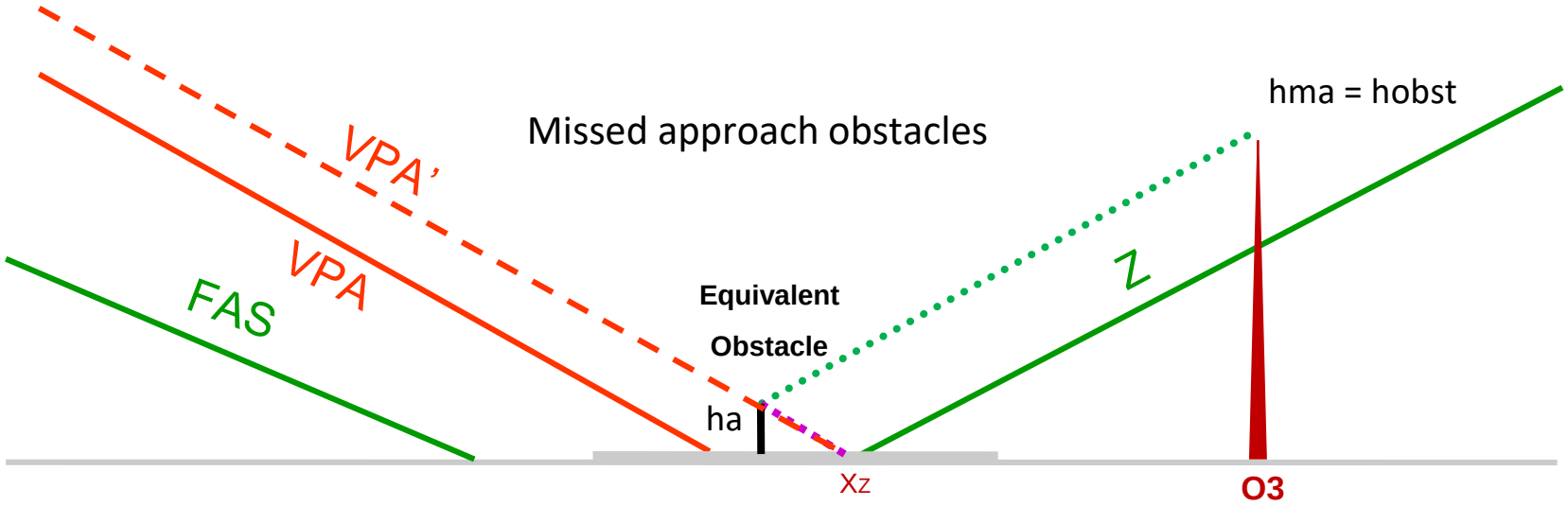
Central surface :
hVPA' central =[(Xobst-Xz) tanVPA]

Side surfaces :
hVPA'= hVPA' central +[(ABS(Yobst) - Yprimary) / Yprimary] x 30

2- Computation of ha : **ha = [(h'ma / tanZ) + (Xobst - Xz)] / [(1/tanZ) + (1/tanVPA)]**

3- OCH = ha + HL

Obstacles after Xz & penetrating Z central surface



Central surface : Height of Z central surface =[(Xobst-Xz) tanZ]

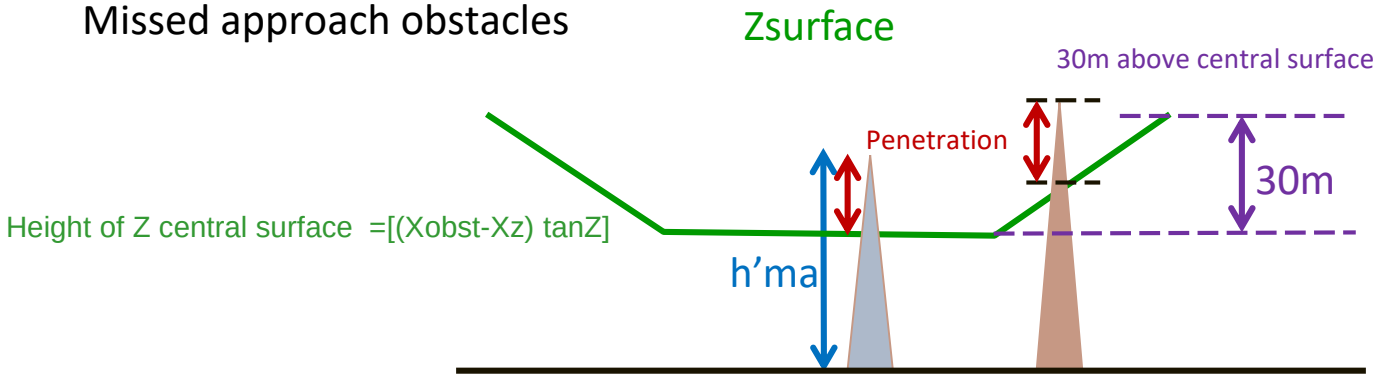
Computation of ha : height in approach (Equivalent height of the obstacle in approach: Same OCH)

ha = [(hma / tanZ) + (Xobst - Xz)] / [(1/tanZ) + (1/tanVPA)]

OCH = ha + HL

Obstacles after Xz & penetrating Z side surfaces

Missed approach obstacles



Height of Z side surface = height of Z central surface + [(ABS(Yobst) - Yprimary) / Yprimary] x 30
with height of Z central surface =[(Xobst-Xz) tanZ]
and with Yprimary = Ysecondary / 2 and Ysecondary = (0,95NM*1852) + (ATT-Xobst) x tan(15°)

1- Computation of corresponding h'ma : h'ma = height of Z central surface + penetration

2- Computation of ha : **ha = [(h'ma / tanZ) + (Xobst - Xz)] / [(1/tanZ) + (1/tanVPA)]**

3- OCH = ha + HL

Obstacles Assessment

- OCH calculation method:
  - Assessment of penetrating obstacles;
  - Ho > Hoas;
  - Identification of approach obstacles and missed approach obstacles;
  - Calculation of equivalent obstacle for Missed approach obstacles (2 computation maybe);
  - Calculation of OCH using HL.

- OCH = max of all individual OCH of the APV OAS

Promulgation

Title : RNAV (GNSS)
Minimum box : LNAV/VNAV

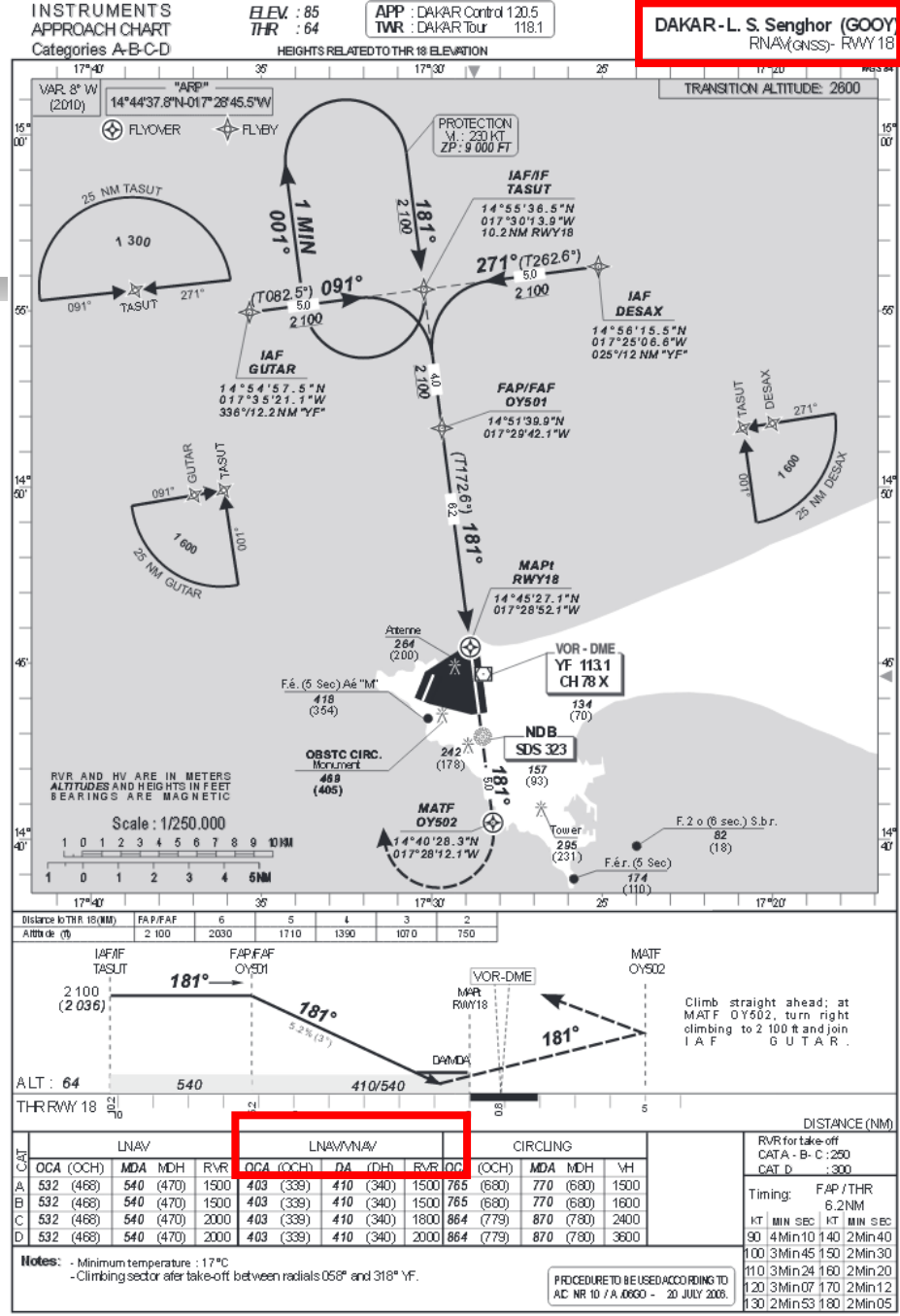
RDH
VPA : X° XX for databases
X° X for charting

Min temperature for which APV BaroVNAV operations are authorized

Temperatue above which the effective VPA will exceed 3.5° (only if this value is possible)

For Databases only :

- FAF and MAPt LNAV



Questions:

Alexandre DAMIBA
adamiba@icao.int