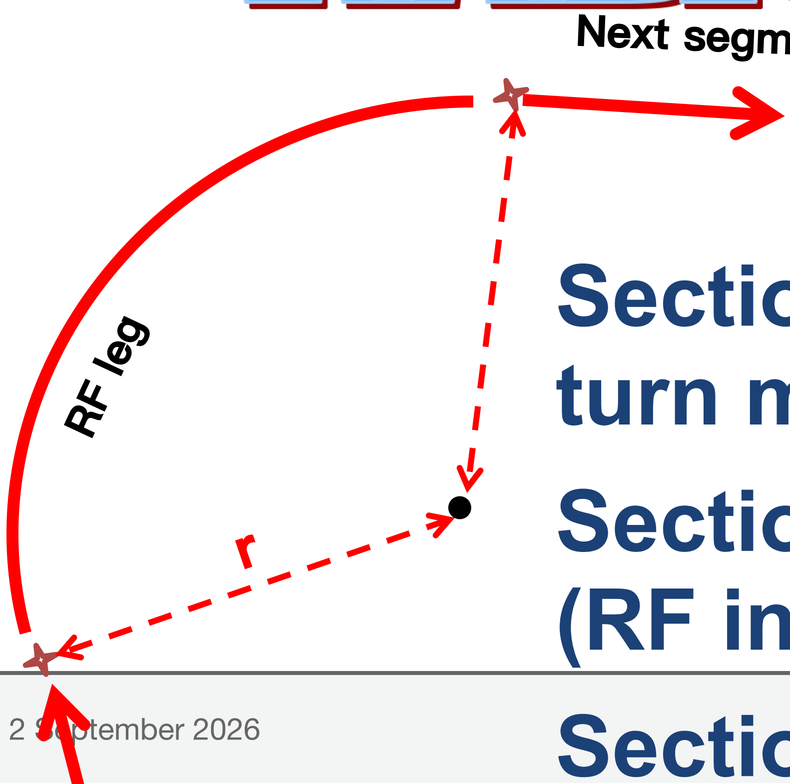
RF LEG
RADIUS TO FIX



Part III

Section 2, chapter 2, § 2.4 « RF turn method »

Section 3, Chapter 1, § 1.4.1.3 (RF in initial departure)

Section 3, Chapter 2, § 2.4 (RF in

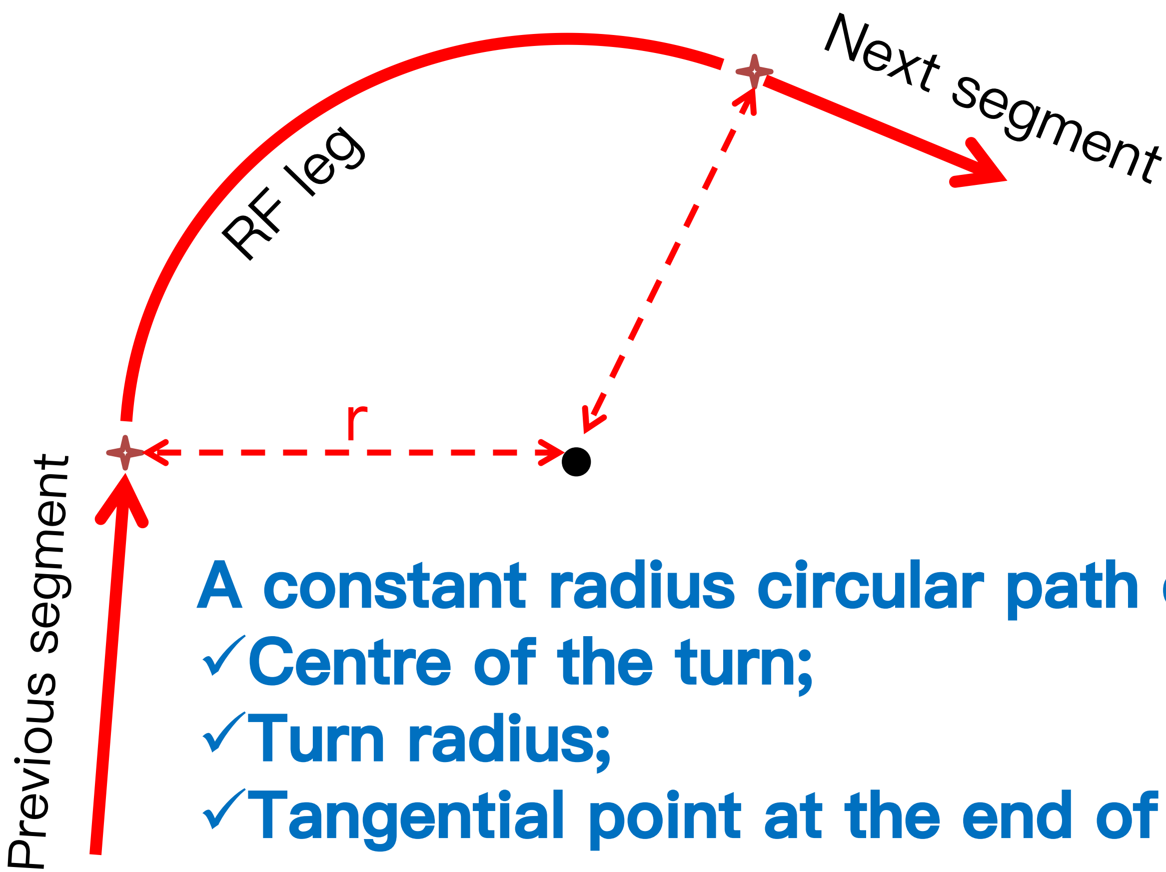
Plan

1. Overview
2. Nomimal segment
3. Protection
4. Assessment of obstacle
5. Method to design RF leg
6. Promulgation

Objectives

1. Know how to design an RF leg
2. Know how to compute tolerance and area width of an RF leg
3. Know how to assess obstacles within an RF leg protection area
4. Know how to publish necessary information

1- Overview : What is an RF segment



A constant radius circular path defined by a:

- ✓**Centre of the turn;**
- ✓**Turn radius;**
- ✓**Tangential point at the end of the turn.**

1- Overview : RF leg versus DME arc

- To maintain the DME arc defined, the pilot flies turning left and right moving in a zigzag couse along the arc
- To maintain the radius defined on RF leg the system will act on bank angle and TAS
- The RF turn is the only turn method for which the track is unambiguously continuously defined during the turn. The RNAV system can construct a defined path that exactly matches the procedure designer's intent.
  - Obstacle rich environment
  - Environmental

RF leg means scalable and repeatable path

1- Overview : Where can we use RF leg

Which PBN applications

- Required only in Advanced RNP
- Can be used in RNP APCH, RNP1,
  - « RF required »pubished on chart

Which phase of flight

- In Departure
- In Approach:
  - Initial
  - Intermediate
    - (RNAV+ILS=> NO RF for intermediate)
  - Missed approach

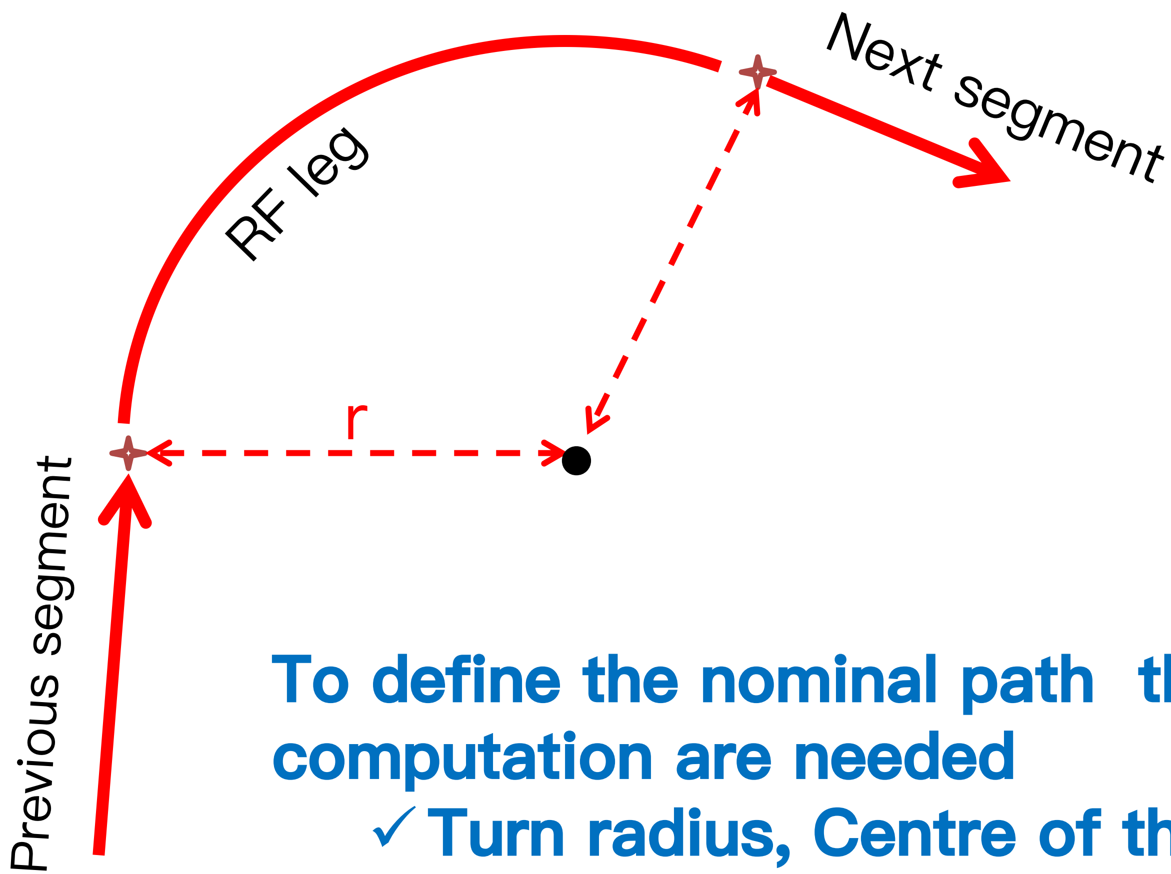
1- Overview : RF leg requirements

- pilots should use a flight director or auto-pilot when flying an RF leg
- the FMC, FD/AP must be capable of commanding a bank angle of up to 25 degrees above 400ft AGL
  - ⇒ No turn below 400 ft
  - ⇒ Max bank angle 25 °
- the flight guidance should remain in LNAV mode while on an RF leg when a procedure is abandoned or a go-around is initiated.
- To accomodate sudden jump due to gust some provisions will be added in the protection area

1- Overview : Conclusions from Track-keeping Studies

- The ATT in the initial departure could be expected to increase from a relatively small number in the same way as the XTT increases
- Aircraft maintained within 0.1NM (185m) of centerline even in rare normal wind conditions.
- Most of the RF turns monitored in the reports required bank angles of less than 20° even in rare normal wind conditions.
- The ICAO wind formula is extremely conservative below 2000' AAL(Above Aerodrome Level) a revised set of wind values for RF design is appropriate for PANS-OPS.
- It is essential that the inbound and outbound tracks are tangential to the RF arcs. If this is not achieved, significantly larger excursions can be expected, not only during the turns but also in the subsequent straight segment.

2- Nominal segment



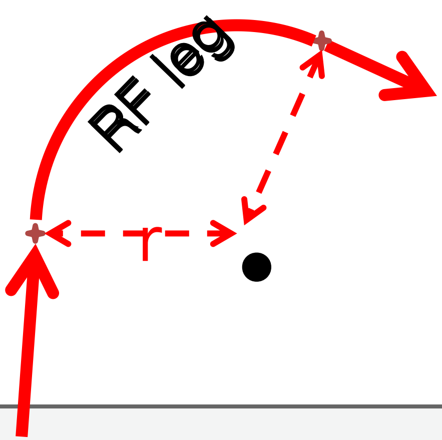
To define the nominal path the following computation are needed

- ✓ **Turn radius, Centre of the turn;**
- ✓ **Tangential point at the beginning and end of the turn.**

2. Nominal segment: Turn radius calculation (1)

WHAT' S NEW

- Radius computed adding a wind component
- Bank angle : can vary up to 25° (not segment dependant)
- Minimum radius to consider:
  - r ≥ 2*RNP
  - r ≥ ½ AW of inbound and outbound segment



$r = (TAS+Vw)^2 / 68626 \cdot \tan\theta$ r in NM, V & Vw in kt

$r = (TAS+Vw)^2 / 127094 \cdot \tan\theta$ r in km, V & Vw in km/h

$r = (TAS+Vw)^2 / g \cdot \tan\theta$ r in m, V & Vw in

2. Nominal segment: Turn radius calculation (2)

How to compute TAS ?

TAS = - max altitude during the turn
-10% slope for SID/Missed approach with an altitude computed at end of RF : arc length on nominal

Which Wind velocity?

- maximum wind speed at the highest point in the turn
- For SID and Missed approach :
  - 10 kt for heigth (h) ≤ 500 ft;
  - 20 kt for 500 ft < h ≤ 1000 ft;
  - 30 kt for 1000 ft < h ≤ 2000 ft;
  - 40 kt for 2000 ft < h ≤ 3000 ft; h.
  - ICAO above 3000ft

2. Nominal segment: RF turn in intermediate segment

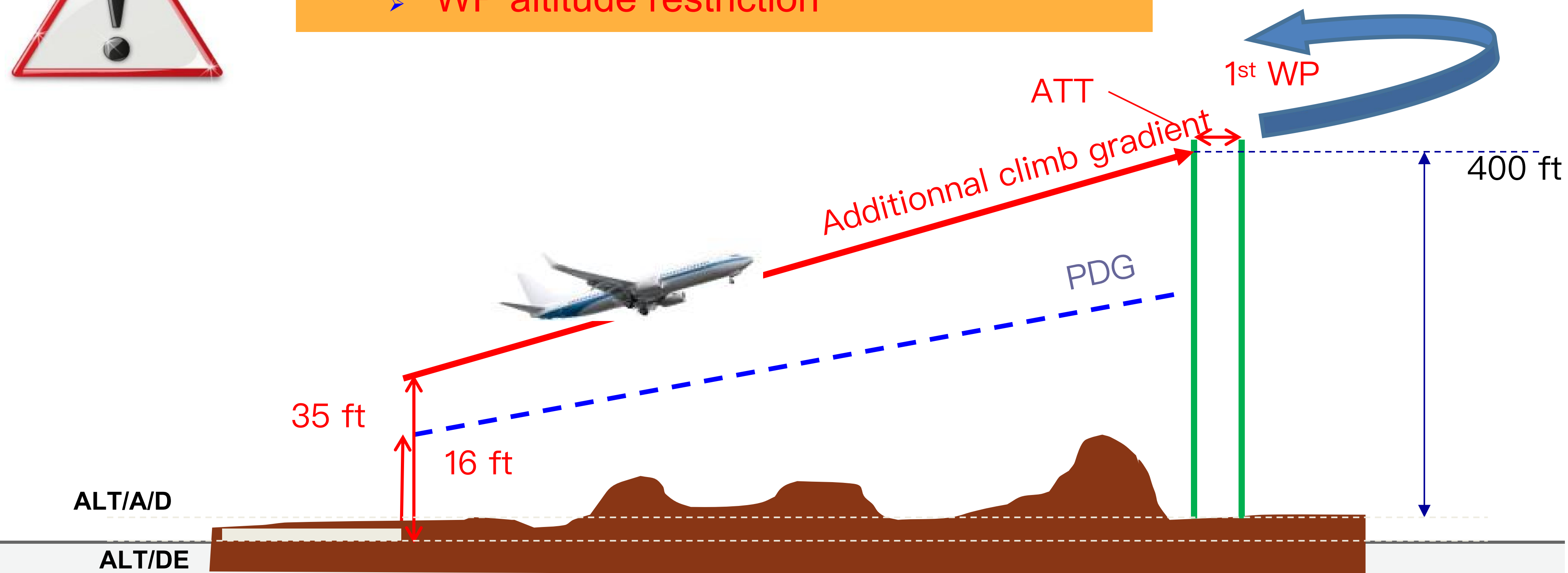
- Min Length : 2 Nm including curved and straight legs
- Max Track change : 45 ˚
- Min radius : 2.55 Nm

2- nominal Segment: Minimal Height in departure segment

Where PDG do not reach 400 Ft/DER at earliest tolerance of WP, an additionnal climb gradient is computed considering 35 Ft height above DER to reach 400ft/ Alt A/D

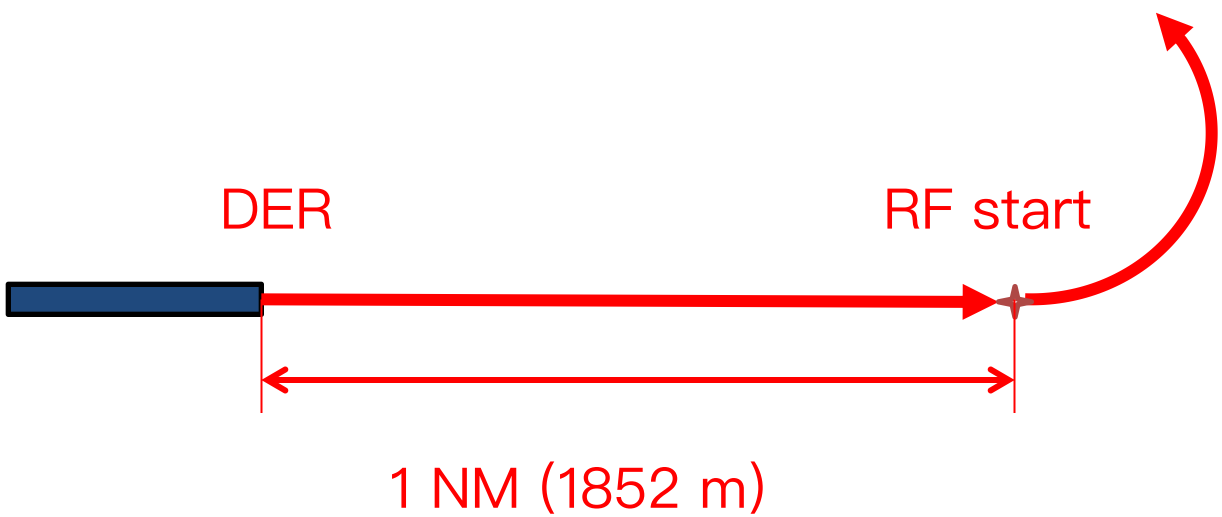
In this case It shall be published:

- An additionnal climb gradient
- WP altitude restriction



2- nominal Segment: **Minimal Distance in departure segment**

Minimum Distance DER- start of du RF



3-Protection: In departure segment,reduced ATT computation for first WP

- **ATT varies proportionally to XTT so to the area semi-width value:**
- **At DER : ½ AW = 150 m so ATT= 0.8 x 150 =120m**
- **ATT is 120 m for X =0**
- **ATT is full value when 15° splay reaches 1/2AW so for x = [1/2AW-150]/tan15°**
- **In between a reduced ATT can be computed as follow**

$$\text{Reduced ATT} = \frac{ATT - 120}{\frac{(1/2AW - 150)}{\tan 15^{\circ}}} * x + 120$$

- x : distance, in meters, from the DER;
- ATT : full value appropriate to the RNP accuracy; and
- 120 m: reduced ATT at the DER.

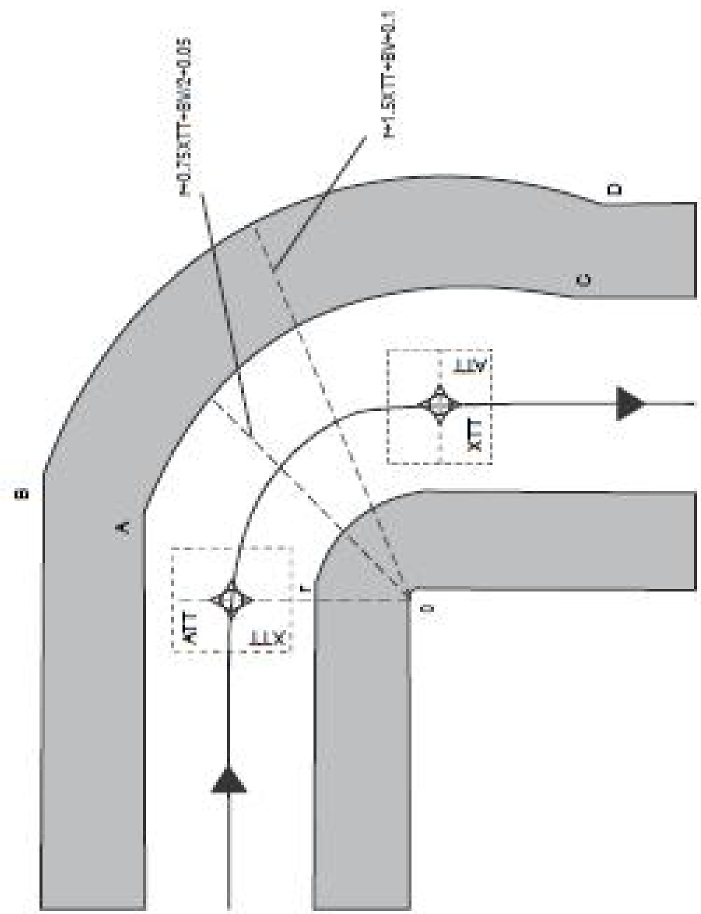
Note: The ATT is reduced if the initial departure is based upon GNSS sensor

3-Protection: ATT – XTT – ½ Area Width for straight segment

Navigation specification		RNP	FTE	IMAL	ATT	XTT	BV	1/2AW
ARNP	greater than 30 Nm 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
RNP1	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		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

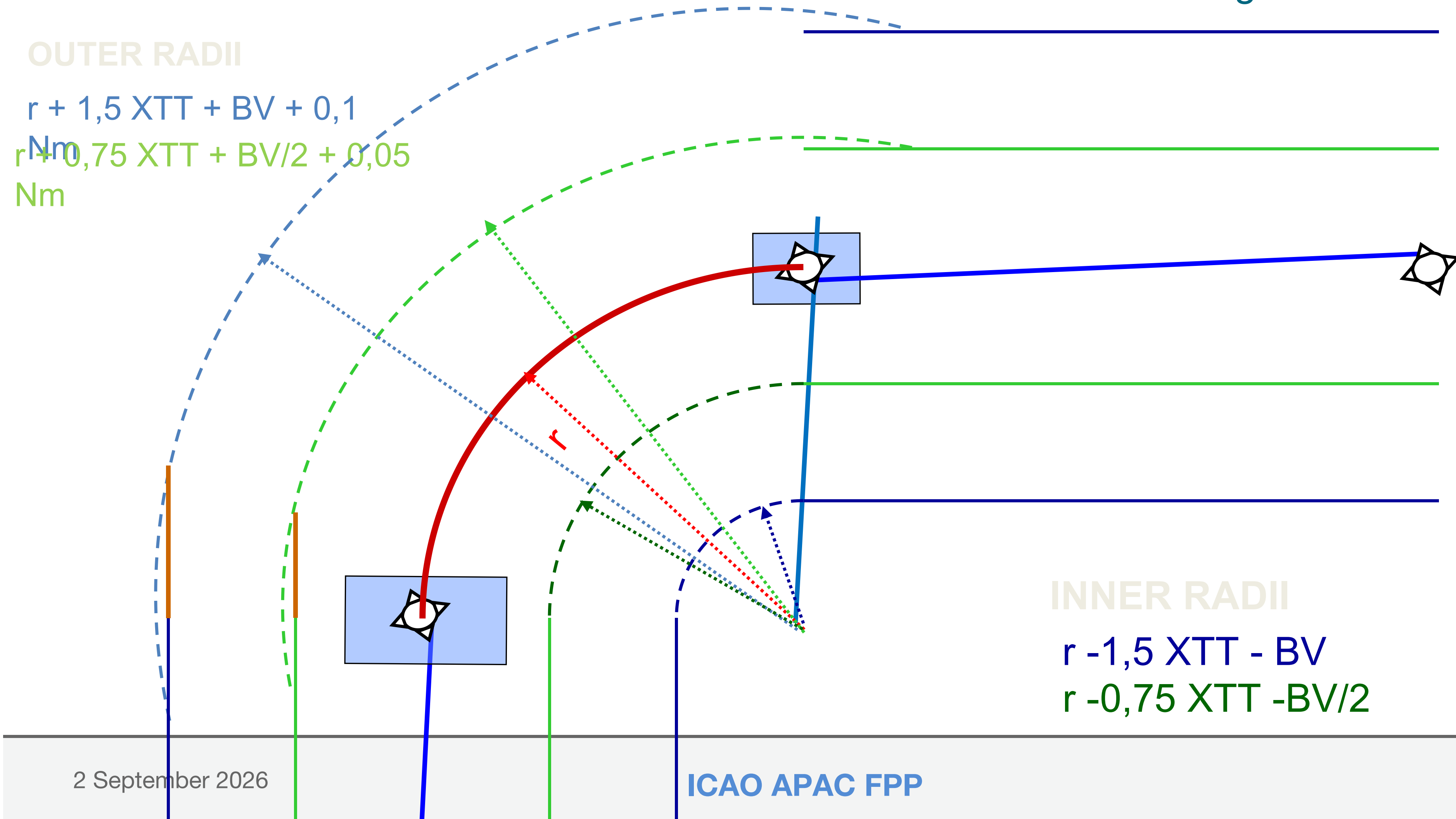
3-Protection: ½ Area Width for RF leg



- Limits of protection area are based upon circles centred on the same center as the nominal RF
- the outer radius computation ≠ inner one
- Primary area is half secondary area:
- Outer secondary area : ½ AW + 0.1(Nm)
- Outer primary area: 1/4 AW +0.05 (Nm)
- Inner secondary area : ½ AW
- Inner secondary area : 1/4 AW

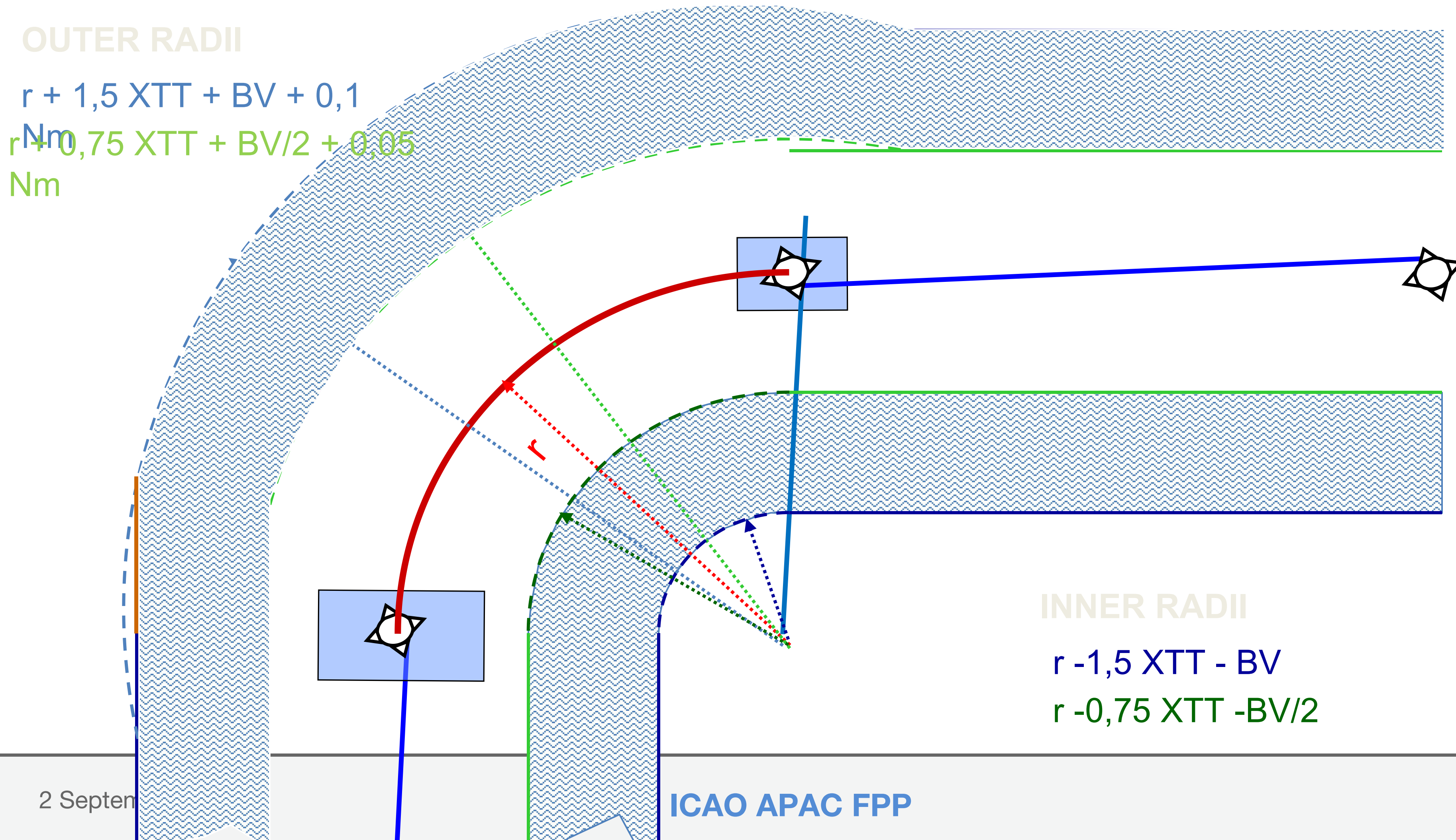
3-Protection: ½ AW for RF leg

Figure III-2-2-13



3-Protection: ½ AW for RF leg

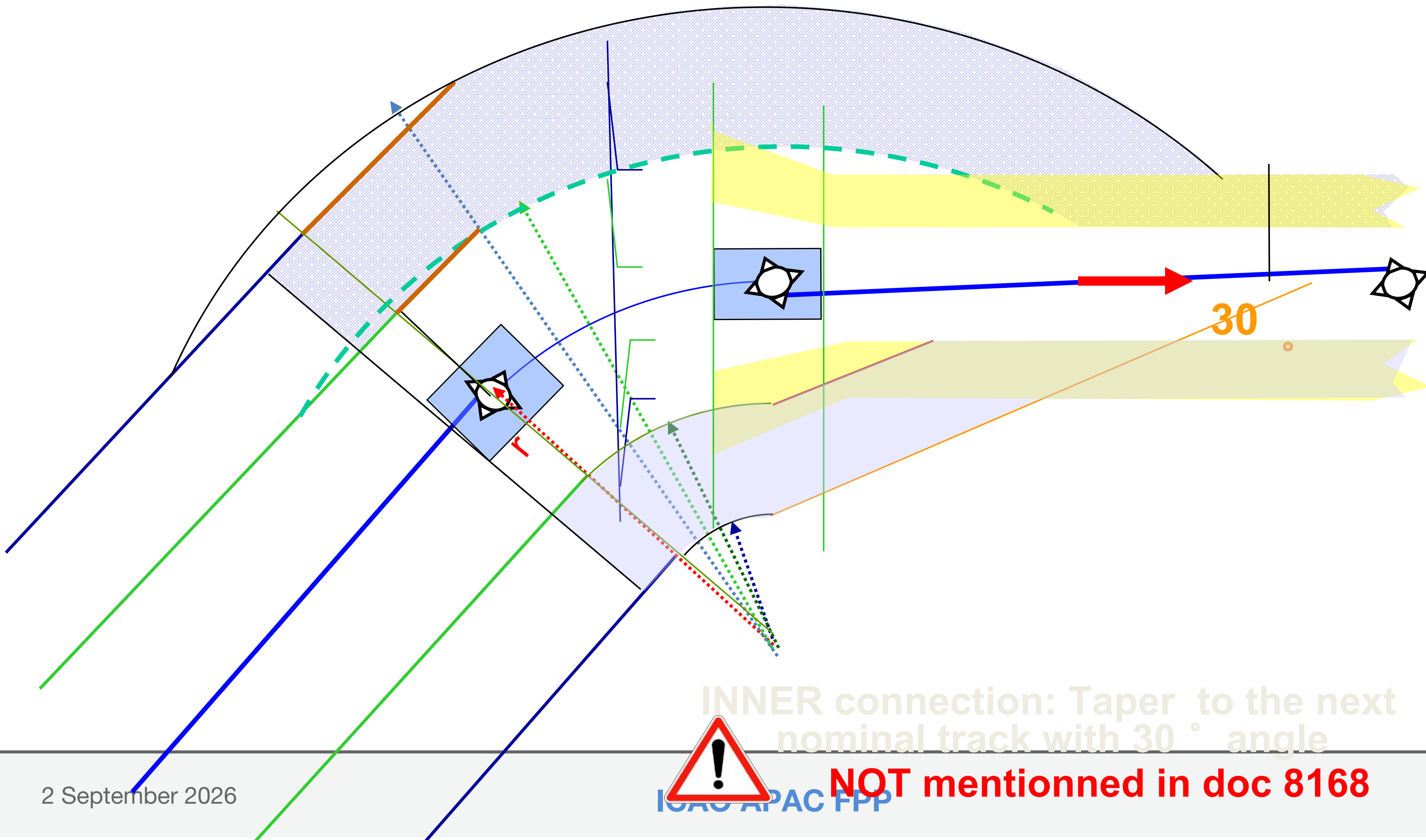
Figure III-2-2-13



3-Protection: ½ AW for RF leg

AW segment 1 > AW segment 2

OUTER connection: until reaching the next straight protection area

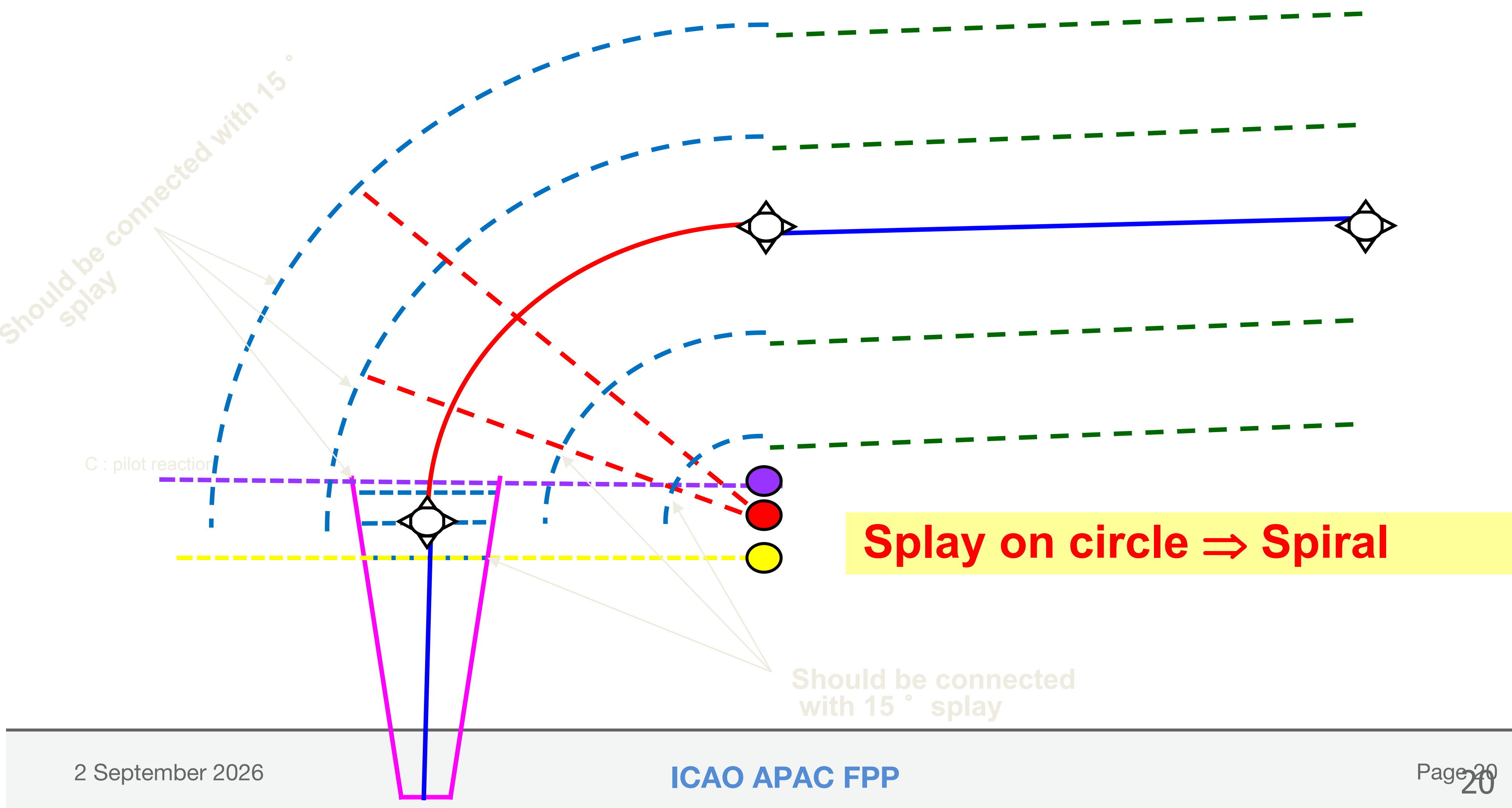


INNER connection: Taper to the next nominal track with 30 ° angle

NOT mentionned in doc 8168

3-Protection: ½ AW for RF leg

AW segment 1 < AW segment 2



3-Protection: ½ AW for RF leg

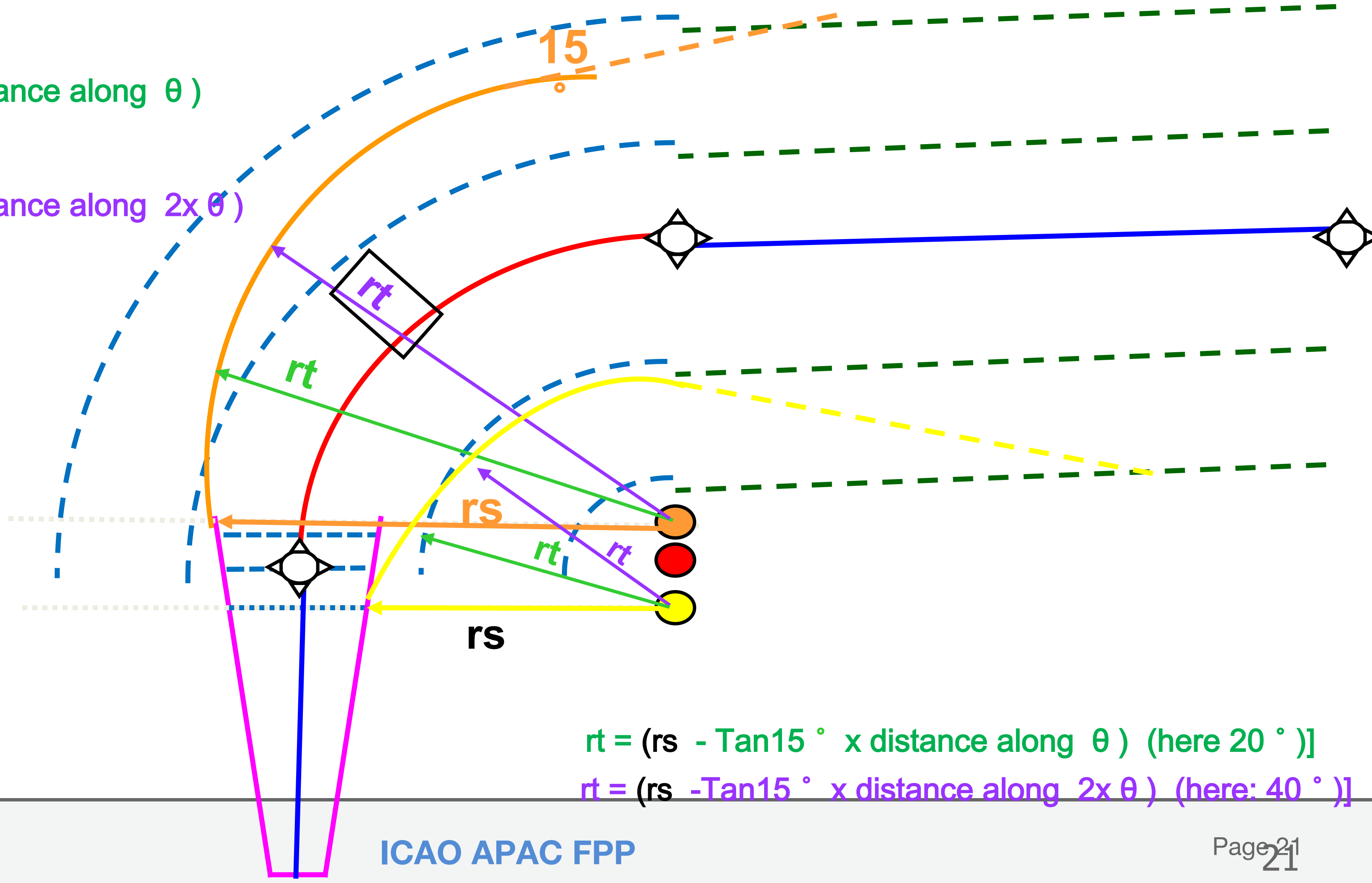
AW segment 1 < AW segment 2

rt = (rs + Tan15° x distance along θ)

(here θ = 20°)

rt = (rs + Tan15° x distance along 2x θ)

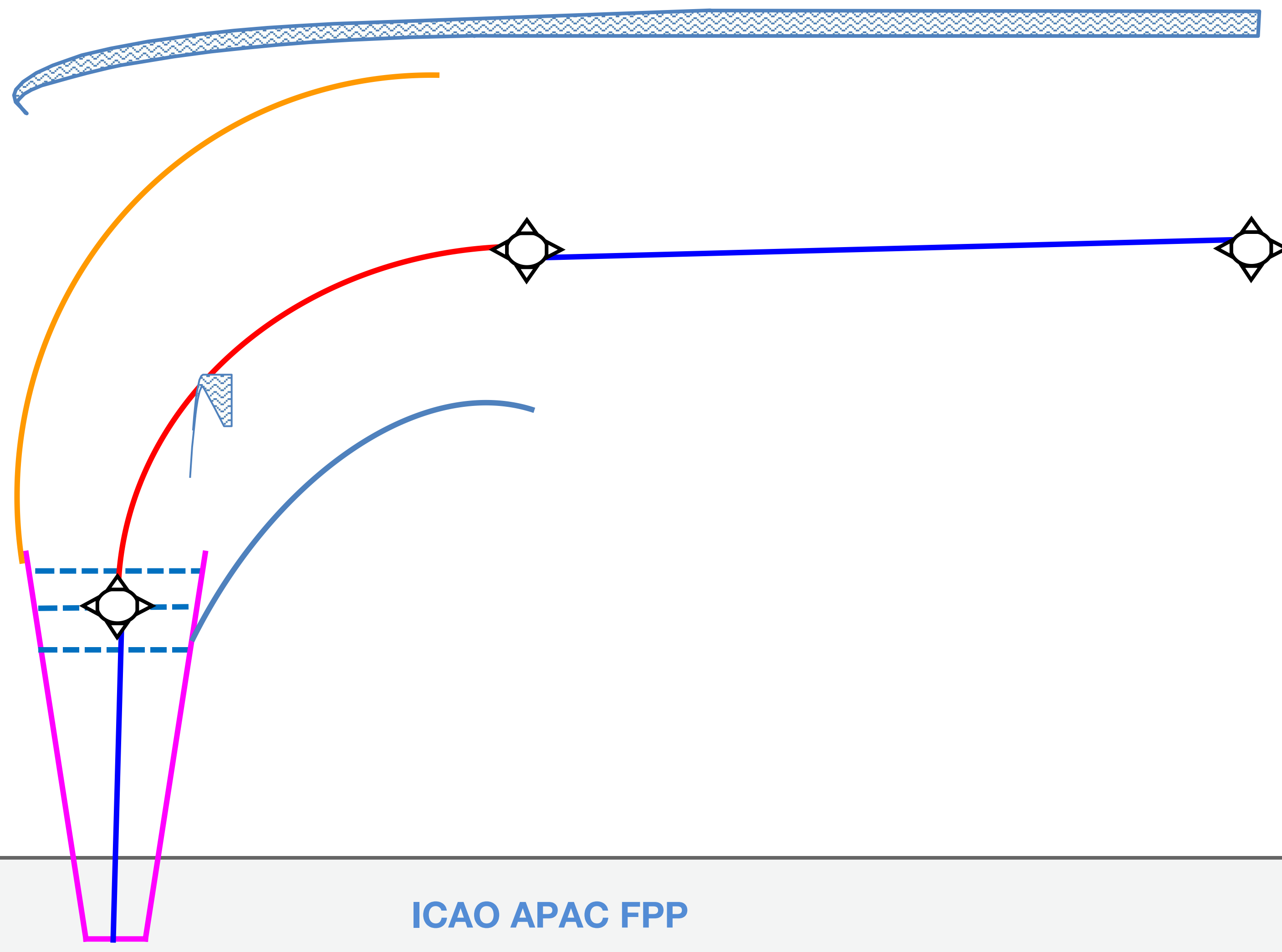
(here : 2 x 20 = 40°)]



rt = (rs - Tan15° x distance along θ) (here 20°)]

rt = (rs -Tan15° x distance along 2x θ) (here: 40°)]

3-Protection: ½ AW for RF leg
AW segment 1 < AW segment 2



4: Assesment of obstacles in RF

WHAT' S remaining

- MOC
- MOC in secondary area
- OIS for departure

WHAT' S NEW

- How to compute the required distance
  - (for MOC in departure or gain in missed approach)
- Body geometry of the A/C in departure

4: Assesment of obstacles in RF leg (in climbing segment)

Distance measured on r-0.1NM

to compute

- OIS height in departure segment
- or gain of height in missed approach

Ho1 ≤ ((pdg-0.8%) (d+d1)) +5

With d1 = ((r - 0.1) $\pi\theta_1$)/180

Ho2 ≤ ((pdg-0.8%)(d+d2)) +5

With d2 = ((r – 0.1)$\pi\theta_1$)/180

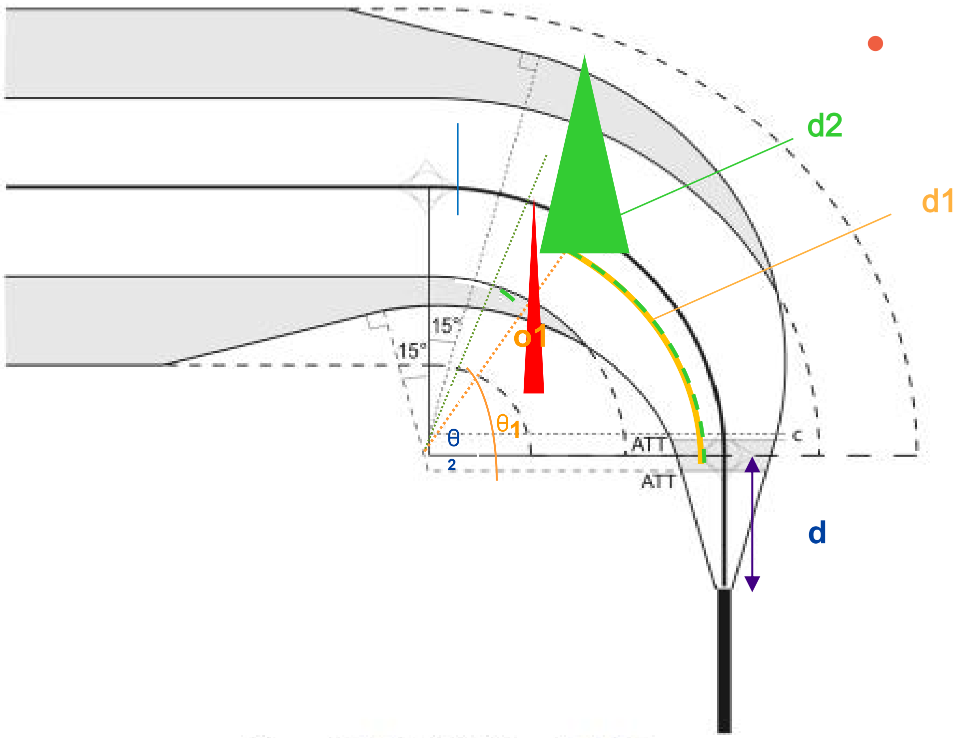
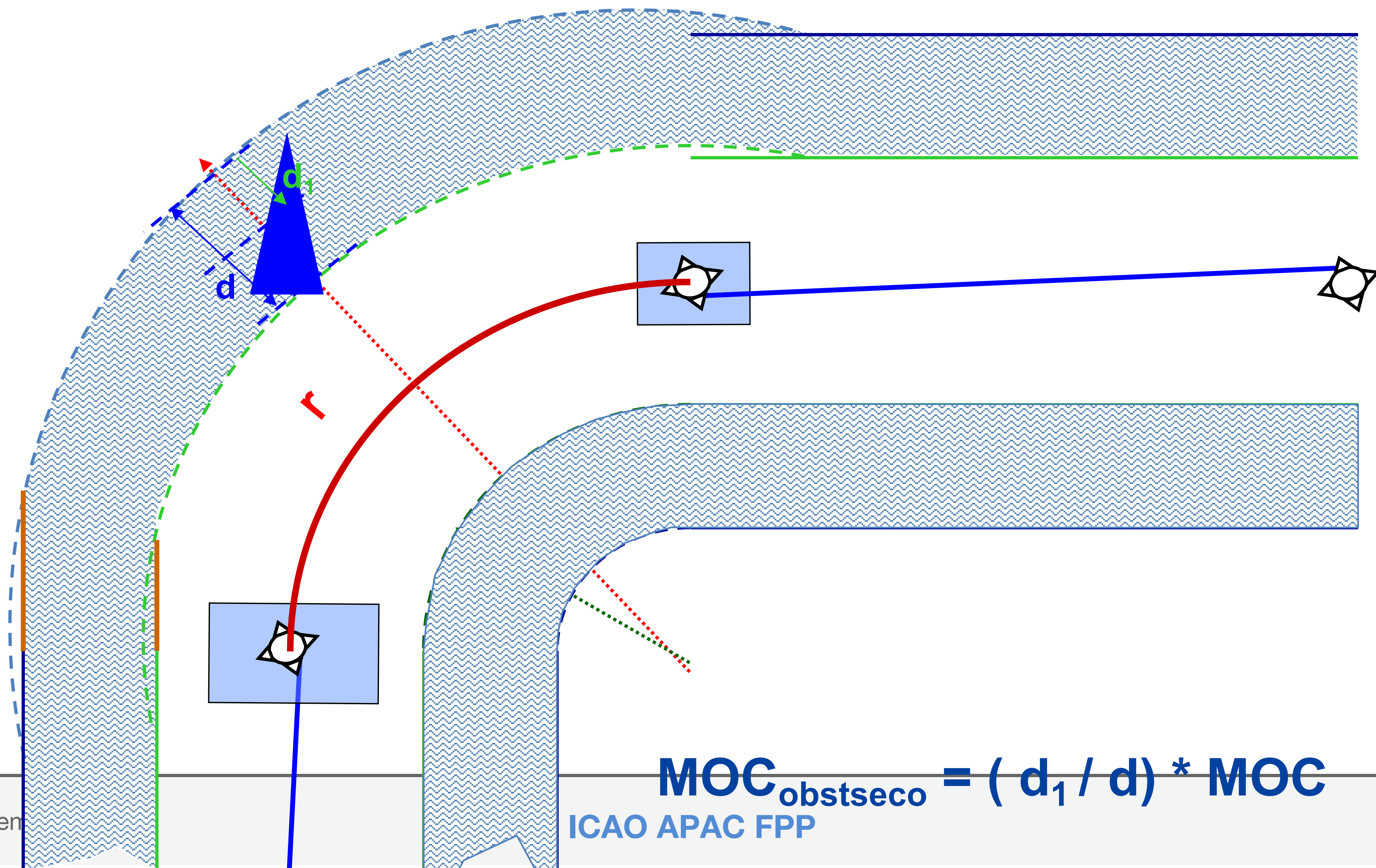


Figure III-2-2-14. Splay in RF turn

4: Assesment of obstacles in secondary area

Figure III-2-2-13



$$MOC_{obstseco} = (d_1 / d) * MOC$$

- Within Straight leg and or RF leg:

Minimum MOC: 0.8% of distance from DER

- Within RF leg:

As long as 75m of MOC is not reached, Body Geometry of the A/C is taken into account

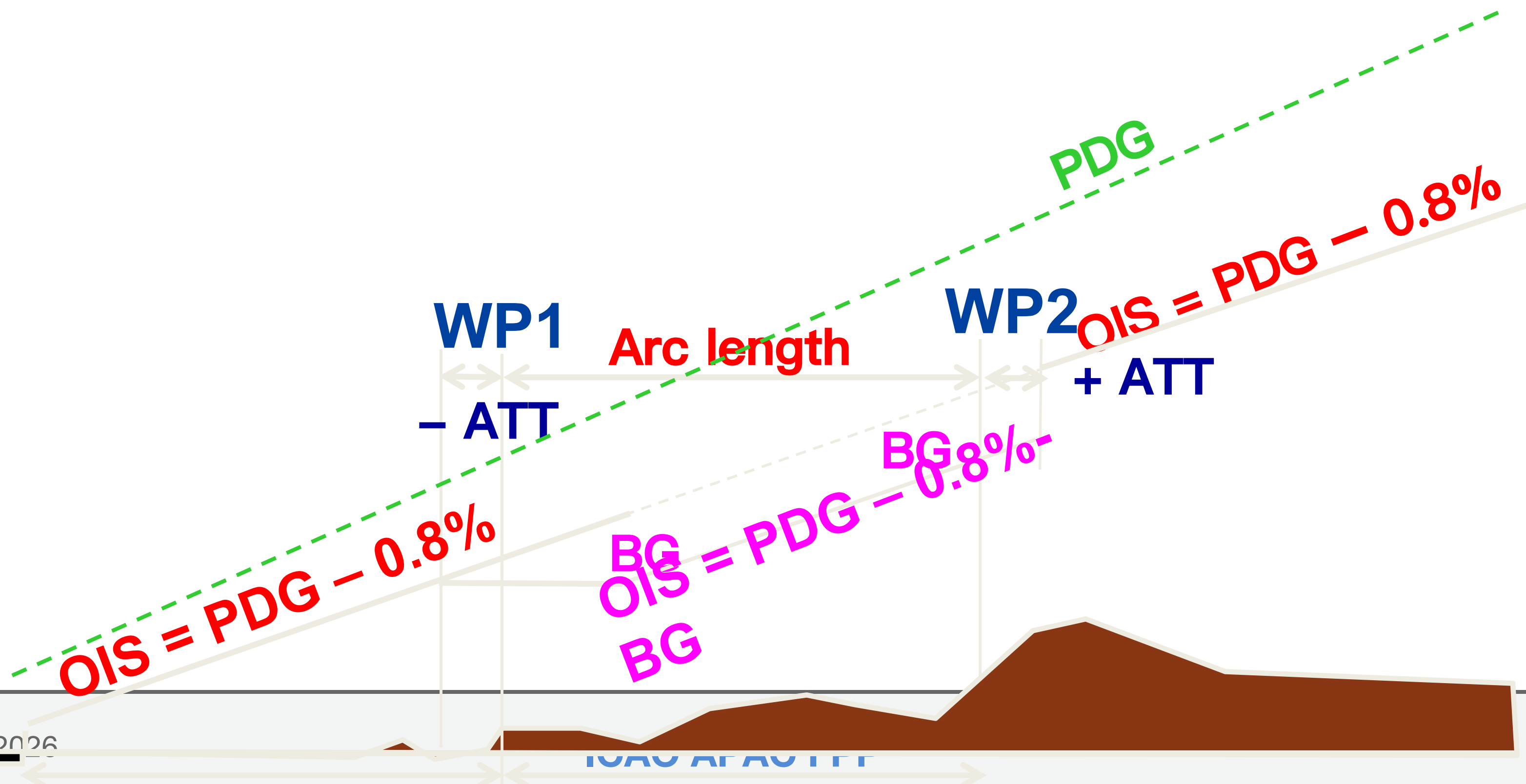
BG = wing semi–span*sin (α +5)

e α=angle of bank

For wing semi-span = 40m (132ft) and bank 25 ° BG = 20m

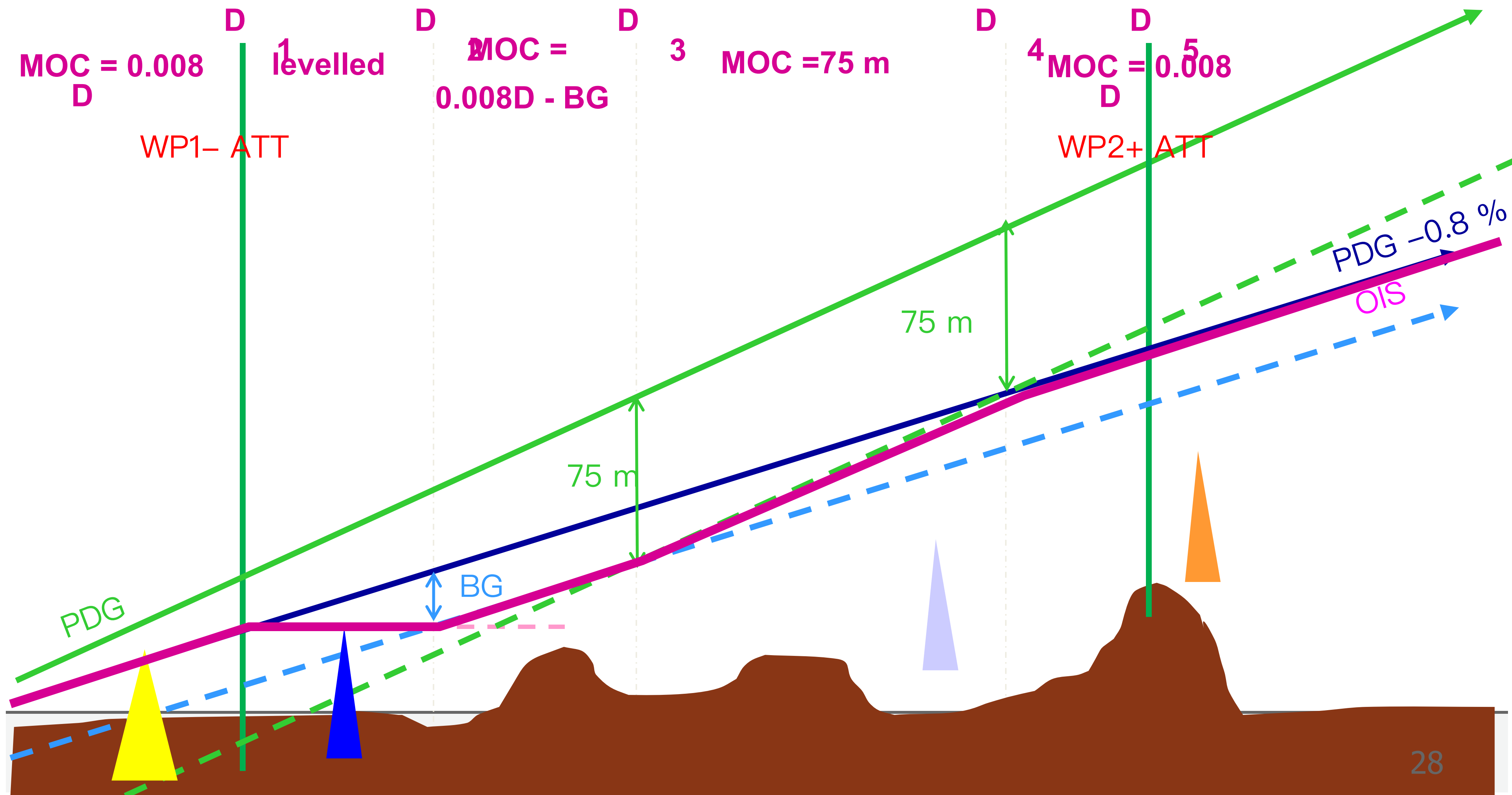
4: Assesment of obstacles in departure segment: body geometry (BG)

- **If MOC < 75 m in RF : OIS takes BG**
  - Leveled from '- ATT' to full BG
  - Lowered of BG <u>along RF</u> until 75 m

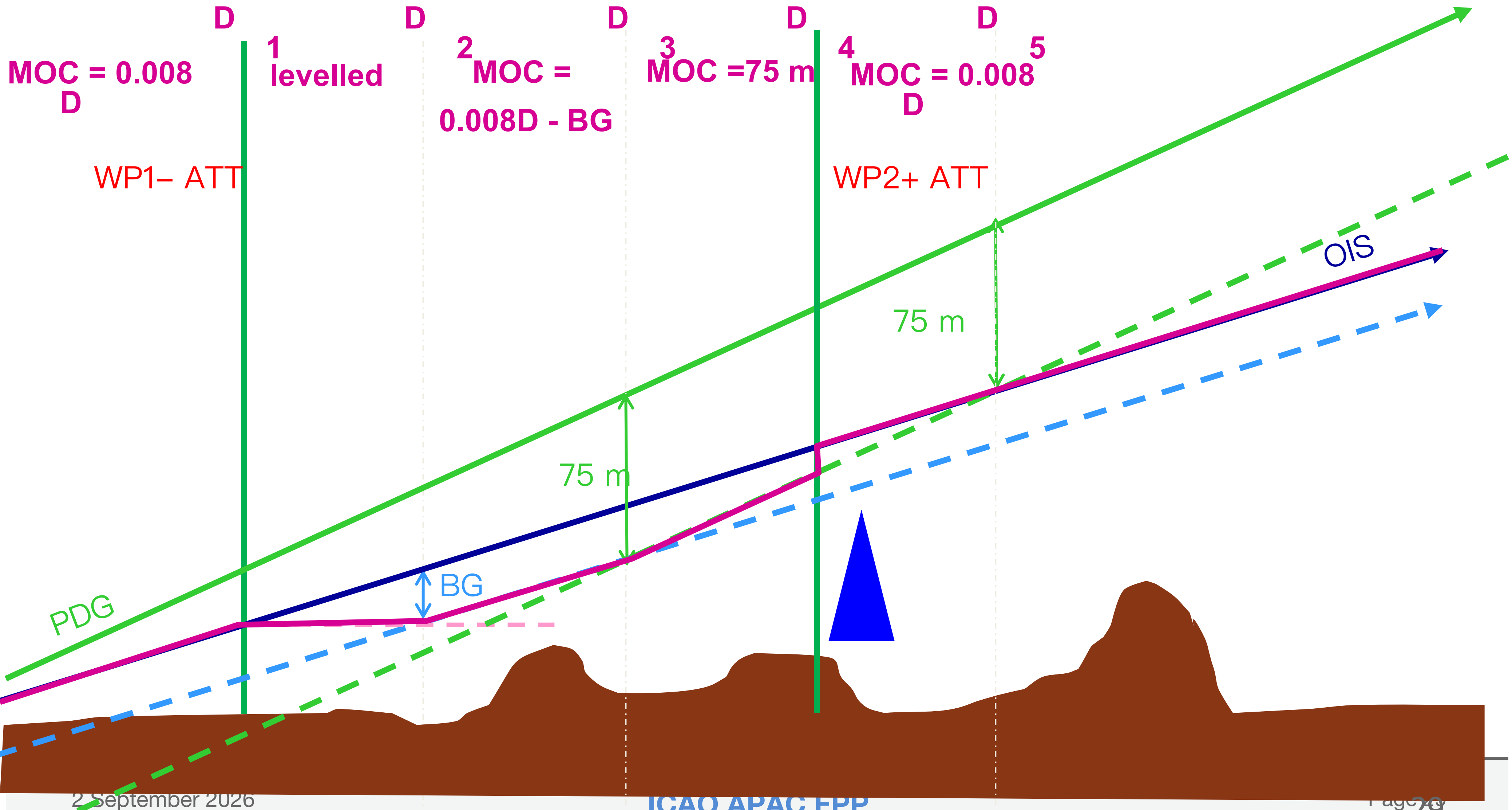


4: Assesment of obstacles in departure segment

MOC value above is the one for primary area



4: Assesment of obstacles in departure segment



4: Methodology

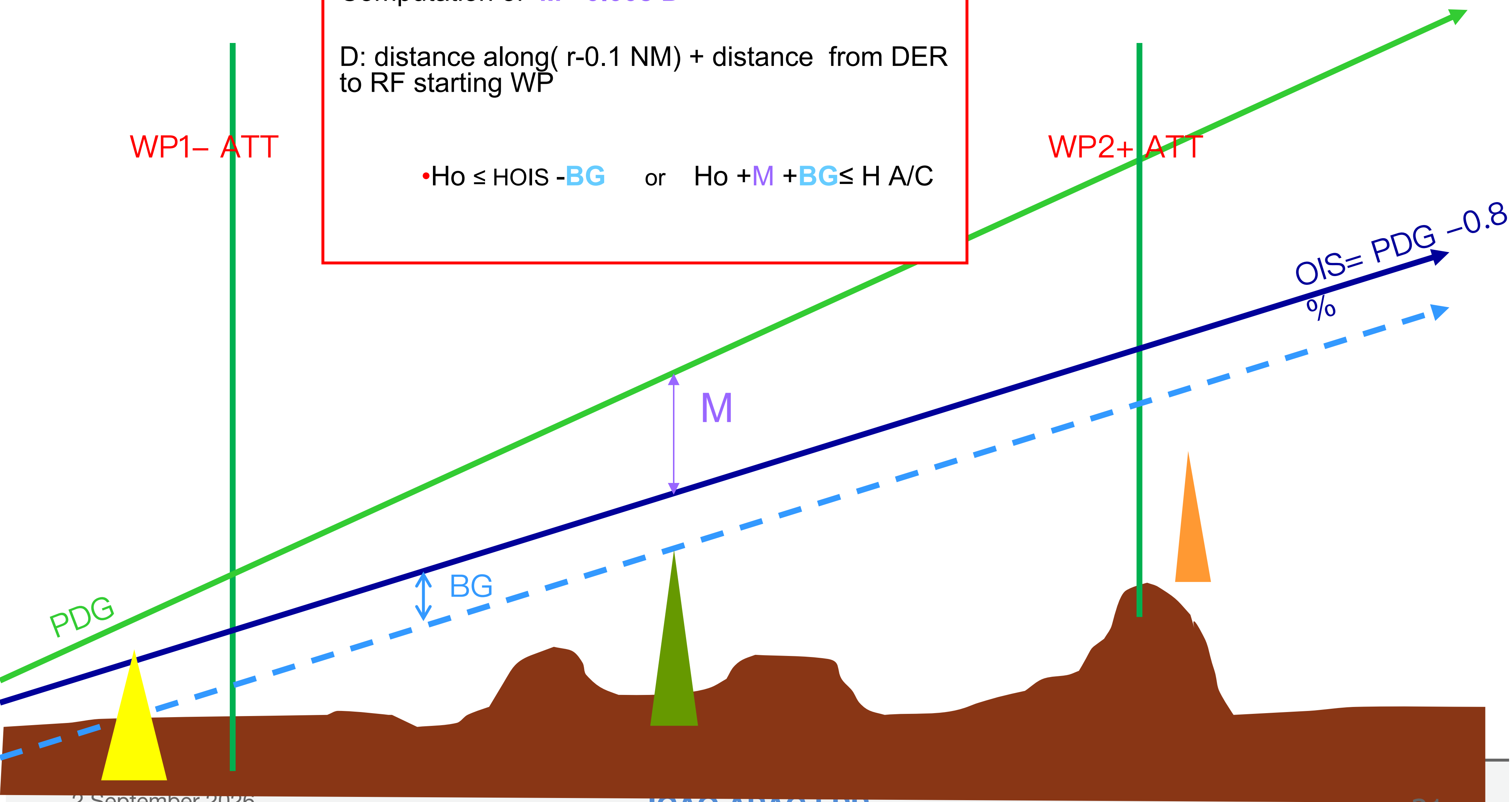
- Step 1 : Define the nominal path (e.g: starting waypoint,radius ander center of the RF and ending waypoint) regarding terrain, airspace, noise abatment
- Step 2 : check that :
  - ✓ Distance between first Waypoint and DER ≥ 1 Nm
  - ✓ bank angle ≤25 °
  - ✓ radius ≤ ½ AW
  - ✓ radius ≤ 2NP
- Step 3 : Compute WPs tolerances and protection areas
- Step 4: Draw straight initial protection area
- Step 5: Asess obstacles and compute PDG from DER up to the starting WP of the RF leg
- Step 6 : Ckeck if PDG reaches 400 Ft at the earliest tolerance of the starting WP of RF leg, if not compute the additionnal climb gradient.
- Step7: Draw protection area
- Step8: Assess obstacle by first lowering of 20 m the OIS
  - ➢ if no obstacle are penetrating: PDG is OK
  - ➢ If not ; assess more accurately.
- Step 9: Create textual and coding description

4:Majoring method of assesment of obstacles in departure segment:Lowering OIS by BG Value

Computation of **M= 0.008 D**

D: distance along(r-0.1 NM) + distance from DER to RF starting WP

- Ho ≤ HOIS -**BG** or Ho +M +**BG**≤ H A/C



How to asess more accurately ?

- To assess accurately , the appropriate MOC shall be applied
- To know which MOC is applicable in primary area it is necessary to compute:
  - Levelled height at RF starting WP(-ATT)
  - M = 0.8%D with D: distance along(r-0.1 NM) + distance from DER to RF starting WP
  - As long as M ≥75m No BG is taken into account
- In secondary area
  - Only the margin M is linearly decreasing
  - when BG is taken into acount in the MOC computation, take full value for« BG »

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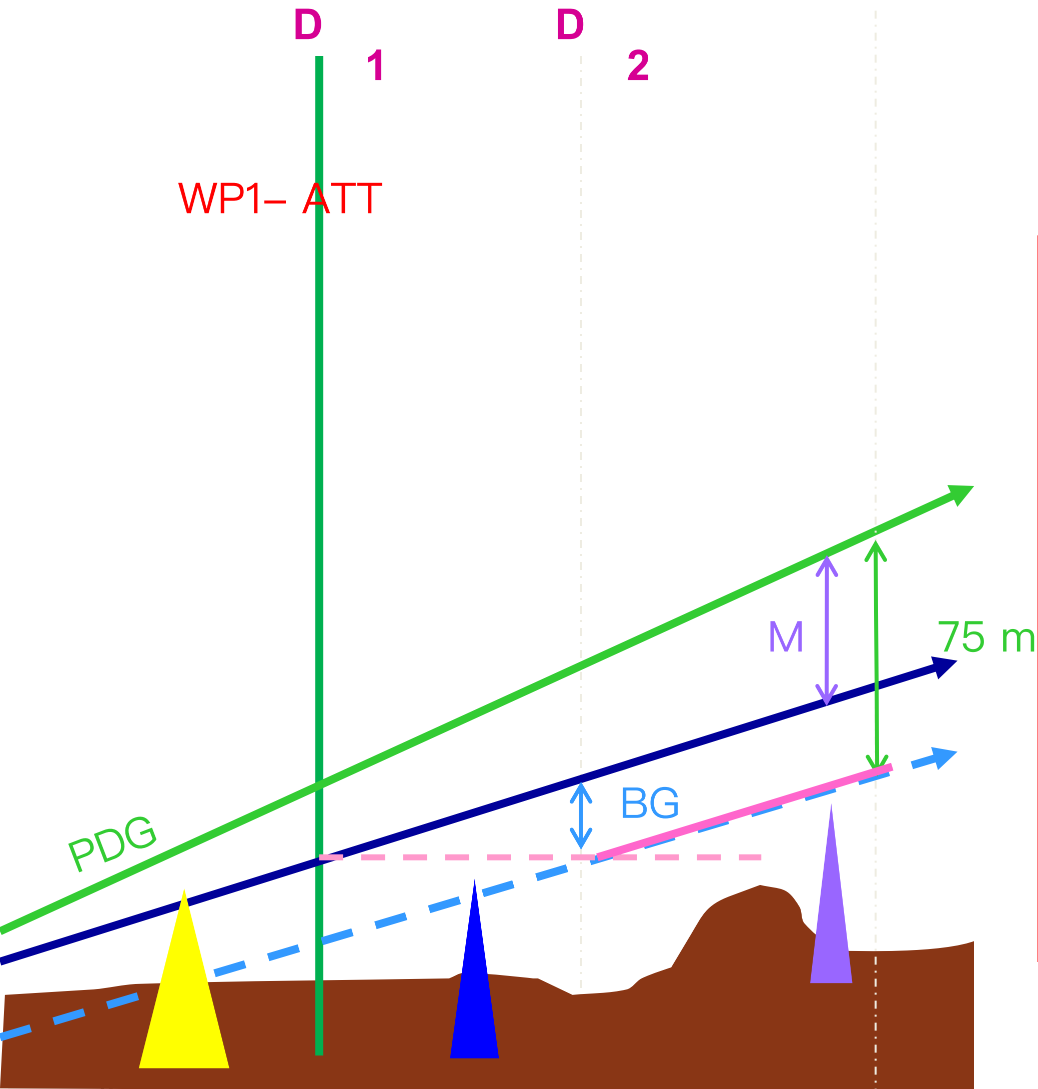
4: Assesement of obstacles in departure



M computation: **M= 0.008 D**

D: distance on arc(r-0.1 NM) + distance DER to the earliest tolerance of the starting waypoint (D1)

If M < 75 - BG

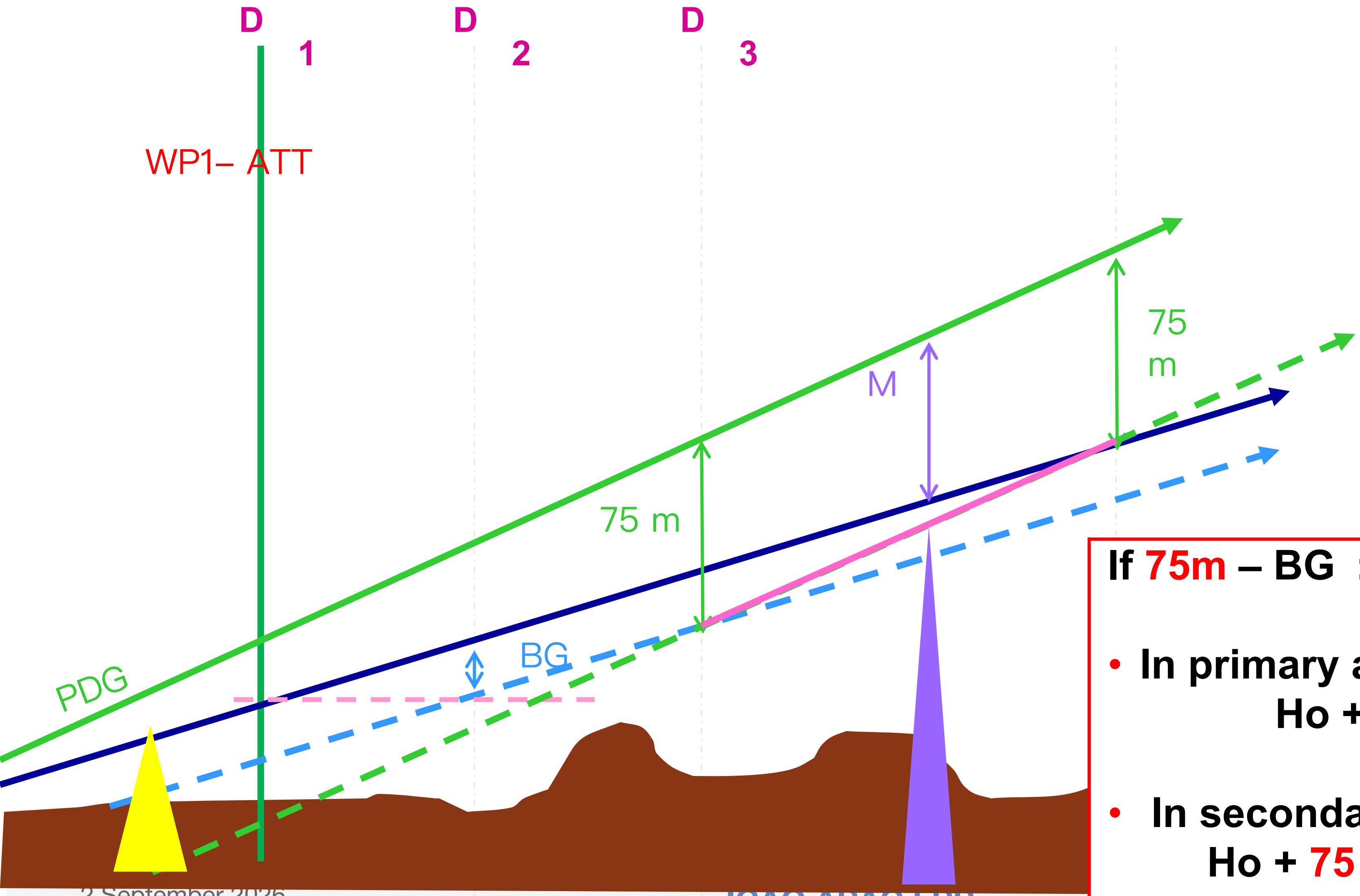
- In primary area:

  Ho +M +**BG**≤ H A/C

- In secondary area

  Ho + **% M** +**BG** ≤ H A/C

4: Assesement of obstacles in departure



If 75m – BG ≤ M ≤ 75

- **In primary area :**
  Ho +75 ≤ H A/C

- **In secondary area**
  Ho + 75 - (1-x%) M ≤ H A/C

4: Assesment of obstacles in departure

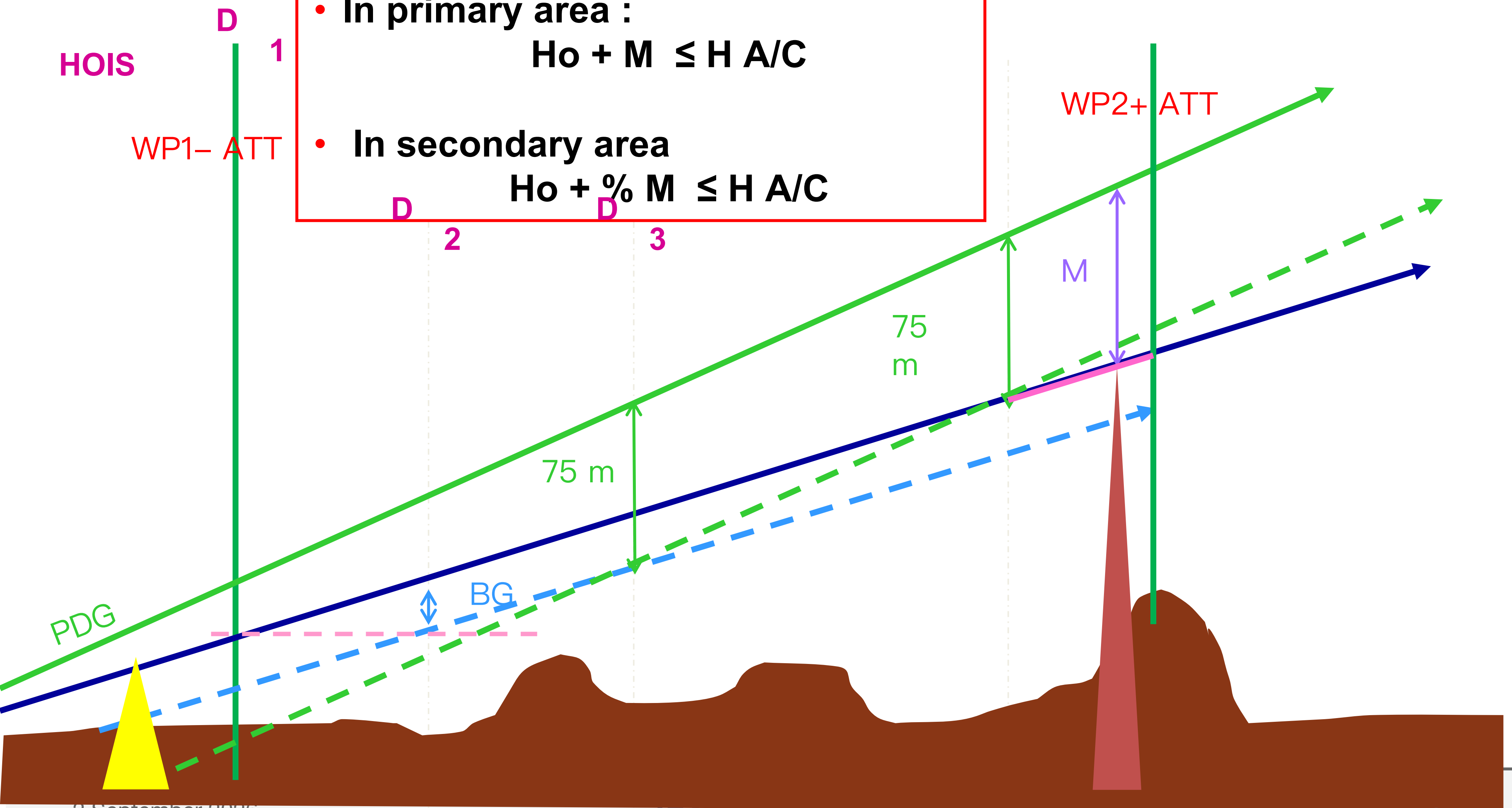
If M ≥ 75 m until WP2 + ATT

- **In primary area :**

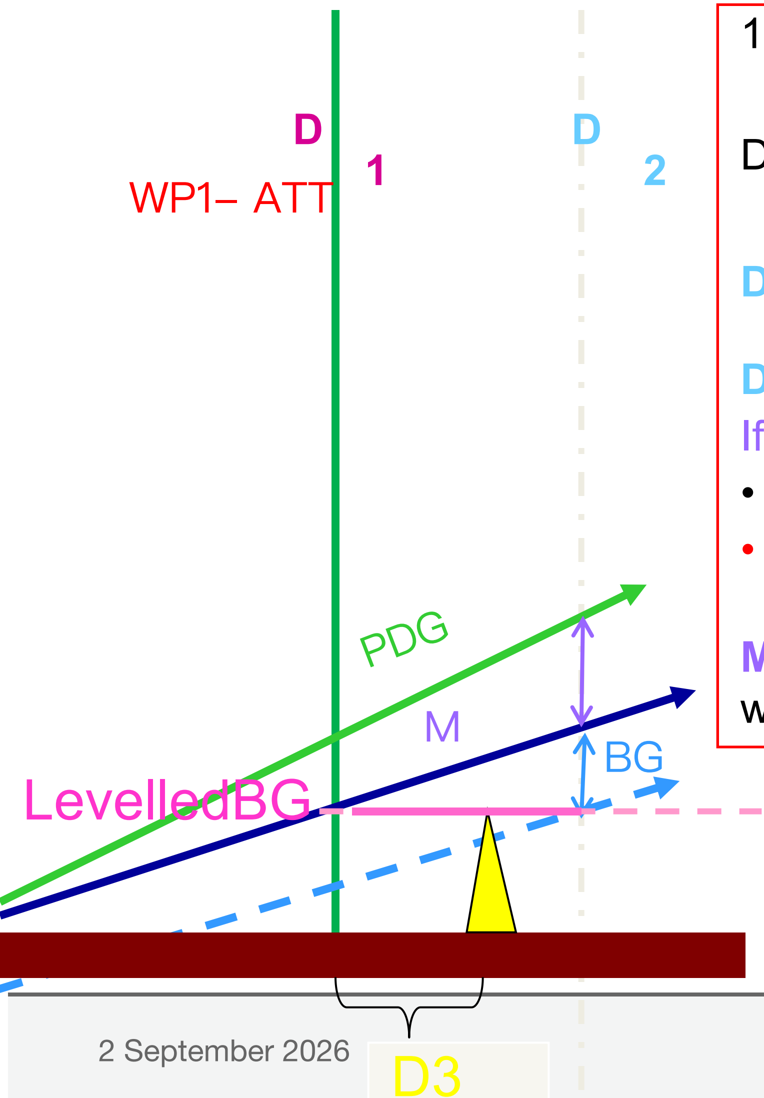
  Ho + M ≤ H A/C

- **In secondary area**

  Ho + % M ≤ H A/C



4. Assesment of obstacles in the levelleved segment e.g between D1 and D2:



1. Computation of levelled BG :

LevelledBG = D1 ***climb gradient**$_{\mathbf{OIS}}$ + 5 (here in meter)

D1 distance between DER and earliest WP1 so WP1-ATT

D2: Distance from earliest starting WP to reach « LevelledBG + BG»

D2 = BG / climb gradient$_{\mathbf{OIS}}$

If D3 ≤ **D2**

- In primary area: Ho ≤ LevelledBG
- In secondary area : Ho≤ LevelledBG +% M

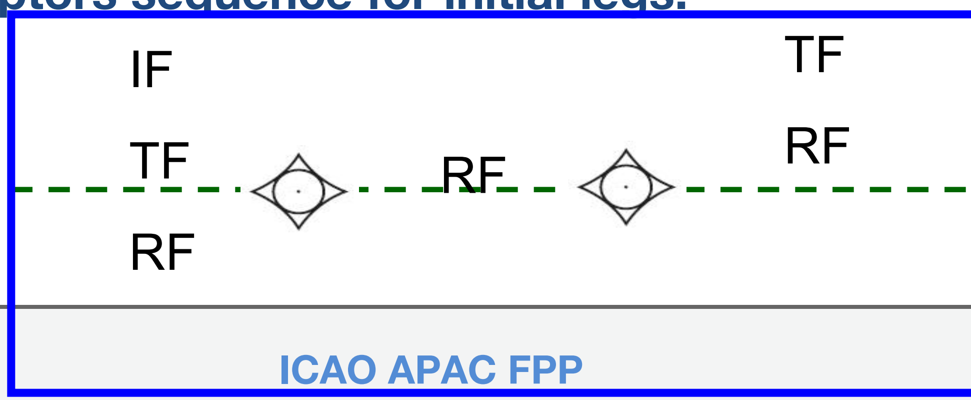
M computation :**M= 0.008 (D1+D3)**

with D3 distance between obstacle and WP1-ATT

Note : The closer to the primary area boundary the obstacle is, the larger is the % of M and the lower is the height of the area

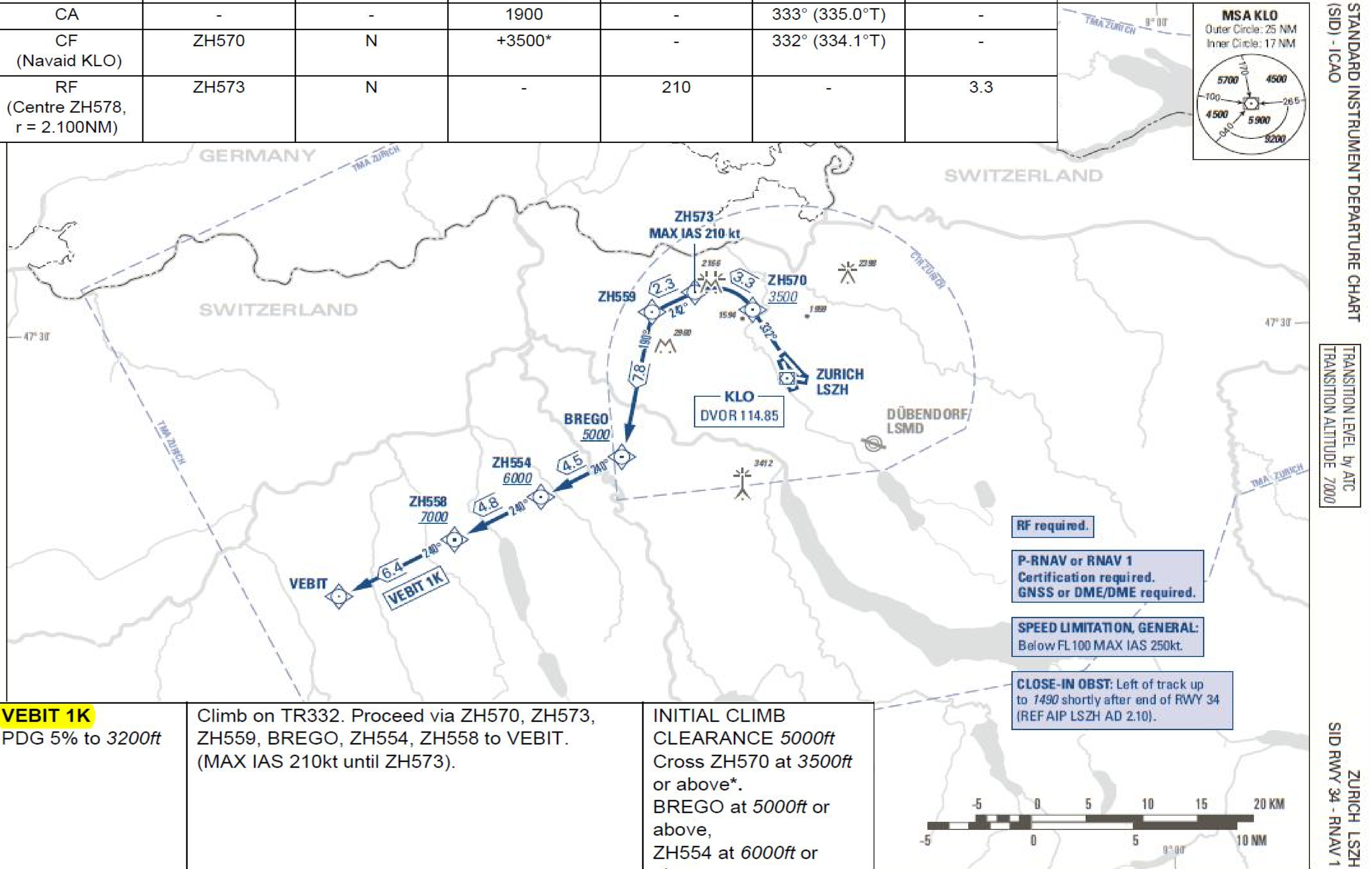
5. Publication

- ✓ If the PDG doesn't reach 400 ft at the start of the RF turn, publish:
  - ✓ An additional gradient and;
  - ✓ An altitude restriction at the waypoint
- ✓ RF is a required functionality for ARNP:
  - ✓ When using RF in any other application, on the chart is mentioned a note:
  - ✓ "RF required"!
- ✓ Path descriptors sequence for initial legs:



Procedure Description of RNAV 1 SID VEBIT 1K (see chart LSZH AD 2.24.7.6 - 1)

Path terminator	Waypoint	Flyover	Altitude (ft)	Speed limit (kt)	Track	Distance (NM)
CA	-	-	1900	-	333° (335.0°T)	-
CF (Navaid KLO)	ZH570	N	+3500*	-	332° (334.1°T)	-
RF (Centre ZH578, r = 2.100NM)	ZH573	N	-	210	-	3.3



VEBIT 1K PDG 5% to *3200ft*	Climb on TR332. Proceed via ZH570, ZH573, ZH559, BREGO, ZH554, ZH558 to VEBIT. (MAX IAS 210kt until ZH573).	INITIAL CLIMB CLEARANCE *5000ft* Cross ZH570 at *3500ft* or above*. BREGO at *5000ft* or above, ZH554 at *6000ft* or above, ZH558 at *7000ft* or above

Questions ?