PANS-OPS Flight Procedure Design Training for CAAs

23 August – 03 September 2021

2 – General principles

(Doc. 8168, Vol. 2, Part I, section 2)

Outlines

1. Navigation facilities
2. Fixes
3. Fix tolerances
4. Fixes satisfactory criteria
5. Protection area
6. Aircraft parameters
7. Turns protection

Navigation facilities

- Provide navigation information:
  - Position;
  - Track guidance;
  - Vertical guidance;
  - Distance;
  - Etc.
- Information is received on-board with corresponding receivers.

Conventional navigation

Flight parameters control:

Speed	→	Airspeed indicator
Altitude	→	Altimeter
Bank angle	→	Horizon
Vertical profile (climb, descent)	→	Variometer

Trajectory control:

Heading	→	Compass
Time	→	Chronometer
NDB	→	ADF RMI, ADF RMI
VOR	→	VOR RMI, CDI
ILS	→	CDI RMI (LOC, GP)
DME	→	DME receiver

PBN navigation

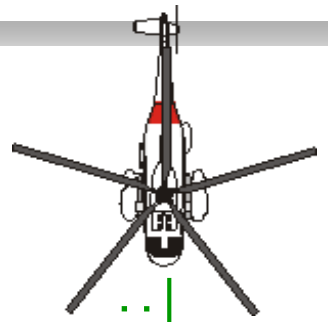
Flight parameters control

- Speed → Airspeed indicator
- Altitude → Altimeter
- Bank angle → Horizon
- Vertical profile (climb, descent) → Variometer

Trajectory control

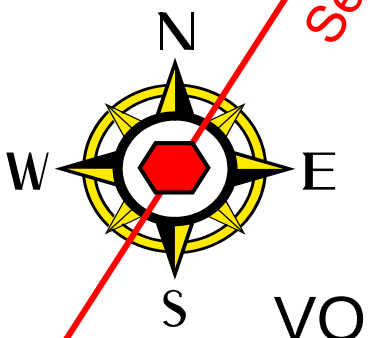
- Heading → Compass
- Time → Chronometer
- Navigation infrastructure → ADF RMI, ADF RMI
  - VOR-DME → FMS - HSI
  - DME/DME → FMS - HSI
  - GNSS → GNSS receiver

VOR guidance



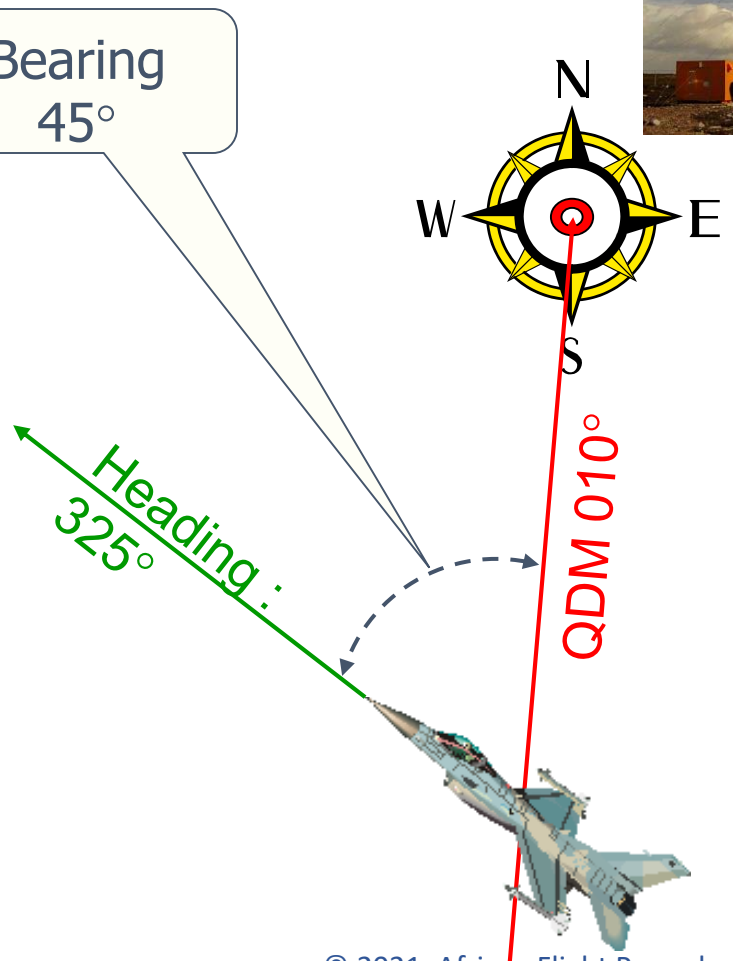
Heading : 176°

Selected radial : 210°



VOR facility

NDB guidance



ILS guidance

- ILS components:
  - LOC (Localizer):
    - lateral guidance;
    - Frequency: VHF.
  - GP (Glide path):
    - Vertical guidance;
    - Frequency: UHF.
  - L-DME or Markers:
    - Distance
    - L-DME:
      - Frequency: VHF;
      - Coupled with L-DME.

Fixes

- Terminal are fixes:
  - Initial Approach Fix : IAF (mandatory);
  - Intermediate approach Fix : IF;
  - Final Approach Point/Fix : FAP/FAF
  - Holding Fix : HF;
  - Missed Approach Point (MAPt) : MAPt:
    - Mandatory for NPA.
  - Turning Point or Altitude :
    - Missed approach and
    - Departure.

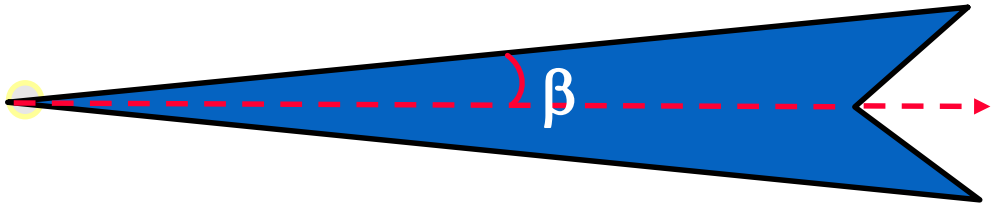
Fix tolerances

- Components of the fix tolerances:
  - Navaid tolerance;
  - Airborne receiving system tolerance;
  - Flight technical tolerance (FTT);
  - Distance to the DME Station;
  - Fixes in link with a geographical position.
- Tolerance area:
  - Area where pilots identify the fix.

Information accuracy

Accuracy of the navaid reflected on:

- Fix : tolerance area
- Trajectory : segment protection area



	Angle β value	
Navaid	**Tracking**	**Intersecting**
NDB	5.2	4.5
VOR	6.9	6.2
LOC	2.4	1.4

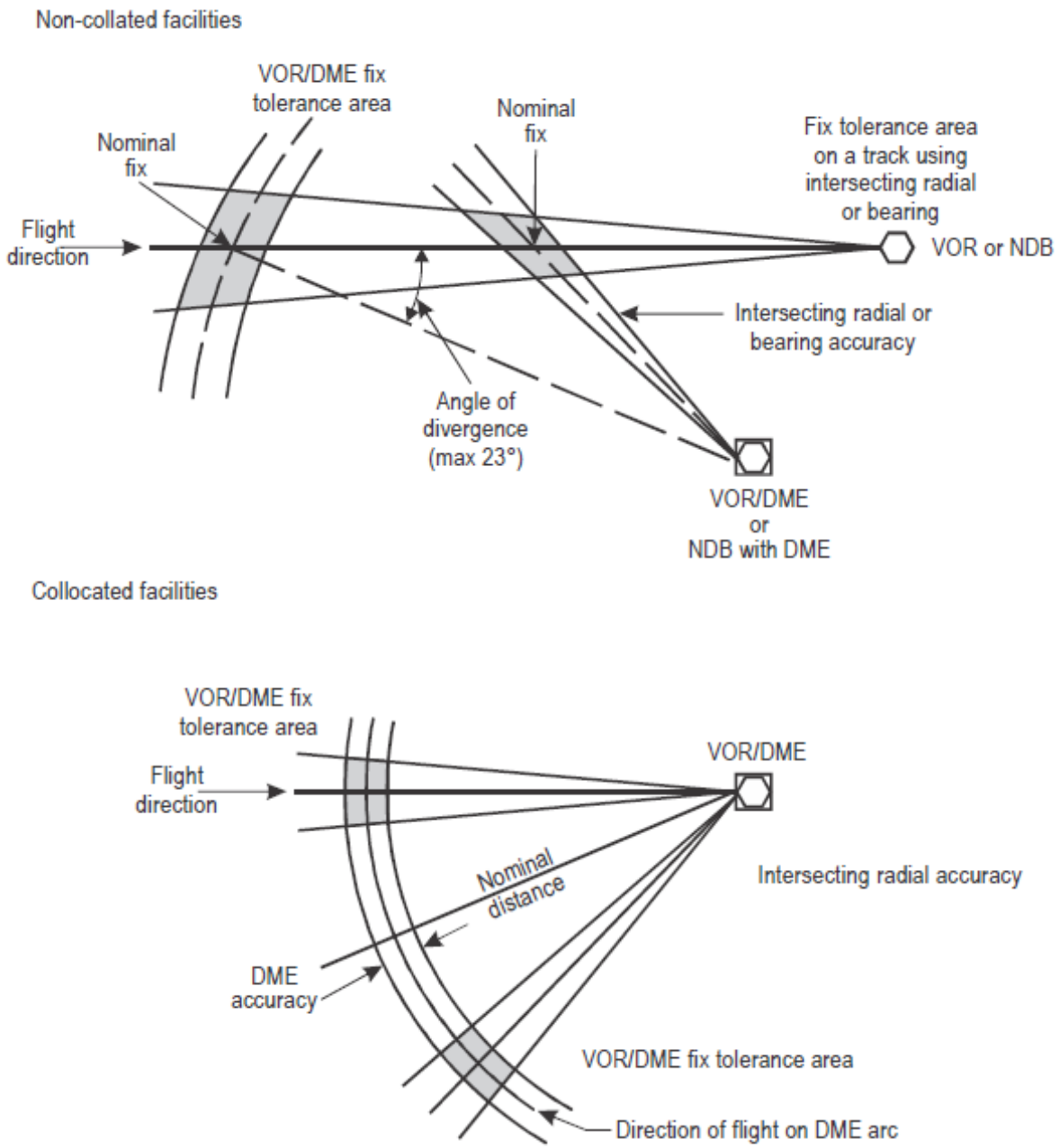
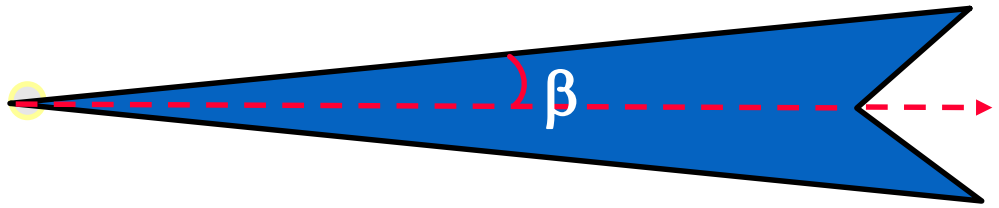


Figure I-2-2-1. Intersection fix tolerance areas

Fix tolerances

Information accuracy



	Angle β value	
Navaid	**Tracking**	**Intersecting**
NDB	5.2	4.5
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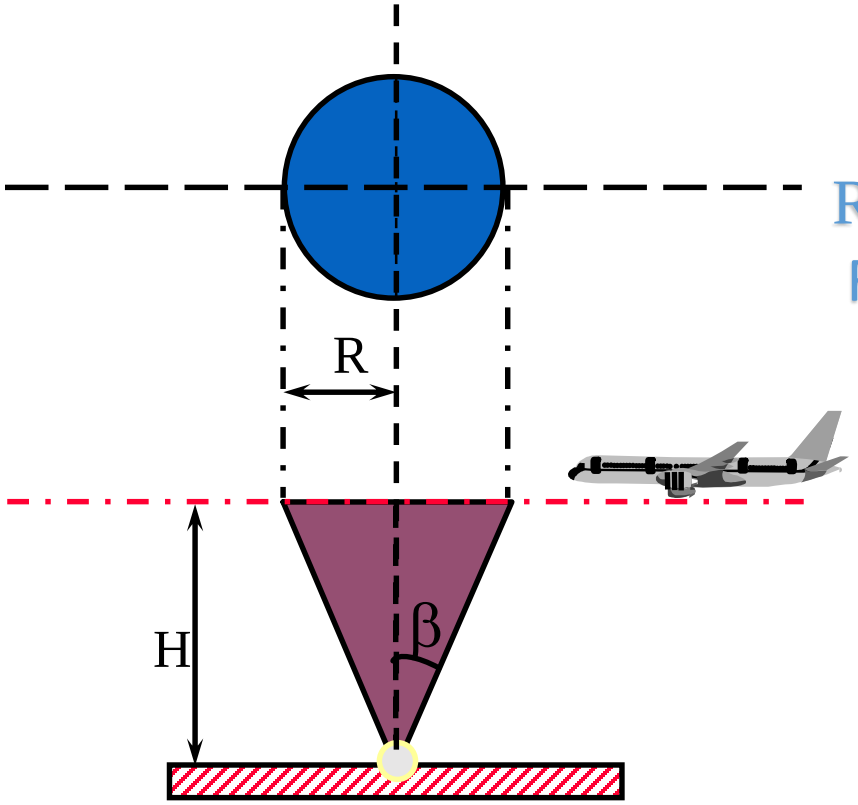
LOC	2.4	1.4

Fix tolerances

VOR and NDB dead cone zone



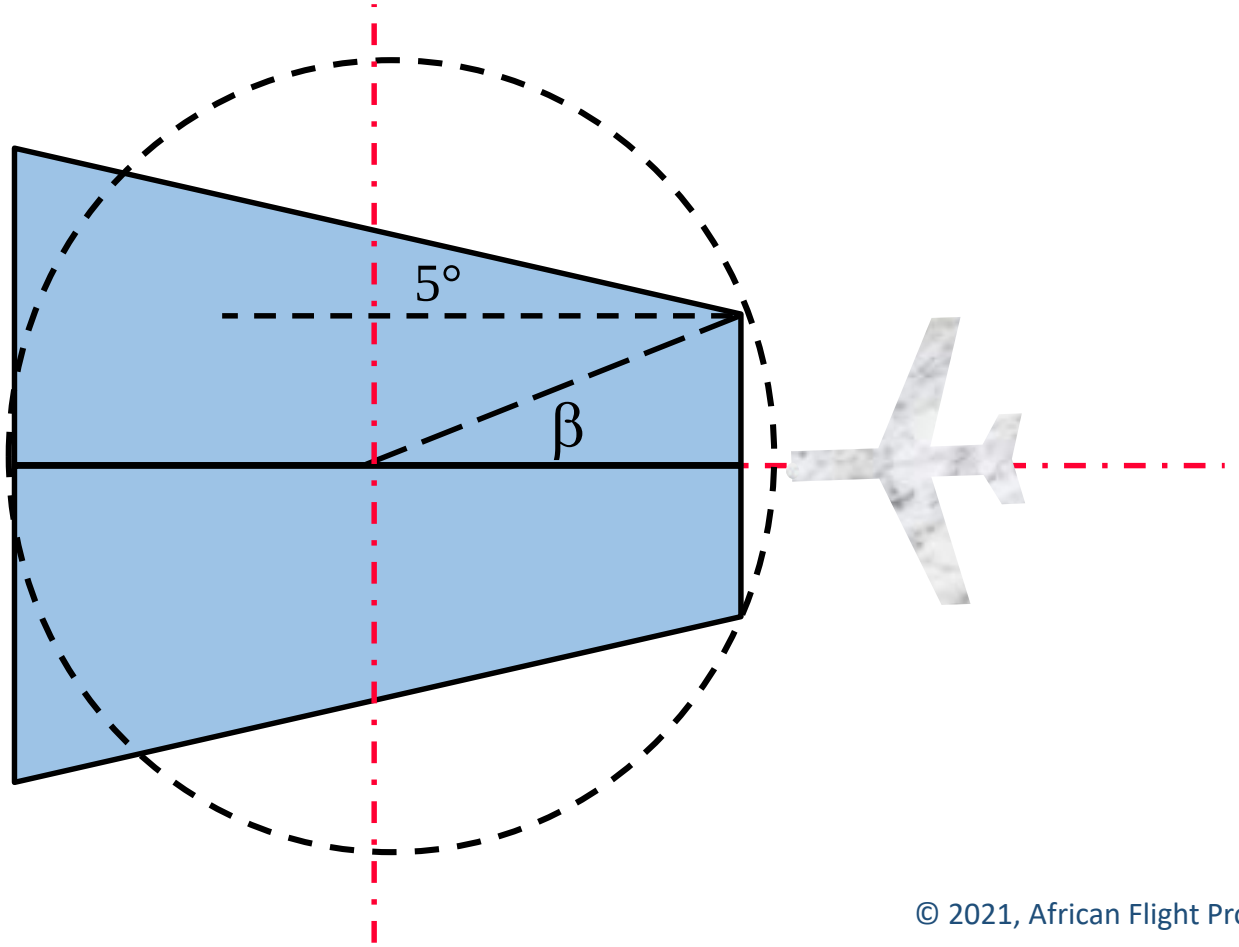
VOR or NDB

$R = H \times \tan(\beta)$ with R and H in km or

$R = 0.164 H \tan(\beta)$ with H in thousands of ft and R in NM

Navaid	Angle β value (°)
NDB	40
VOR	50

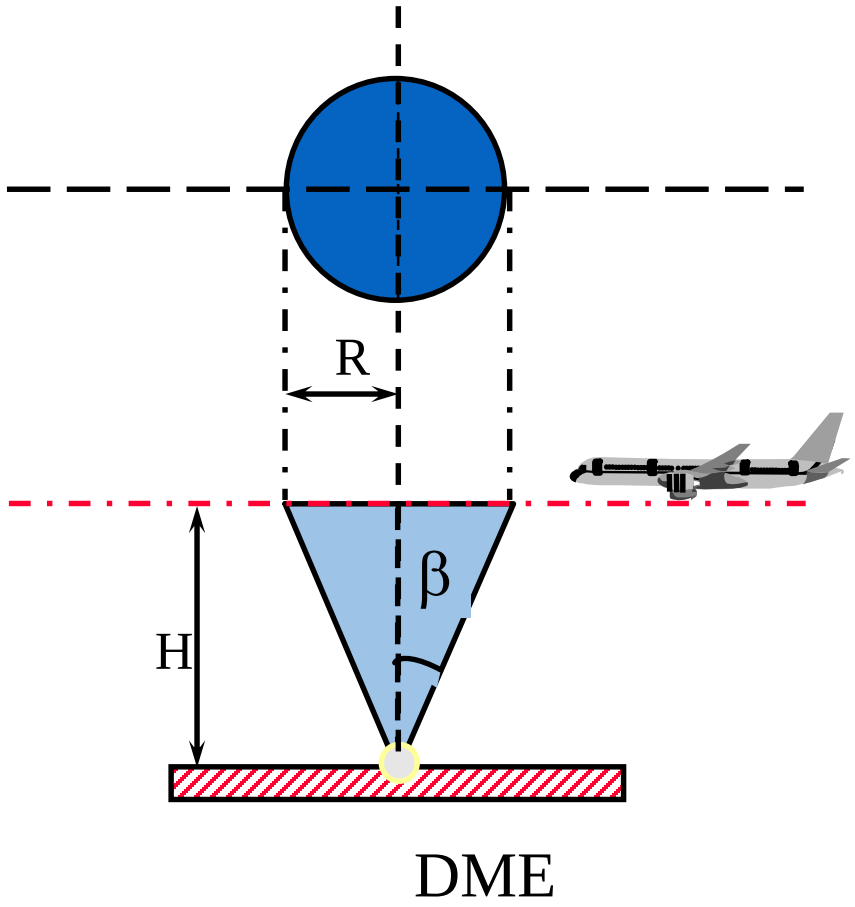
Tolerance overhead VOR and NDB



β	ICAO
V O R	5 °
N D B	1 5 °

Fix tolerances

Tolerance overhead VOR and NDB



- Fixes using DME defined only outside the DME station dead cone;
- DME issues:
  - Provide slant distances , while;
  - Procedure designer uses horizontal distances.
- Minimum usable ground distance:

  D = Hxtan(55°)
- Fix location varies with aircraft altitude

Tolerance of TP over VOR or NDB

- Turning Point along Missed Approach
  - Constant value of +/-0.5 NM up to :
    - 2 500 ft for VOR;
    - 3 600 ft for NDB.
  - Above : use regular dead cone zone.

Waypoint tolerances (PBN)

- 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 = RNP Value
  - ☞ATT = 0.8 x XTT

Fixes satisfactory criteria

- IAF and IF : +/- 2 NM
- FAF : +/- 1 NM
- Step down fix meets criteria of corresponding segment
- MAPt : computed value
- No criteria for TP (due to constant value)

Protection area

- Navigation facility accuracy
- Human factors
  - Reaction time prior to requested actions;
  - Skill to perform requested actions.
- Wind effect

Aircraft parameters

- Five categories : From A to E (H)
  - Max and min Speed must be known by both:
    - Pilots;
    - Designers;
    - Air traffic controllers.
  - Speed limitations are possible (Only the maximum):
    - Must be displayed on chart.
  - Speed table available.

Table I-4-1-2. Speeds (IAS) for procedure calculations in knots (kt)

Aircraft category	V_{at}	*Range of speeds for initial approach*	*Range of final approach speeds*	*Max speeds for visual manoeuvring (circling)*	*Max speeds for missed approach*	
					Intermediate	*Final*
A	<91	90/150(110*)	70/100	100	100	110
B	91/120	120/180(140*)	85/130	135	130	150
C	121/140	160/240	115/160	180	160	240
D	141/165	185/250	130/185	205	185	265
E	166/210	185/250	155/230	240	230	275
H	N/A	70/120**	60/90***	N/A	90	90
Cat H (PinS)***	N/A	70/120	60/90	NA	70 or 90	70 or 90

V_{at} Speed at threshold based on 1.3 times stall speed V_{so} or 1.23 times stall speed V_{slg} in the landing configuration at maximum certificated landing mass. (Not applicable to helicopters.)

Altitude (feet)	*Conversion factor*							
	ISA–30	*ISA–20*	*ISA–10*	*ISA*	*ISA+10*	*ISA+15*	*ISA+20*	*ISA+30*
10 000.0	1.0967	1.1194	1.1418	1.1637	1.1852	1.1958	1.2063	1.2270
11 000.0	1.1136	1.1369	1.1597	1.1822	1.2042	1.2150	1.2258	1.2470
12 000.0	1.1309	1.1547	1.1781	1.2011	1.2236	1.2347	1.2457	1.2674
13 000.0	1.1485	1.1730	1.1970	1.2205	1.2435	1.2549	1.2661	1.2884
14 000.0	1.1666	1.1917	1.2162	1.2403	1.2639	1.2755	1.2871	1.3098
15 000.0	1.1852	1.2108	1.2360	1.2606	1.2848	1.2967	1.3085	1.3318
16 000.0	1.2041	1.2304	1.2562	1.2814	1.3062	1.3184	1.3305	1.3544
17 000.0	1.2235	1.2505	1.2769	1.3028	1.3281	1.3406	1.3530	1.3775
18 000.0	1.2434	1.2710	1.2981	1.3246	1.3506	1.3634	1.3761	1.4011

TAS= k*IAS

IAS has to be converted into True Air Speed using the conversion factor k:

$$TAS = IAS \times 171233\,[(288 \pm VAR) - 0.00198H]^{0.5} \div (288 - 0.00198H)^{2.628}$$

where: VAR = Temperature variation about ISA in °C, H = Altitude in feet.

Turn parameters

- Altitude;
- Indicated airspeed (IAS)
- Wind;
- Bank angle (α);
- Flight Technical Tolerance (FTT).

Turns protection

Turn radius

$$R = \frac{(6\,355 \tan(\alpha))}{\pi TAS}$$

Where:

- R: rate of turn in °/s (3° max)
- TAS in km/h
- α : Bank angle in °

$$R = \frac{(3\,431 \tan(\alpha)}{\pi TAS}$$

Where:

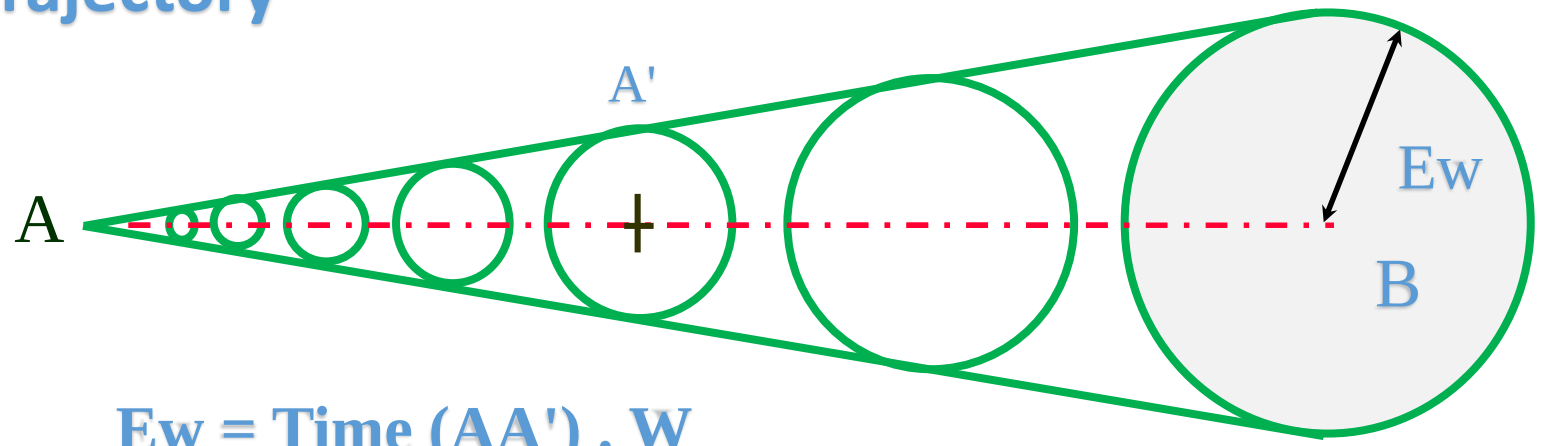
- R: rate of turn in °/s(3° max)
- TAS in kt
- α : Bank angle in °

$$r = \frac{TAS}{20\pi R}$$

Where:

- r: turn radius in km or NM
- TAS in kt

Wind effect: Straight trajectory



Ew = Time (AA') . W

Ew = T(AB) . W

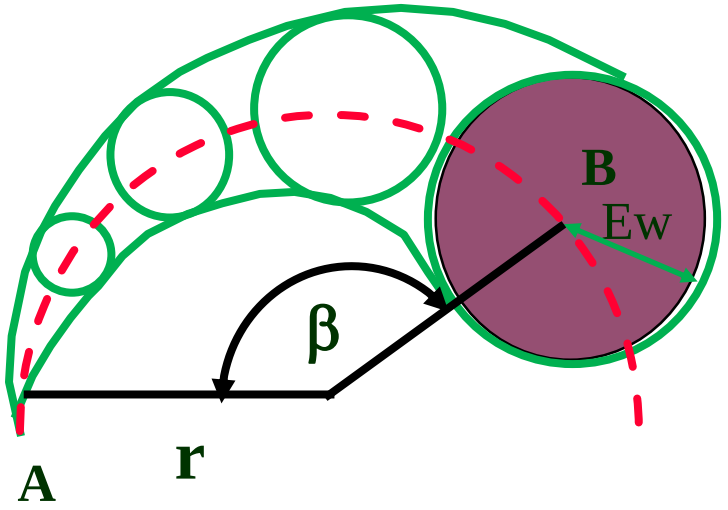
W : Wind speed (in m/s) and T : Time in s
Ew is the wind effect (radius of circle in m)

Turns protection

Wind effect: Curved trajectory

$$Ew = T\,(AB)\,.\,W$$

$$Ew = \frac{r.\theta.W}{TAS}$$



with $T(AB) = (\beta\, r) / TAS$

β In rd, r in m, TAS in m/s

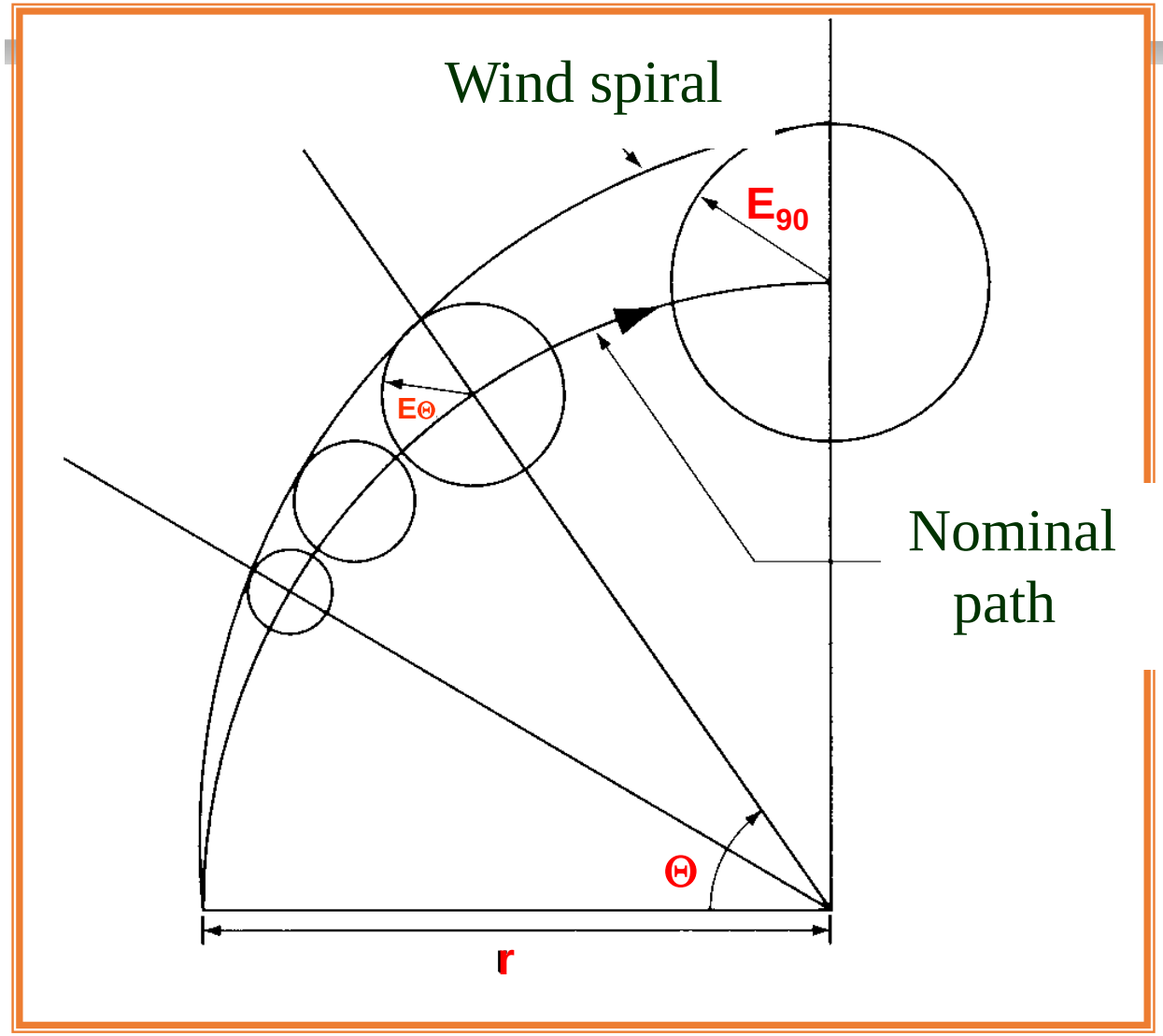
W : Wind speed (in m/s) and T : Time in s

Ew is the wind effect (radius of circle in m

Turn protection

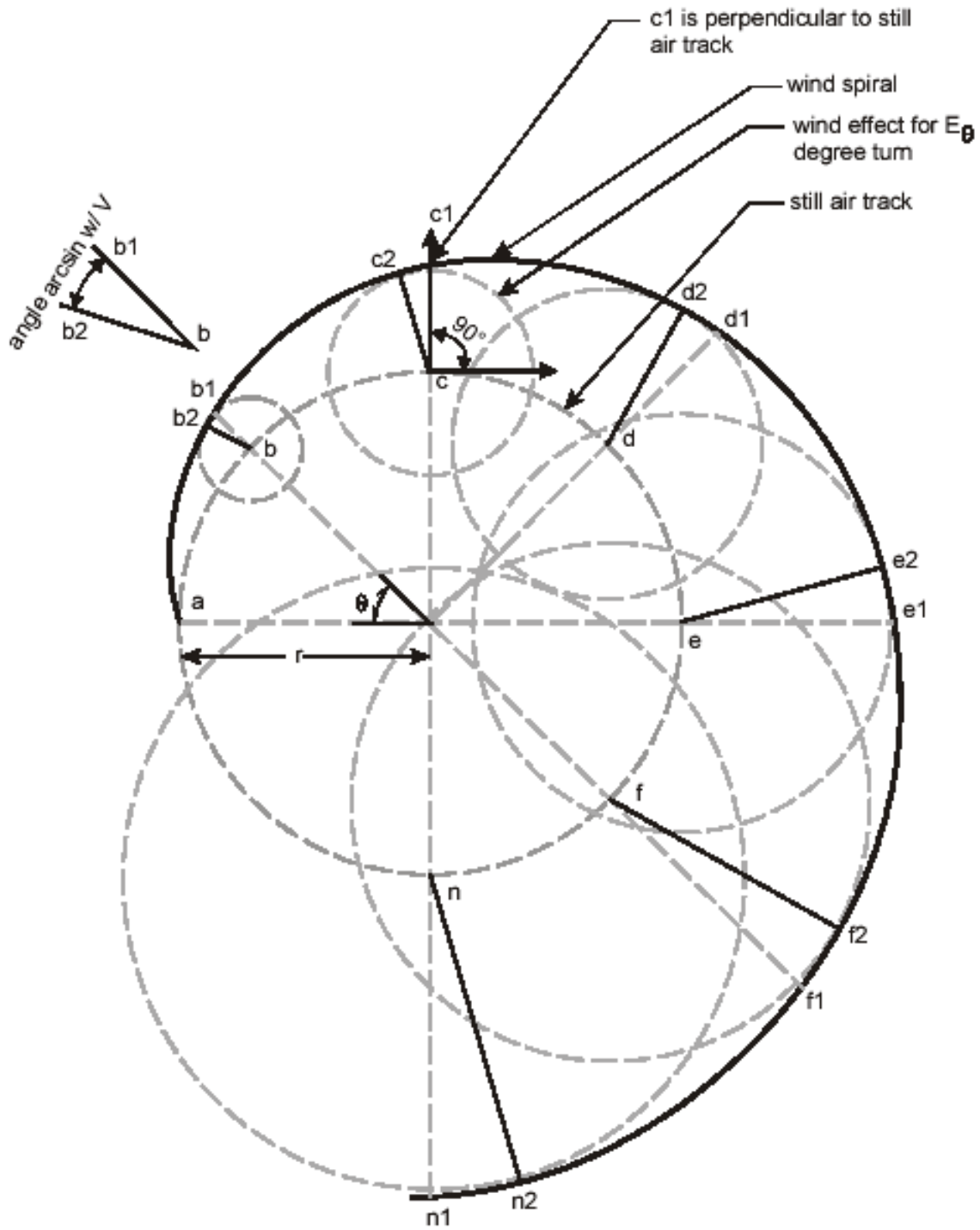
- Outer limit : wind spiral
  - Wind conditions blowing paths outside nominal path
  - Not a trajectory
  - But the envelop of actual turning paths
- Inside limit : not a wind spiral but lines
  - Wind conditions keeping paths inside nominal
- Three methods for turn protection:
  - Wind spirals;
  - Simplified spirals (bounding circles);
  - Method of arcs (for small turns).

Wind spirals

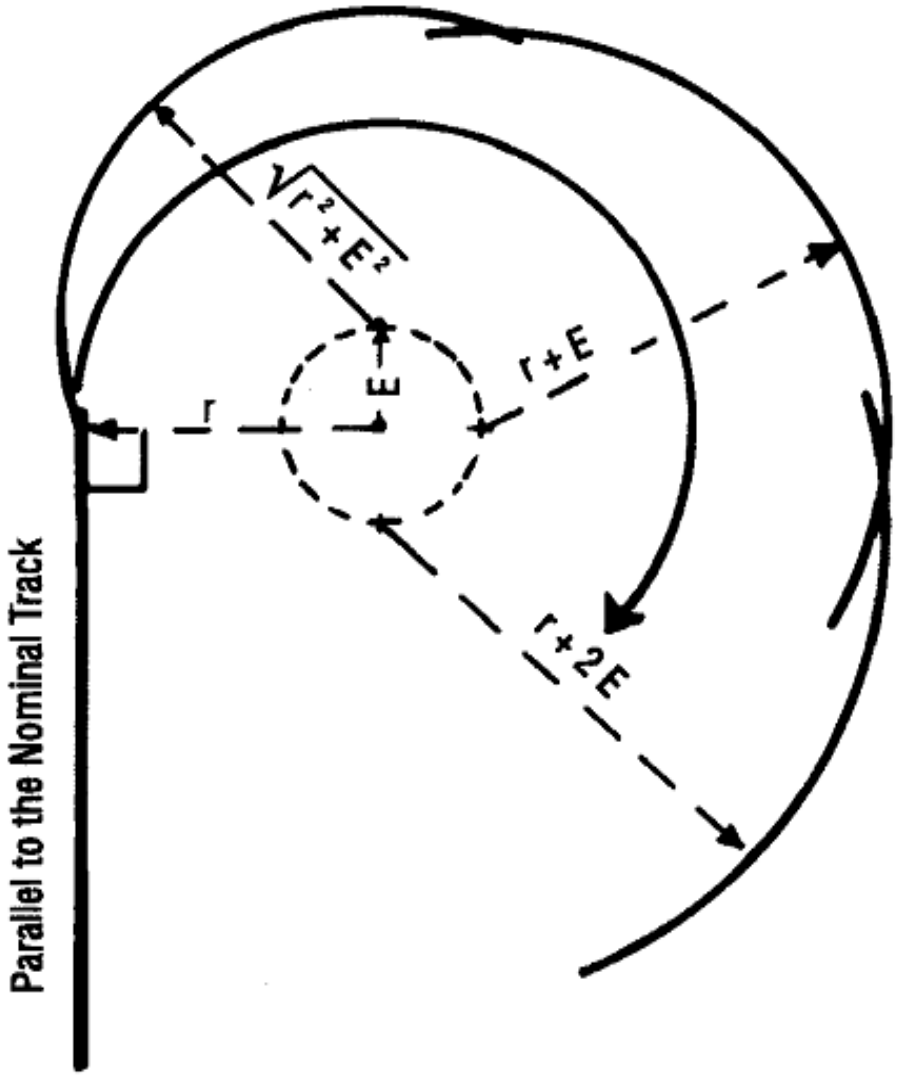


E : Wind effect
r : radius of turn
Θ : Angle of turn

Wind spirals



Simplified Wind Spiral (bounding circles)



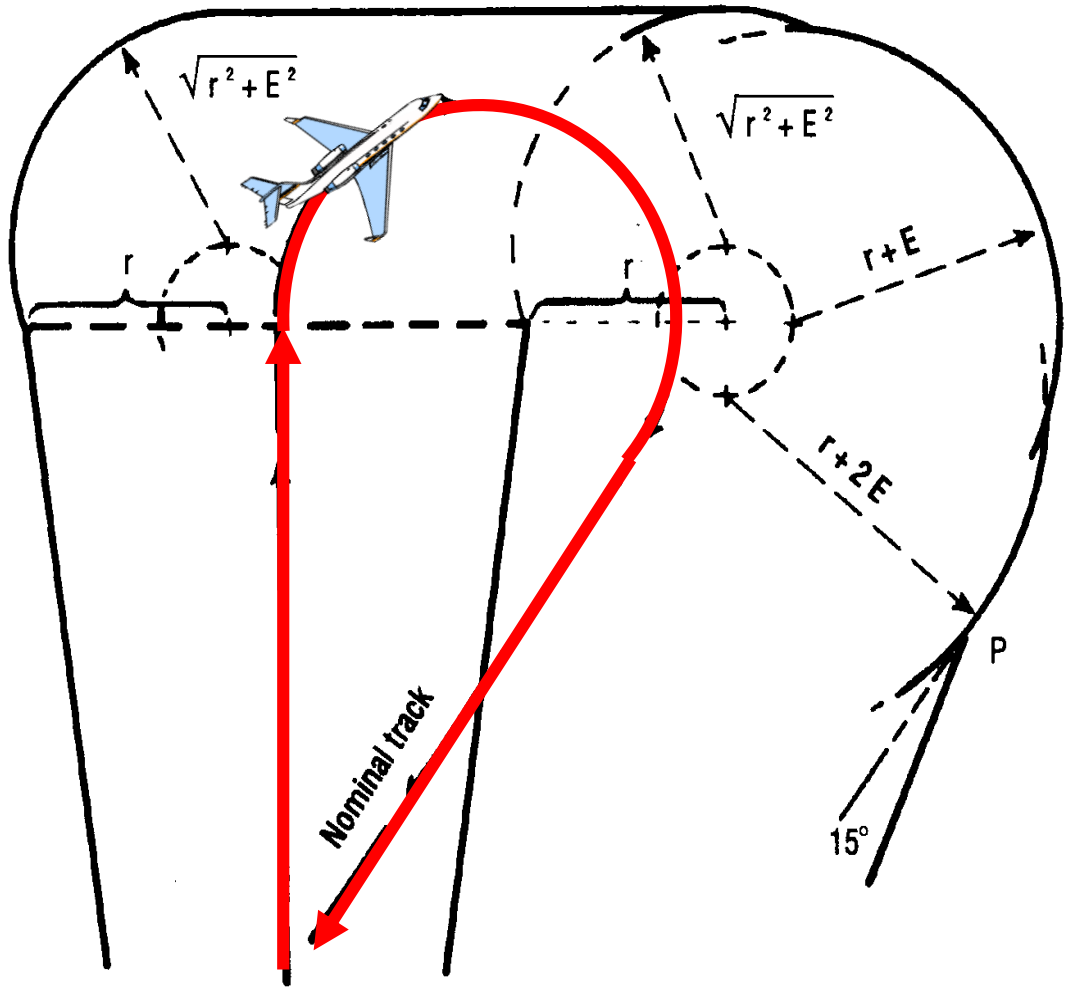
$$Ew_{90°} = \frac{Vw}{40R}$$

Where:

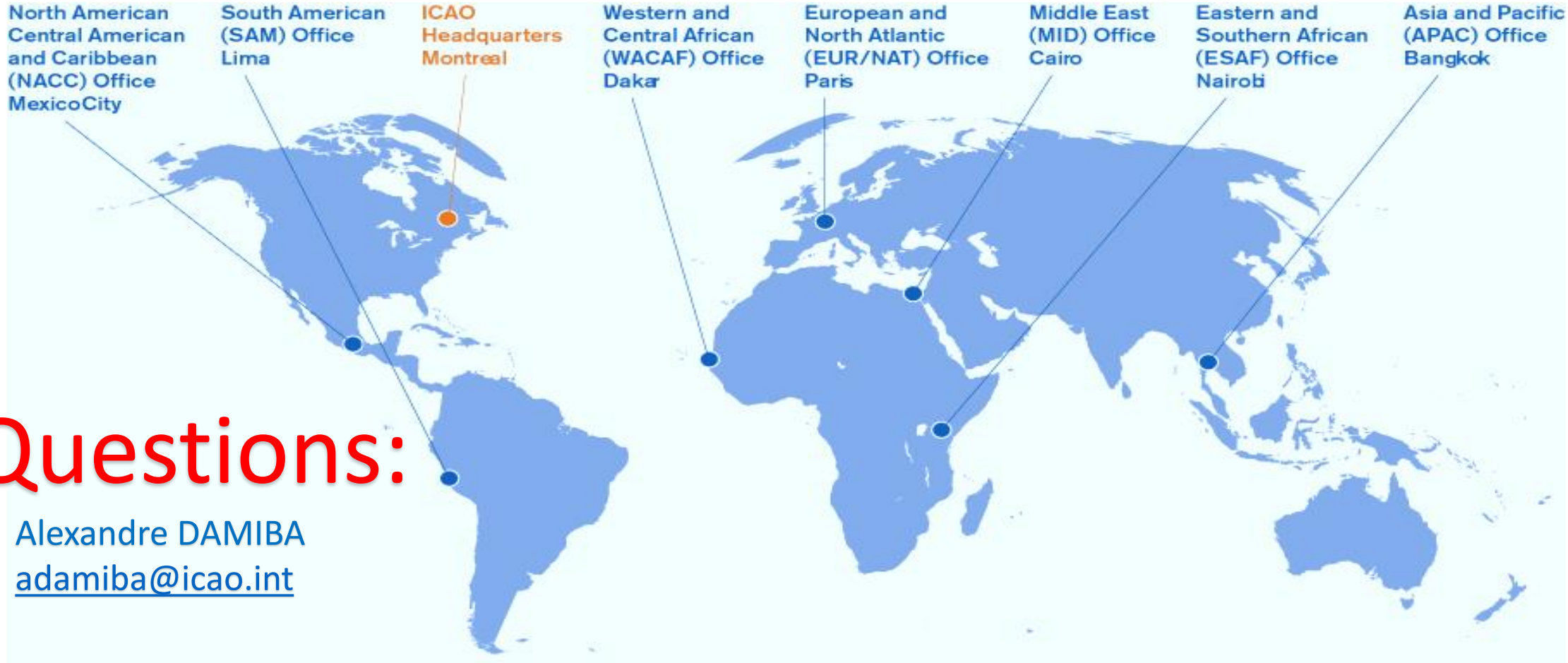
- ***Vw: Wind velocity in kt***
- ***R: Turn rate in °/s***

r = Radius of turn
E = Wind Effect for 90°of turn

Simplified Wind Spiral (bounding circles)



r = Radius of turn
E = Wind Effect for 90°of turn



Questions:

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