PANS-OPS Flight Procedure Design Training for CAAs

23 August – 03 September 2021

15 – ARIC 424 coding

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Objectives

- Know:
  - the coding instructions and related Path Terminators;
  - The allowed Path Terminator sequencing and associated waypoints;
  - The different impacts of PT on flight paths.
- Identify the limit of application of a speed or altitude constraint on arrival and on departure

Outlines

1. **Regulatory framework**
2. **General:**
   - ☞ ARINC 424 ,an industry standard;
   - ☞ Path terminator types;
   - ☞ Procedure design application.
3. **Coding rules:**
   - ☞ Initial and terminal Path terminators;
   - ☞ Path Terminator sequencing;
   - ☞ Required data of a Path Terminator.
4. **Examples of procedure's coding.**

ARINC 424 an industry standard

- Established since 1929, **Aeronautical Radio, Incorporated (ARINC)** previously owned by the Carlyle Group;
- Carlyle group sold in August 2013 to Rockwell Collins.
- Major provider of transport communications and systems engineering solutions for eight industries: aviation, airports, defense, government, healthcare, networks, security and transportation.
- ARINC standards:
  - 400 series : installations, wiring, data bases & databases;
  - 500 series : older analog equipment;
  - 600 series : data management, etc.
  - 700 series : forms, fit and function of avionics
  - 800 series : aviation standards for aircraft (fiber optics and buses).

ARINC 424 an industry standard

- ARINC 424 is an industry standard for the preparation and transmission of data for the assembly of airborne navigation system data bases.
- Each navigation element in the database is uniquely defined and stored in the master user file which can be accessed for any intended navigation purpose.
- ARINC 424 was developed in support to conventional navigation.

- **Although not developed for flight procedure designers, sufficient background information about ARINC 424 will enable them to perform their tasks so that misinterpretations and errors are significantly reduced.**

Path terminators

Currently 23 different path terminators defined in ARINC 424.

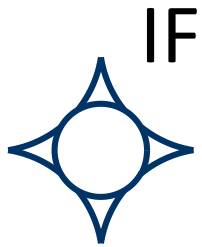
- Arc to a Fix - AF
- Course to an Altitude - CA
- Course to a DME Distance - CD
- Course to a Fix - CF
- Course to an Intercept - CI
- Course to a Radial Termination - CR
- Direct to a Fix - DF
- Fix to an Altitude - FA
- From a Fix for a Distance - FC
- From a Fix to a DME Distance - FD
- From a Fix to a Manual Termination - FM
- Racetrack Course Reversal (Alt Term) - HA

But only 11 are acceptable for RNAV procedures

- Racetrack (Single Circuit - Fix Term) HF
- Racetrack (Manual Termination) HM
  - Initial Fix - IF
  - Track to a Fix - TF
  - Procedure Turn - PI
  - Constant Radius Arc - RF
  - Heading to an Altitude - VA
  - Heading to a DME Distance - VD
  - Heading to an Intercept - VI
  - Heading to a Manual Termination - VM
  - Heading to a Radial Termination - VR

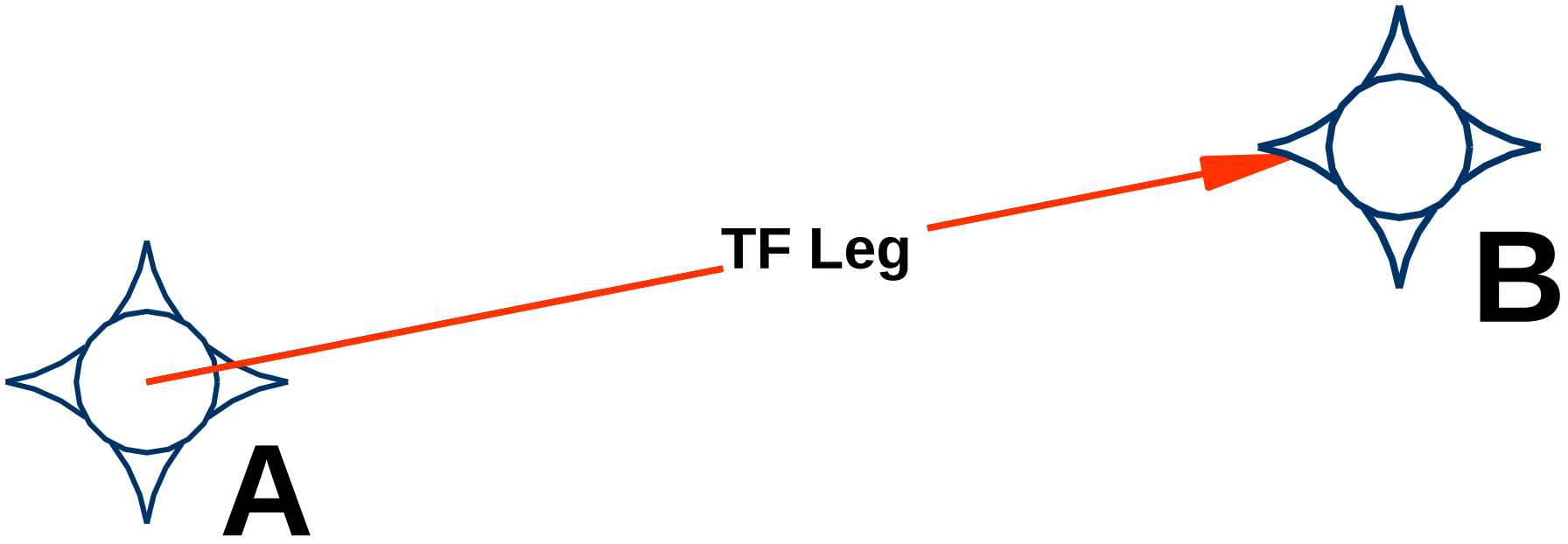
Initial Fix (IF)

- "IF" is the starting waypoint of a route or transition.
  - ☞e.g : Path terminator associated with the first waypoint of STAR is coded IF.

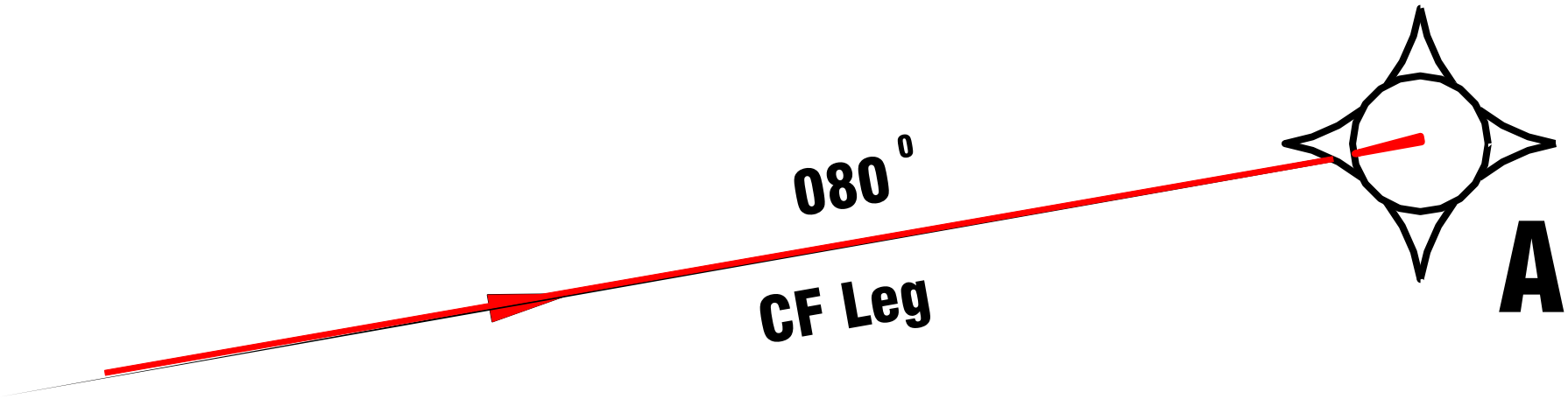


IF in coding ≠ Intermediate Fix in procedure

Track to Fix (TF)

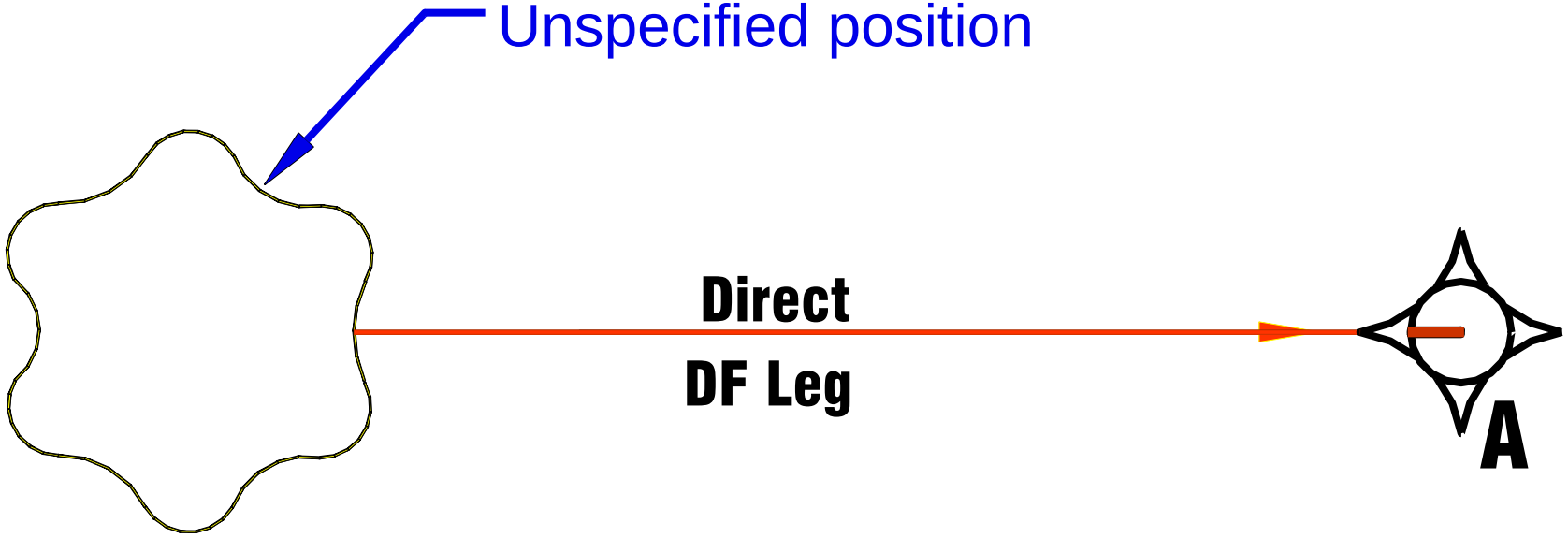


Course to Fix (CF)



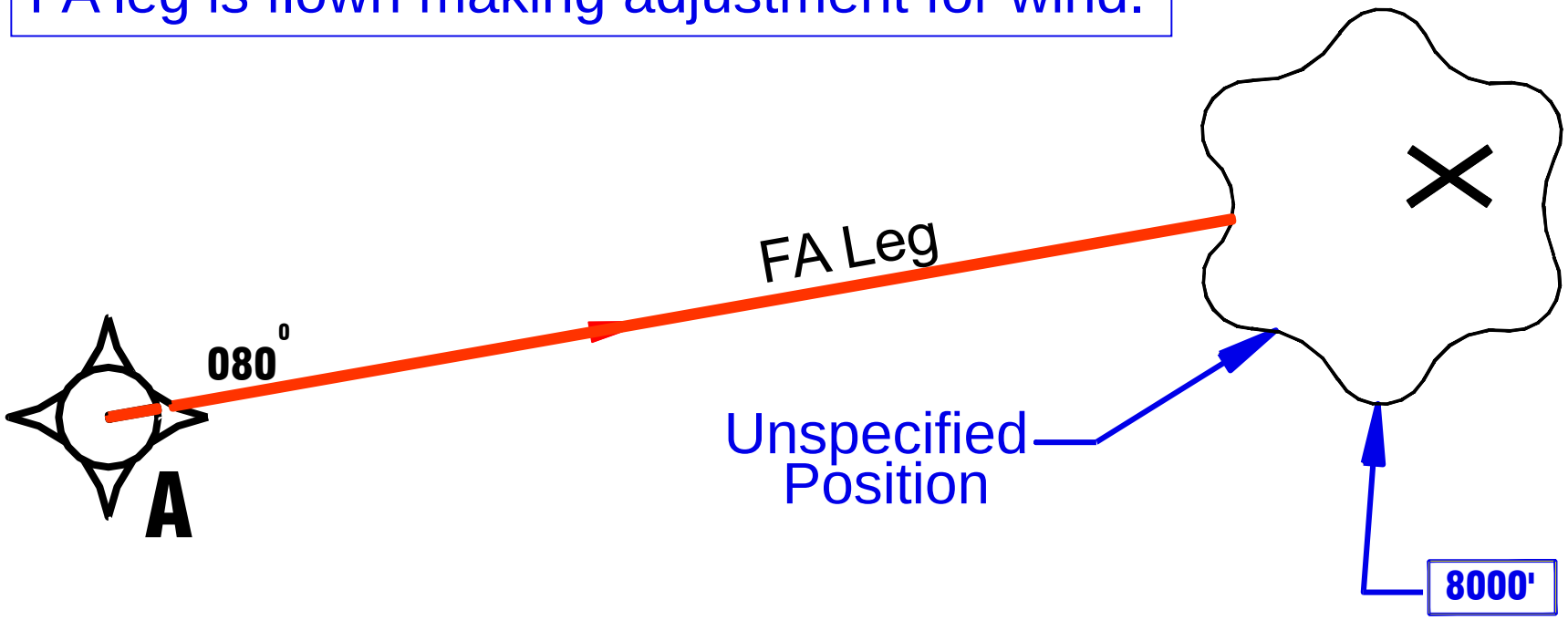
Course is flown making adjustment for wind.

Direct to Fix (DF)



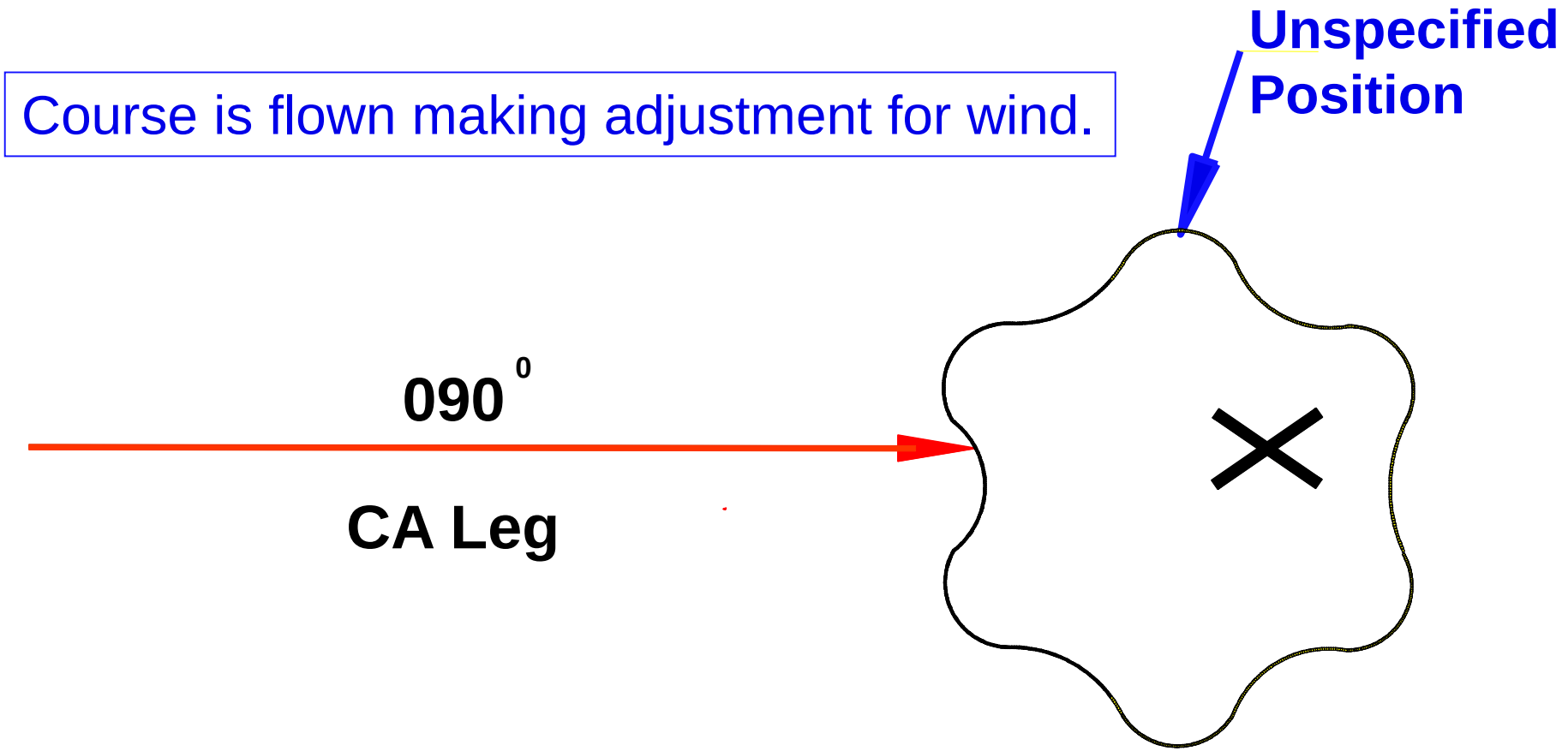
Fix to Altitude (FA)

FA leg is flown making adjustment for wind.



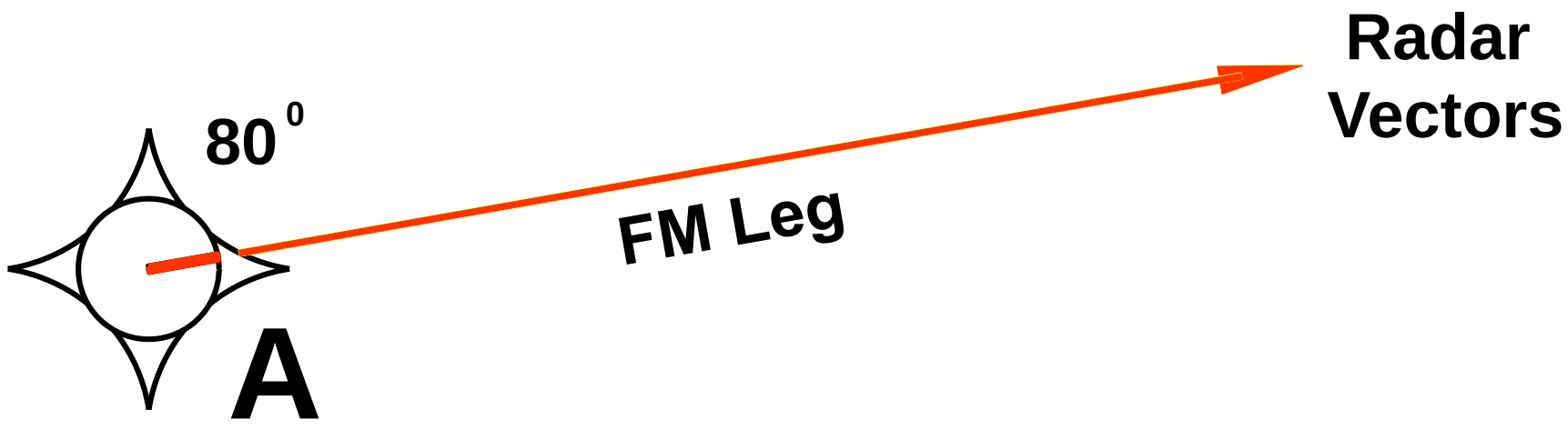
Course to an Altitude (CA)

Course is flown making adjustment for wind.



Fix to Manual termination

FM leg is flown making adjustment for wind.

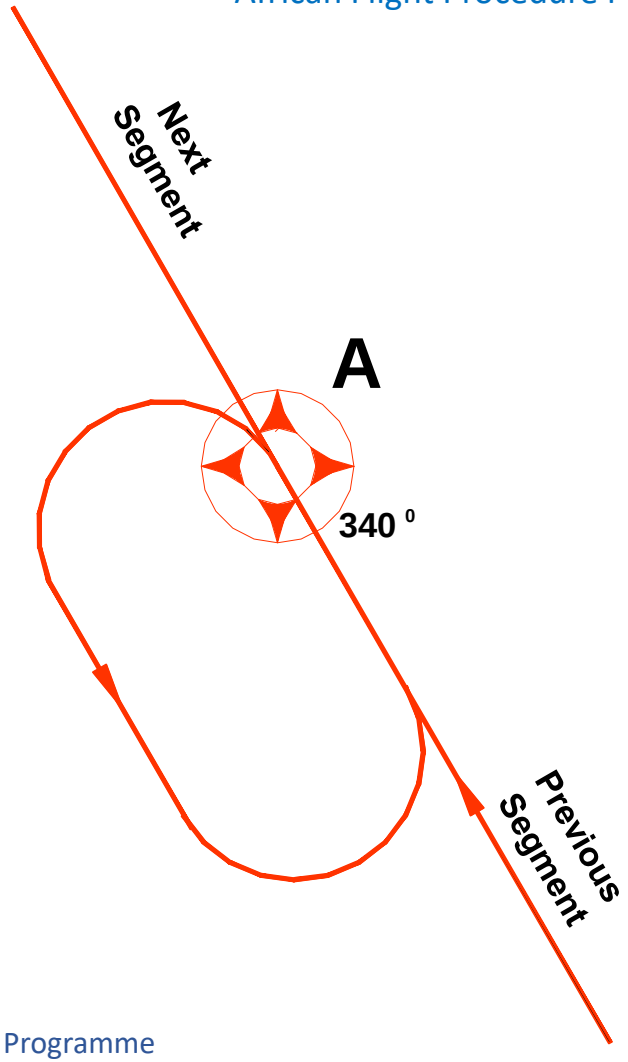


Racetracks & Holdings (HA, HF, HM)

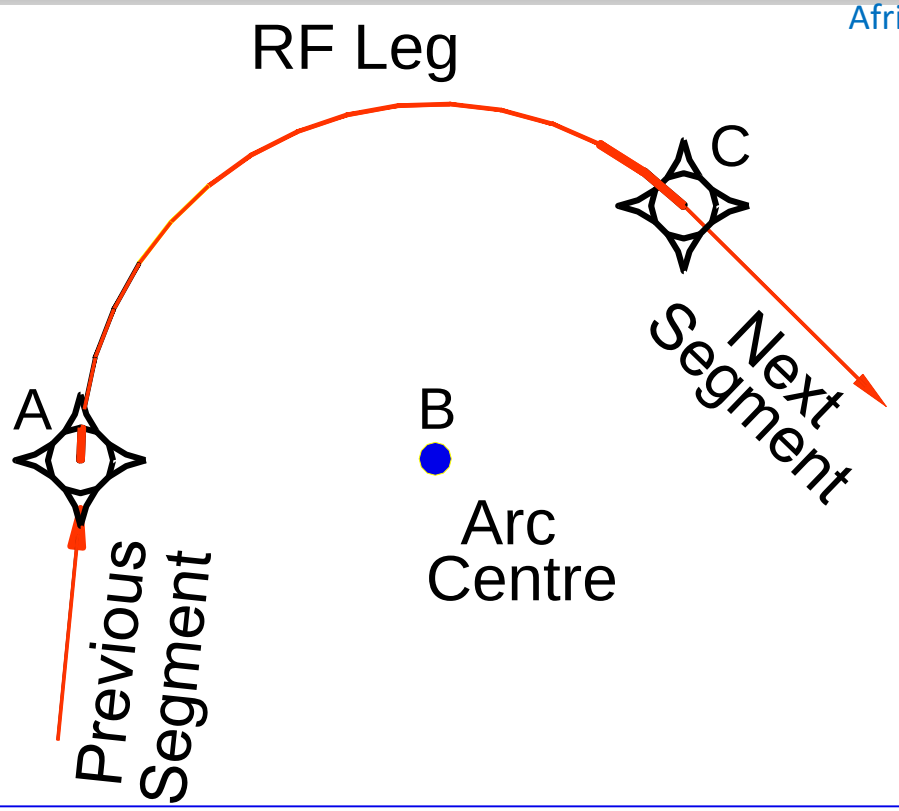
HA - Terminates at an altitude

HF - Terminates at the fix after one orbit

HM - Manually terminated



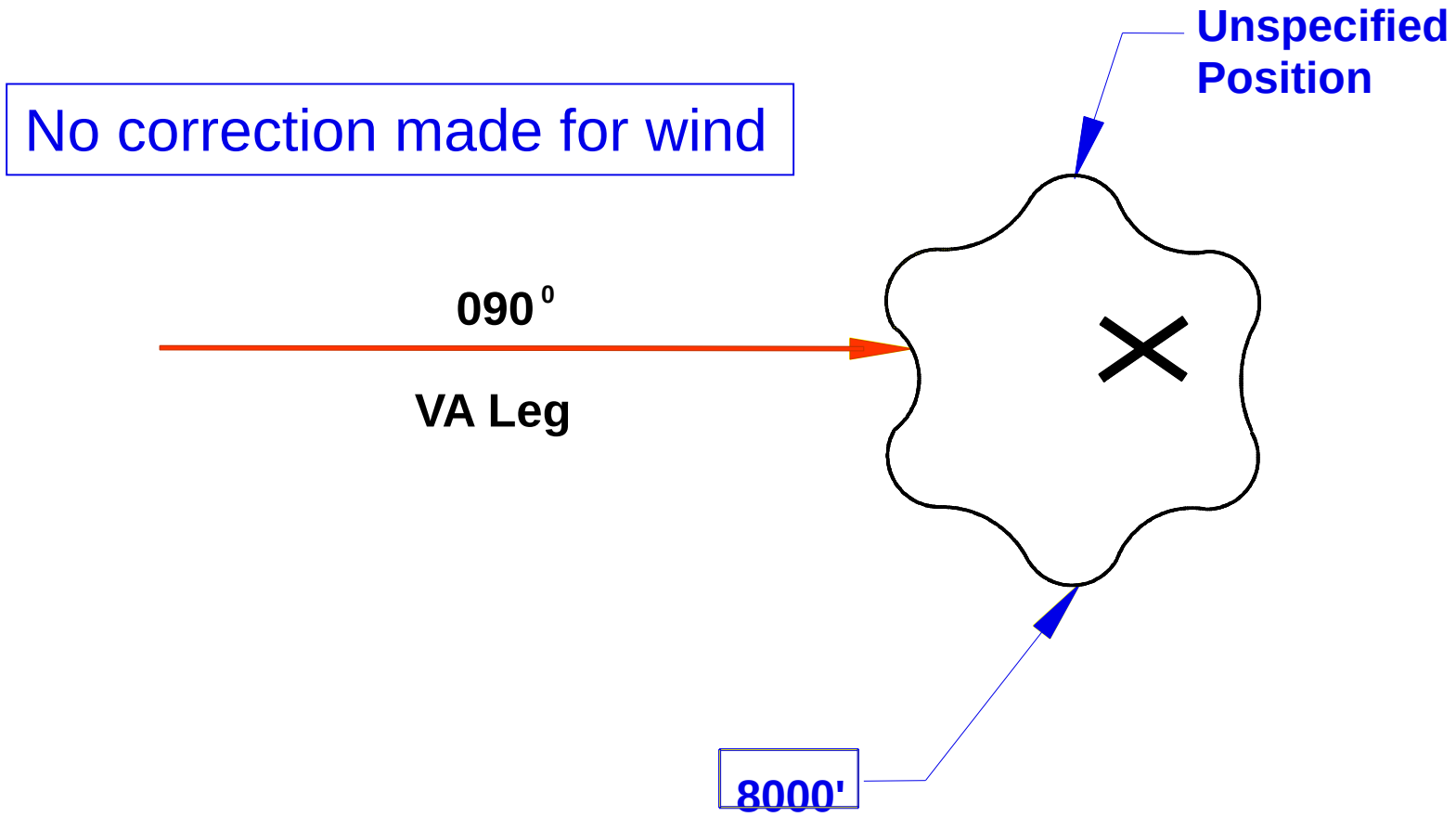
Radius to Fix (RF)



Only required for RNP AR.

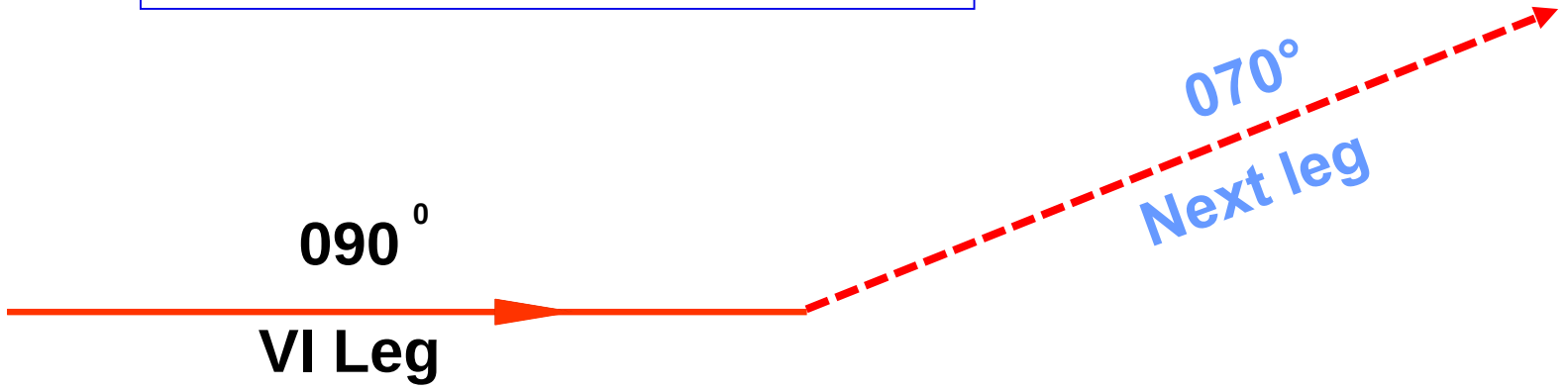
For other application, it can be addressed in national standard and can be used if a note is added on chart

Heading (V) to an Altitude (VA)

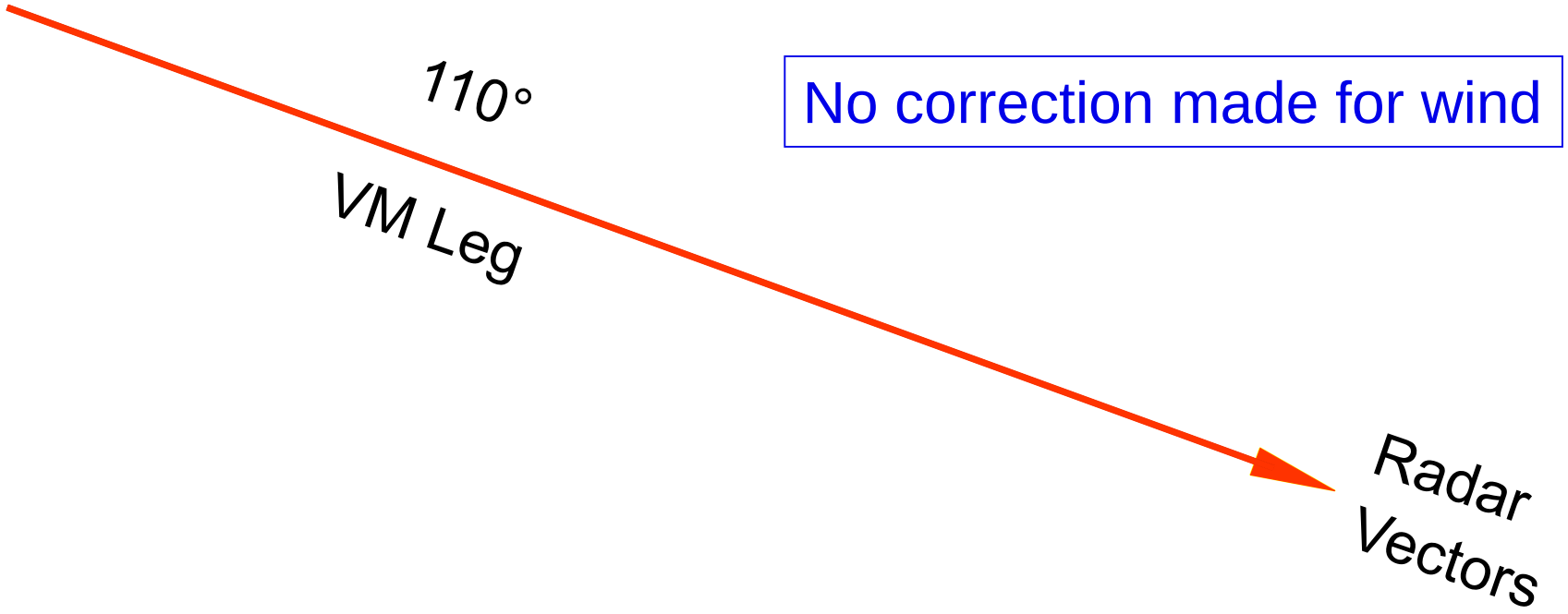


Heading (V) to an Intercept (VI)

No correction made for wind



Heading (V) to Manual termination



No correction made for wind

Procedure design application

- Application of PT bounded by a comprehensive set of rules developed and updated by industry since 1980 and published as an ARINC specification (ARINC 424, Navigation System Database)
- As the procedure designer is concerned with a sub-set of the path terminators, it is imperative that he adheres strictly to these rules if the procedure is to be correctly coded in the airborne navigation database.
- **Warning**
- Dual-conditional transitions, such as “climb to XXXX feet by waypoint NNNNN”, or “at waypoint YYZZZ but not below XXXX feet, turn right direct to (waypoint)”, cannot be used;
- Altitude and speed restrictions shall only be applied at a waypoint; and
- Details on any specific restrictions applied to a procedure shall be published.

Procedure design application

- Path terminators should be used to define each leg of an RNAV route from take-off until the en-route segment and from the point where the aircraft leaves the en-route segment until the end of the RNAV procedure(s).
- Path terminators are not used to construct en-route segments or other routes outside terminal airspace.
- Many aircraft are equipped with RNAV systems that are only capable of using a sub-set of the available ARINC 424 path terminators.

Initial & final Path terminator

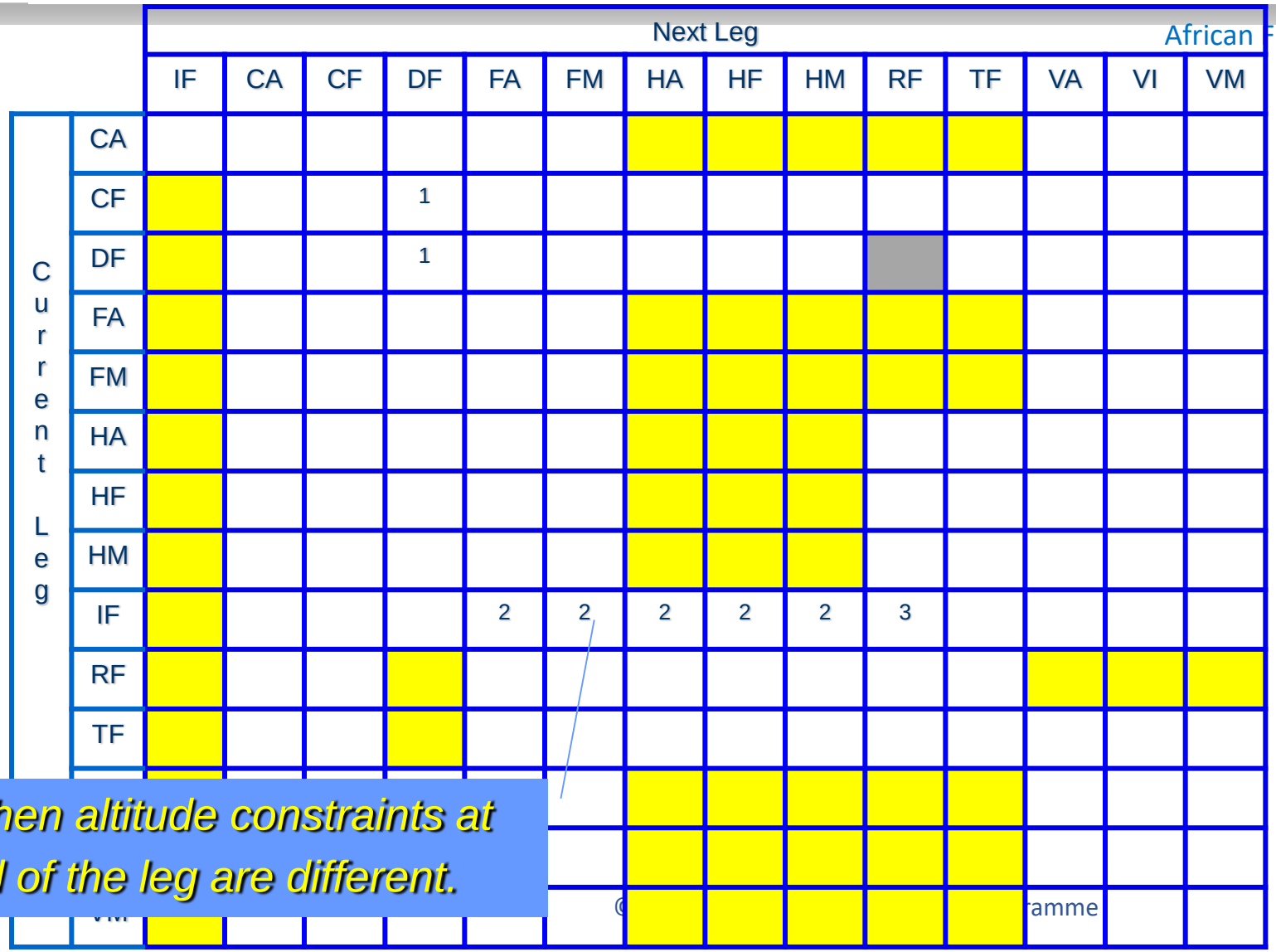
RNAV Procedure	Initial Leg	Final Leg
SID	CA, CF, FA, VA, VI	CF, DF, FM, HA, RF, TF, VM
STAR	IF	CF, DF, FM, HM, RF, TF, VM
Approach	IF	CF, TF, RF
Missed Approach	CA, CF, DF, FA, HA, HM, RF, VI, VM	CF, DF, FM, HM, RF, TF, VM

Initial & final Path terminator

Notes:

- *The only valid starting path terminators for the SID, from a procedure design perspective, are CA or CF.*
- *FM or VM may be used to terminate 'Open STARs' when radar vectoring is provided to final approach. The choice of track (FM) or heading (VM) depends upon ATC requirements.*
- *RF may only be used for RNP procedures flown by aircraft equipped with systems that are compatible with ARINC 424-17, or later.*

Path Terminator sequencing



Current Leg \ Next Leg	IF	CA	CF	DF	FA	FM	HA	HF	HM	RF	TF	VA	VI	VM
CA														
CF				1										
DF				1										
FA														
FM														
HA														
HF														
HM														
IF					2	2	2	2	2	3				
RF														
TF														
VM														

(2) Only when altitude constraints at each end of the leg are different.

Path Terminator sequencing

Notes:

1. *A shaded space indicates that the "current leg/next leg" sequence is not permitted.*
2. *A CF/DF, or DF/DF sequence can only be used when the termination of the first leg is intended to be overflown, otherwise alternative coding needs to be used.*
3. FA, CA and VA should be followed by DF or CF (DF recommended);
4. TF to flyover shall be followed by TF or CF;
5. If a procedure requires a DF after a flyover then the previous leg shall be coded CF or DF;
6. DF cannot follow a fly-by waypoint; and
7. The waypoint at the start and end of an RF leg is not coded as flyover.

Required data - CA & CF

Path Terminator	Waypoint Identifier	Fly-over	Turn Direction	Recommended Navaid	Magnetic Course	Path Length	Altitude Restriction 1	Altitude Restriction 2	Speed Limit	Vertical Angle	Arc Centre
CA			O		✓		6		O		
CF	✓	1	O	✓	✓		O	O	O	O	

✓ - Required
O – Optional

1 - Required for CF/DF only.
6 - Altitude 'at or above

Shaded spaces represent data that are not applicable to that path terminator

Required data - DF, FA & FM

Path Terminator	Waypoint Identifier	Fly-over	Turn Direction	Recommended Navaid	Magnetic Course	Path Length	Altitude Restriction 1	Altitude Restriction 2	Speed Limit	Vertical Angle	Arc Centre
DF	✓		O	O			O	O	O		
FA	✓		O	✓	✓		6		O		
FM	✓		O	✓	✓		O		O		

✓ - Required

O – Optional

1 - Required for DF/DF only.

6 - Altitude 'at or above

Shaded spaces represent data that are not applicable to that path terminator

Required data - IF, RF & TF

Path Terminator	Waypoint Identifier	Fly-over	Turn Direction	Recommended Navaid	Magnetic Course	Path Length	Altitude Restriction 1	Altitude Restriction 2	Speed Limit	Vertical Angle	Arc Centre
IF	✓			O			O	O	O		
RF	✓	O	✓	O	3	5	O	O	O	O	✓
TF	✓	O	O	O	O	O	O	O	O	O	

✓ - Required

O - Optional

2 - Inbound tangential track
3 - Outbound tangential track
5 - Along track distance

Shaded spaces represent data that are not applicable to that path terminator

Required data - VA, VI & VM

Path Terminator	Waypoint Identifier	Fly-over	Turn Direction	Recommended Navaid	Magnetic Course	Path Length	Altitude Restriction 1	Altitude Restriction 2	Speed Limit	Vertical Angle	Arc Centre
VA			O		4		6		O		
VI		O	O	O	4		O	O	O		
VM	O		O		4		O		O		

✓ - Required

O - Optional

4 - Heading

6 - Altitude 'at or above

Shaded spaces represent data that are not applicable to that path terminator

Required data – Recommended navaid

- Unfortunately, there are different ways to get magnetic variation in a TMA:
  - individual navaid station declination;
  - variation at ARP;
  - magvar model etc.;
- And not all systems use the station declination.
- The RECOMMENDED NAVAID is required for certain procedure legs to enable the RNAV system to use the STATION DECLINATION value for MAGNETIC VARIATION.

For CF FA FM leg, a recommended navaid is required

Required data – Speed & altitude restrictions

- All SPEED and ALTITUDE restrictions in RNAV procedures should be applied at SPECIFIC WAYPOINTS.
- Speed and altitude restrictions that are only applied during specific time periods are NOT CODED in database.
- Some legacy systems can only process speed restrictions in combination with an altitude restriction.

Required data – Speed & altitude restrictions

- On SIDs, the speed limit applies to all legs UP TO and including THE TERMINATOR of the leg on which the limit is encoded. If a second speed limit is coded on a subsequent leg, the limit will be applied from that leg backwards to the previous terminator which contained a speed limit.
- On STARS, the speed limit is applied FORWARD to THE END of arrival unless a second speed limit is encoded.

Description of altitude in coding

- At or above : + altitude
- At or below : - altitude
- At : @
- At or above to at or below :
  - ☞B altitude1 altitude2

Coding guidelines: Initial departure tracks

- As there is not a WP at the DER first leg cannot be a TF;
- Remaining Path terminator associated to first WP/altitude on the first leg are CF, DF, FA,VA, CA & IF.
- Experience shows that CA better than FA on initial SID leg.
- VA are often used for departure with parallel runway
  - ☞ As aircraft shall deviate from the track on the same direction and remain //

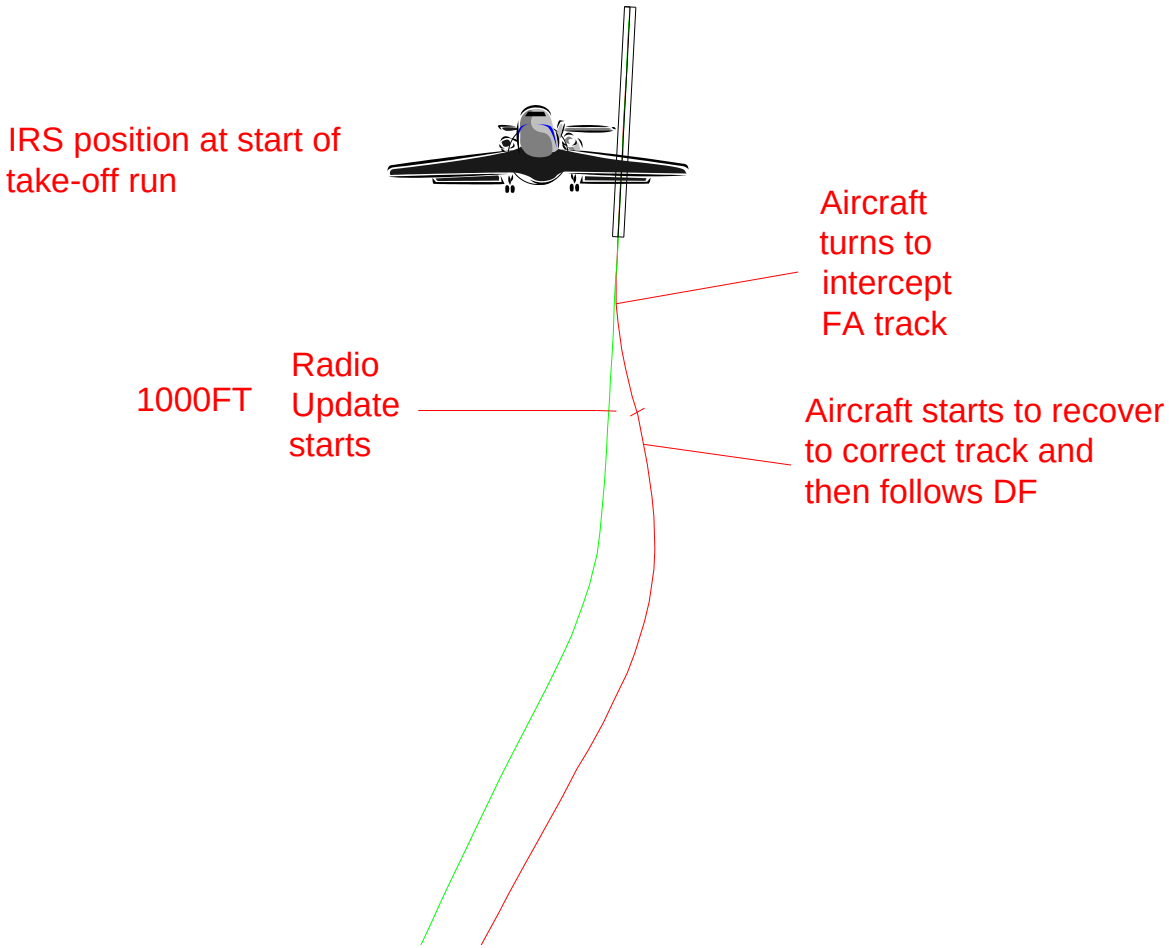
Coding the first 500 FT

- RNAV has little influence on aircraft track-keeping during take-off phase:
  - Autopilots do not engage before 500 ft AGL.
  - RNAV 1 requires LNAV no later than 500 ft AGL.
  - Manual flight may be considered the norm, at present, up to at least 500 ft AGL.
- The procedure definition, in path terminator context, must always start from the runway.

Coding guidelines: initial departure tracks

Why not FA?

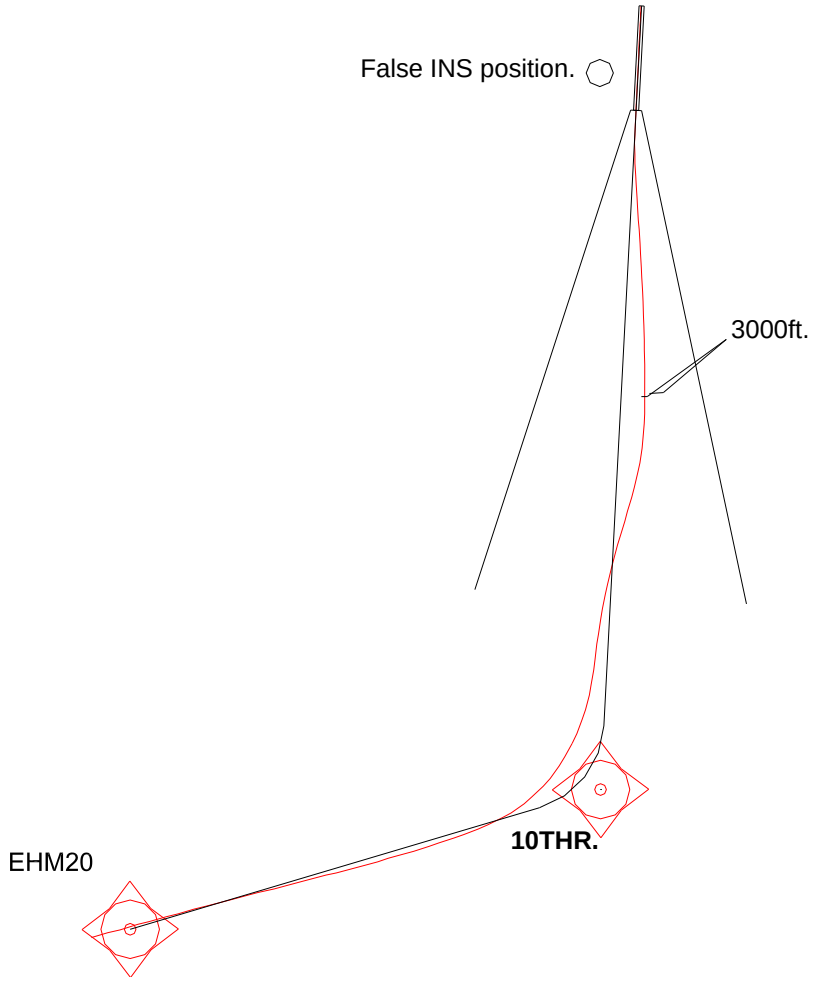
FA(184°;2000 ft)/DF
CA(184°;2000 ft)/DF



Coding guidelines: initial departure tracks

Why not CF?

CF 183º to 10 NM
CF 270º to EHM20
IRS error of 1’ lat and 1’ long
No wind
No radio updating before 3000ft



Coding guidelines: initial departure tracks

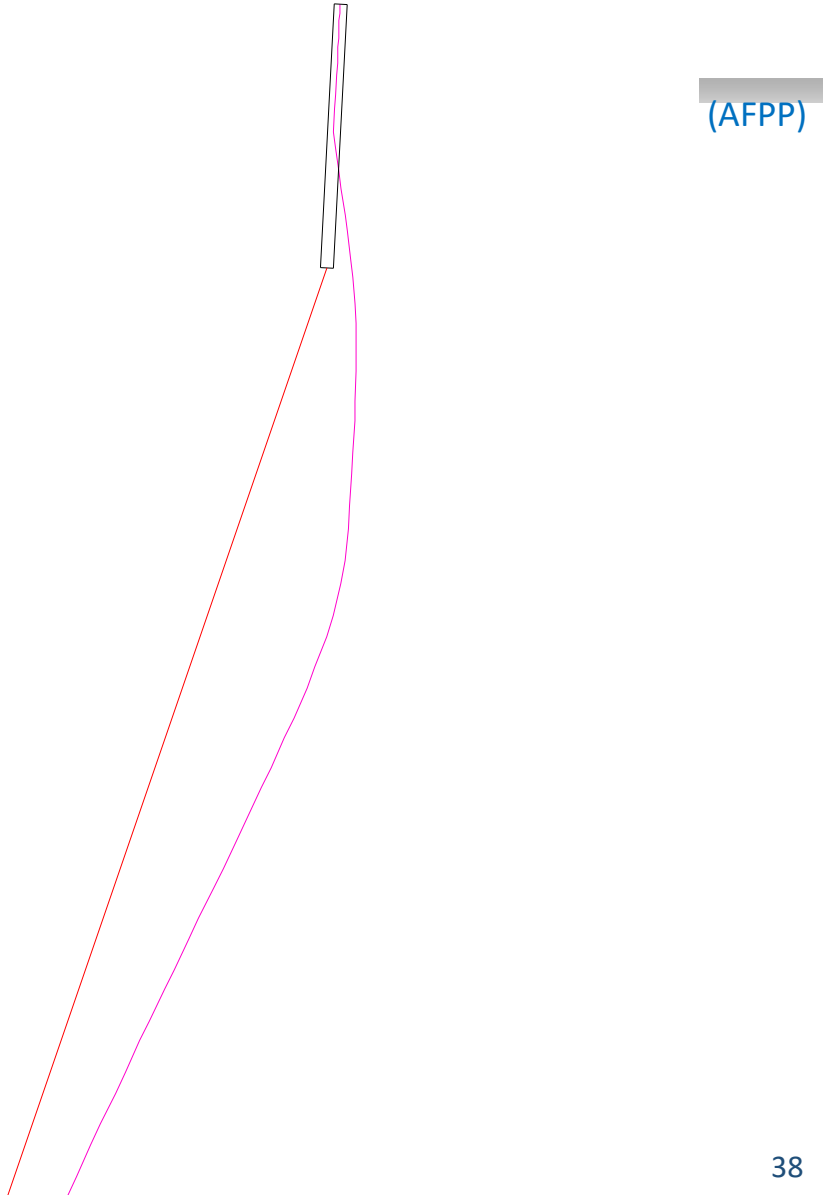
(AFPP)

CA vs VA ?

After 500ft agl, when AP engages, CA recovers to 184 track while VA remains

on 184 heading until 2000ft agl.

CA(184°;2000 ft AGL)/DF



Outlines

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2. **General:**
   - ☞ ARINC 424 ,an industry standard
   - ☞ Path terminator types
   - ☞ Procedure design application
3. **Coding rules:**
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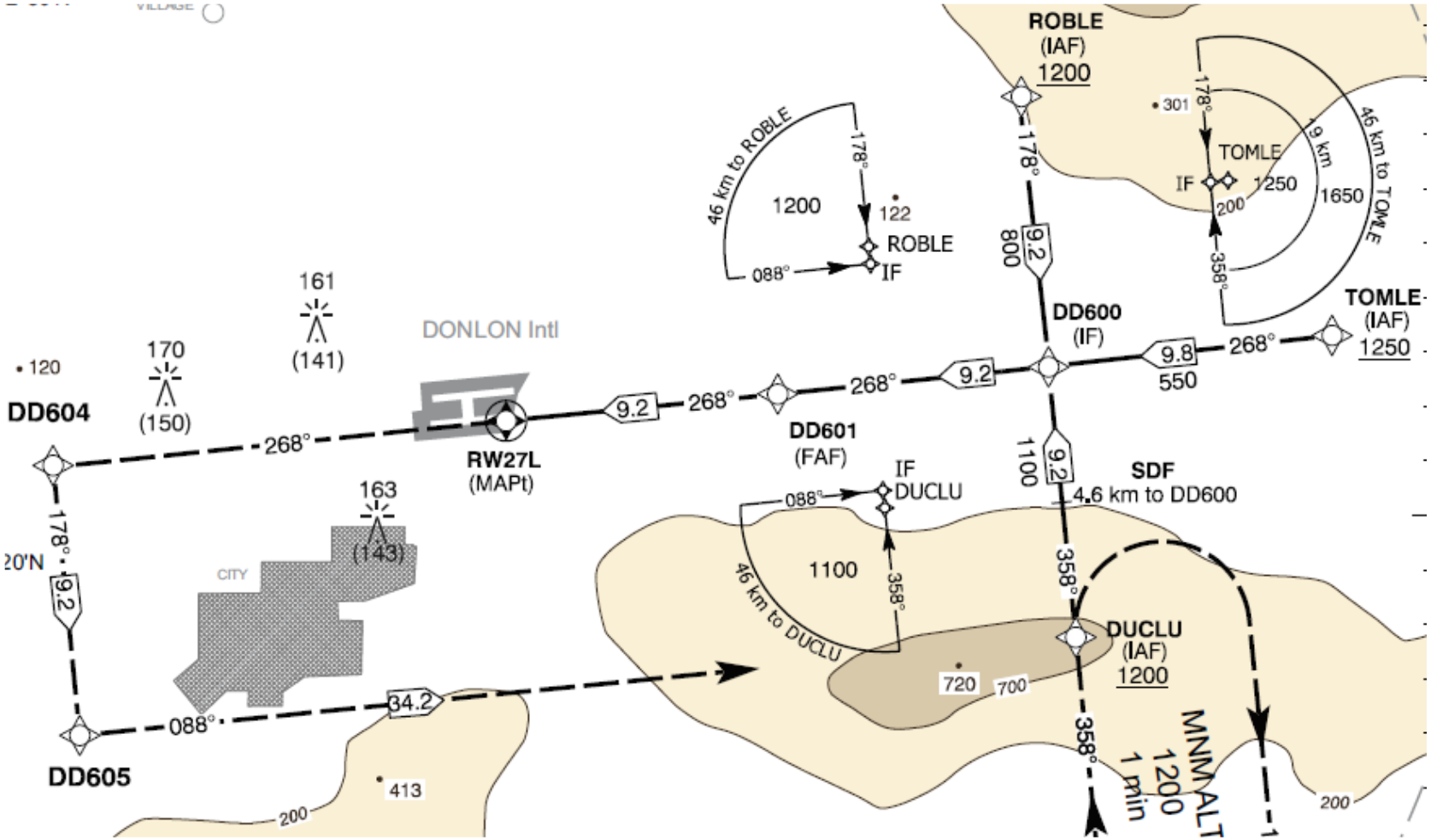
   - ☞ Required data of a Path Terminator
4. **Examples of procedure's coding**

Examples of procedure's coding



TABULAR DESCRIPTION

RNP W RWY 27L											
Serial Number	Path Descriptor	Waypoint Identifier	Fly-Over	Course °M(°T)	Magnetic Variation	Distance (km)	Turn Direction	Altitude(m)	Speed limit (km/h)	VPA/ TCH	Navigation Specification
010	IF	TOMLE	-	-	-	-	-	+1250	-	-	RNP APCH
020	TF	DD600	-	268(264.7)	-	9.8	-	+800	-	-	RNP APCH
010	IF	DUCLU	-	-	-	-	-	+1200	-	-	RNP APCH
020	TF	DD600	-	358(355.3)	-	9.2	-	+800	-	-	RNP APCH
010	IF	ROBLE	-	-	-	-	-	+1200	-	-	RNP APCH
020	TF	DD600	-	178(175.3)	-	9.2	-	+800	-	-	RNP APCH
010	IF	DD600	-	-	-	-	-	+800	-	-	RNP APCH
020	TF	DD601	-	268(265.3)	-	9.2	-	@515	-	-	RNP APCH
030	TF	RW27L	Y	268(265.3)	-	9.2	-	@35	-	-3.0/15	RNP APCH
040	FA	RW27L	-	268(265.3)	+3.0	-	-	-[1)]	-	-	RNP APCH
050	DF	DD604	-	-	-	-	-	-	-	-	RNP APCH
060	TF	DD605	-	178(175.0)	-	9.2	L	-	-410	-	RNP APCH
070	TF	DUCLU	-	088(085.0)	-	34.2	L	+1200	-	-	RNP APCH
080	HM	DUCLU	-	358(355.0)	-	-	R	+1200	-	-	RNP APCH

1) This value is provided by industry.

Questions:

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