Workshop on PBN airspace Design

31 May - 04 June 2021

Area Navigation and Navigation Systems

❑PBN Area Navigation

❑Fixes

❑Path Terminators

❑Transitions

❑Navigation Systems and Sensors

❑Multi-sensor systems

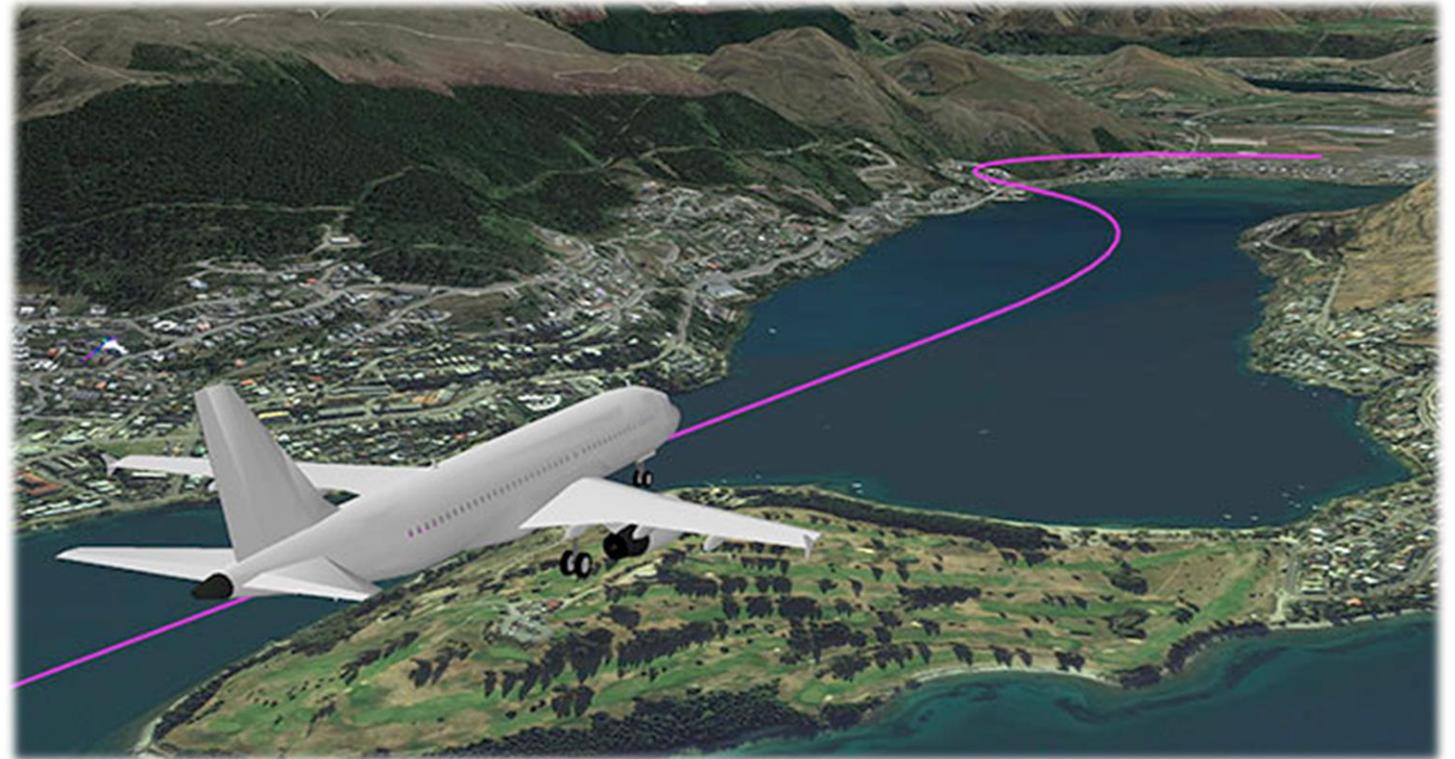❑Ground-based NAVAID dependent and independent systems

Area Navigation &
PBN Navigation Systems

AREA NAVIGATION

PBN area navigation

❑ Area navigation is a method of navigation which permits aircraft operation on any desired flight path…

Advantages of PBN Area Navigation

❑ More efficient TMA design options:

☞ Maneuver around terrain, obstacles and restricted airspace;

☞ RNP 1 with RF turns.

• Controllers know what lateral separation to apply:

☞ 5 or 6 NM

• Airlines know what aircraft to dispatch…

☞ Chart will state GNSS and / or DME/DME/IRU required (C1, D2).

• Separate SIDs for slower and faster climbing aircraft ;

• Parallel routes to accommodate a greater flow of En-route traffic with A-RNP.

ICAO Flight Plan PBN Codes

Navigation Systems and PBN FP 2012 Indicators						
	All	GNSS	INS	DME/DME	DME/DME/IRU	DME/VOR
RNAV 10	A1	A2	A3			
RNP 4	L1					
RNAV 5	B1	B2	B5	B3	B6	B4
RNP 2						
RNAV 2	C1	C2		C3	C4	
RNAV 1	D1	D2		D3	D4	
RNP 1	O1					
A-RNP						
RNP 0.3						
RNP APCH	S1					
+Baro-VNAV	S2					
RNP AR APCH	T2					
+RF	T1					

An example of an older aircraft PBN capability

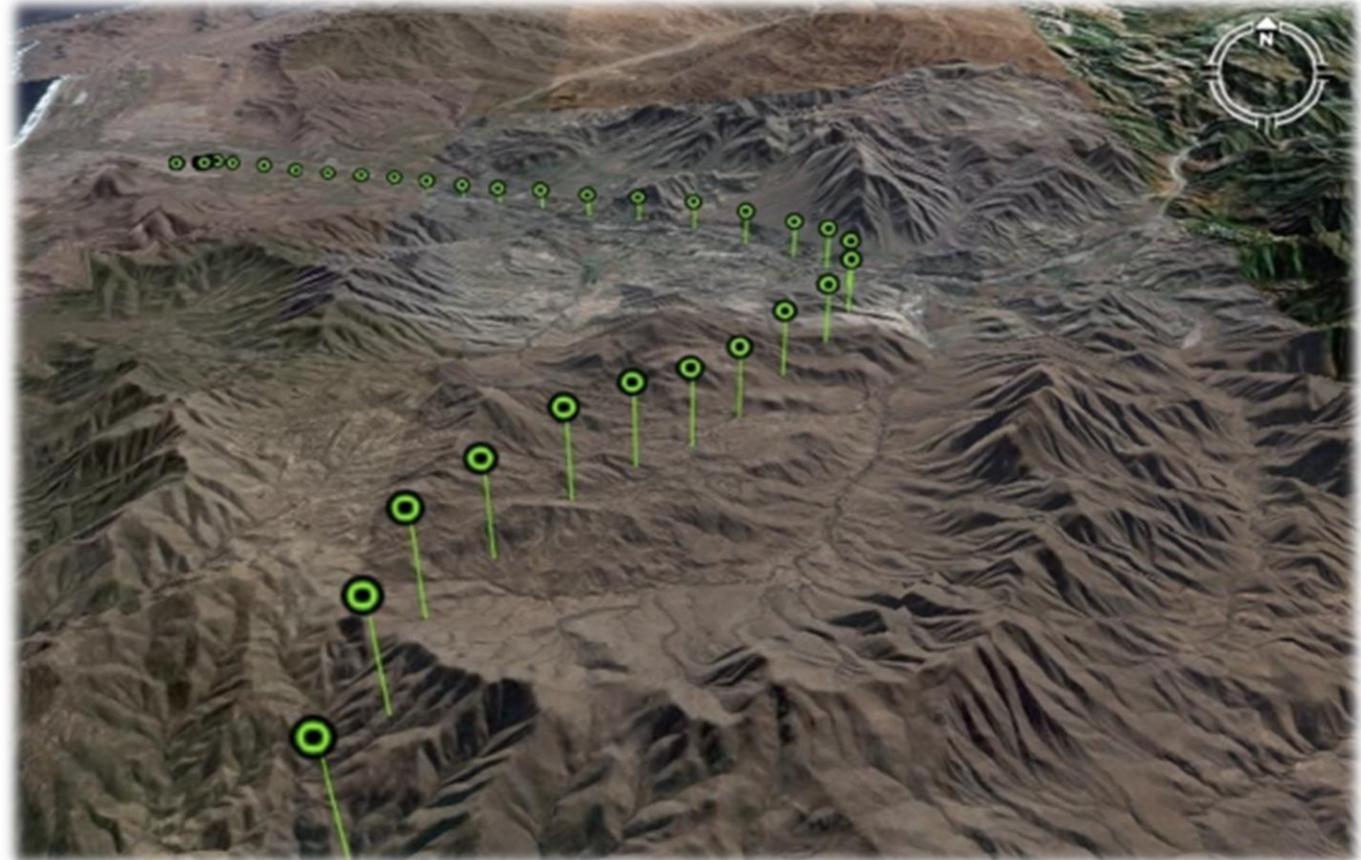Item 18: A3/B5/C3/D3/S1

A3 = INS
B5 = INS
C3 = DME/DME
D3 = DME/DME
S1 = RNP APCH (no Baro-VNAV)

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AREA NAVIGATION FIXES

Area Navigation Fixes (Waypoints)

❑ Fixes are defined by latitude and longitude;

❑ A "fix" is either based on radio aids or it is an area navigation waypoint;

❑ ICAO defines a waypoint as *"a **specified geographical location** used to define an area navigation route... employing an RNAV system"*;

❑ Dakar Airport OOY ARP is a fix...

☞ 14° 44' 22" N

☞ 017° 29' 24" W

❑ A geographic location not definable by NAVAIDs is a waypoint...
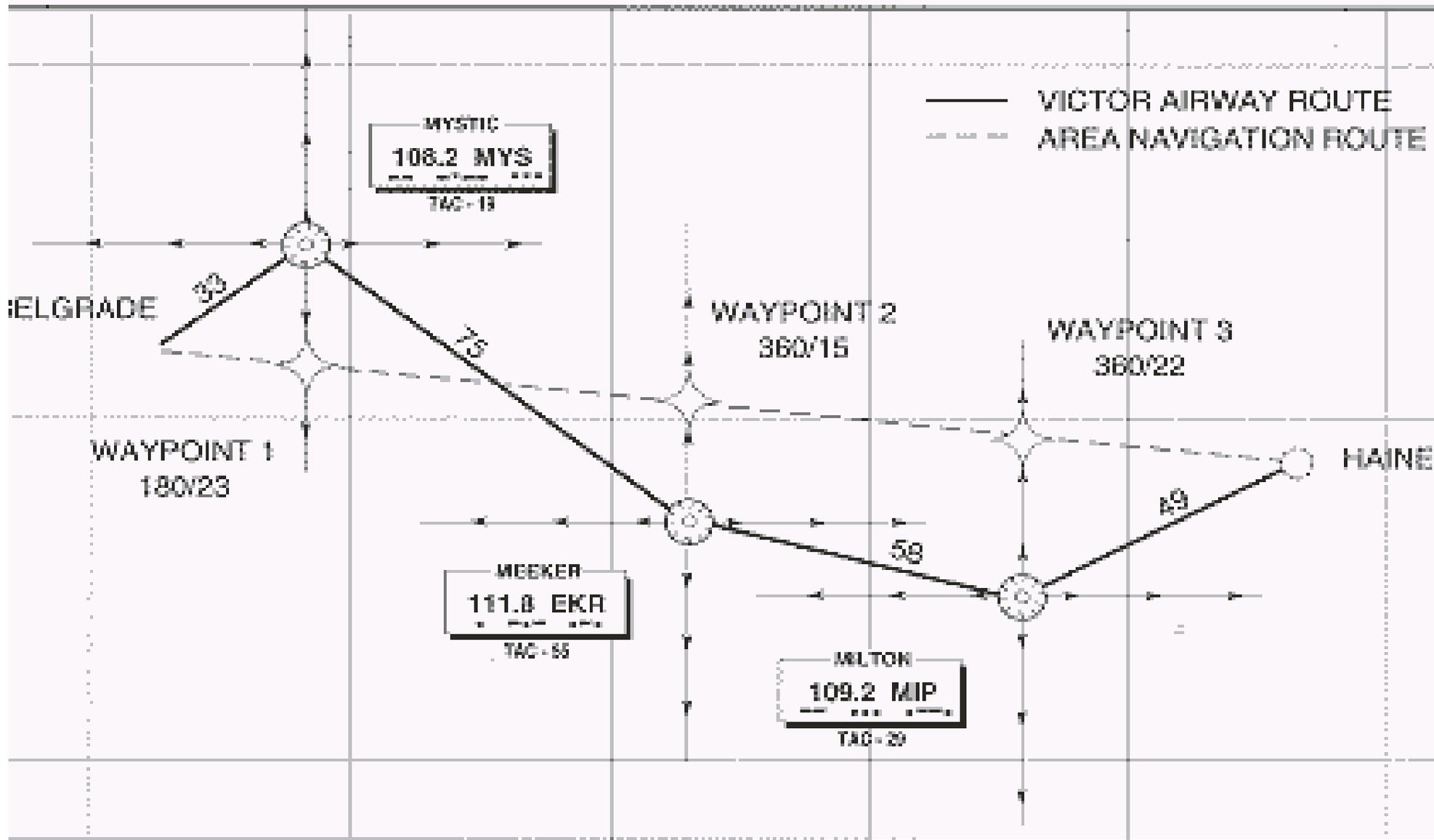
Area Navigation Fixes (Waypoints)

❑ Fixes:

☞ Begin and end segments;

☞ Establish turn points;

☞ Establish descent points;

☞ Establish change in speed.

❑ *Waypoint was the original term, but now all waypoints are referred to as fixes:*

☞ *So IAWP is now IAF;*

☞ *And FAWP is now FAF.*

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PATH TERMINATORS

Area Navigation Route Segments

❑ Area navigation route is composed of a series of legs or **paths**

❑ **Path** is a segment of a flight (track, course or heading) followed by **termination** point …in other words **Path Terminator**

❑ In the TMA **path terminators** are depicted by ARINC 424 leg types,

❑ Fixes are designated by:

☞ Five-letter ICAO name codes – **VUTON**

☞ Missed Approach Point (MAPt) is designated by RWY & number – **RW30**

☞ Sometime by airport designator & numbers – **DB514**

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Leg Types (Path Terminators)

❑ There are 23 defined path terminators:

☞ RNP uses only path terminators that are **predictable** and **repeatable**.

☞ Some holding pattern, heading and altitude **terminators** are "path terminators";

☞ *"CLIMB RWY HEADING TO 3 000"…* is a **VA** path terminator

❑ Usual RNP AR APCH path terminators:

☞ TF (Track to Fix) – standard leg type:

  ▪ Aircraft follows the geodesic path to a fix.

☞ RF (Radius to Fix):

  ▪ Aircraft follows an arc of a circle, defined by a **radius, to a fix**.

❑ En-route airspace uses different path terminator, for example FRT.

Paths

Terminators	Fix to	Track from fix to	Course to	Heading to	Direct to	Racetrack	DME Arc to	Radius from fix
Fix	IF	TF	CF		DF	HF	AF	RF
Altitude		FA	CA	VA		HA		
Manual Termination		FM		VM		HM		
Distance		FC						
DME Distance		FD	CD	VD				
Intercept			CI	VI				
Radial			CR	VR				
Procedure Turn	PI							

Each leg type has a two letter name based on the path and terminator combination

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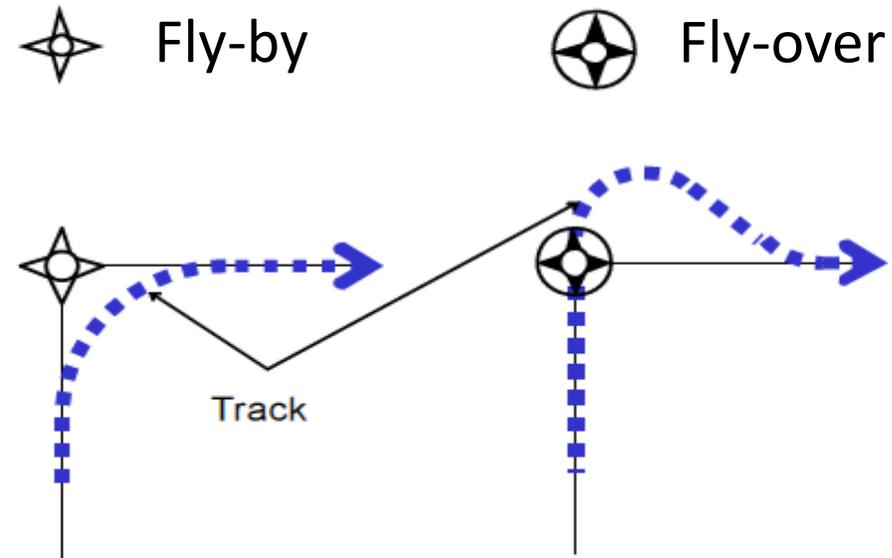# FIX TRANSITIONS

Fix Transitions (Turns)

❑At each fix, the aircraft transitions from the current leg to the next leg.

❑There are three transition types:

☞Fly-by;

☞Fly-over;

☞Fixed Radius.

❑We can also refer to these as turns… so "Fly-by" turn.

Fly-by vs. Fly-over Fixes

- Area Navigation fix

- Defined by Latitude and Longitude (Lat/Long)

- Two types of Fixes:
"Fly-by"
"Fly-over"

Fly-by   Fly-over

Track

MAPt must is always designated as a "**Fly-over**" fix no matter if a turn is specified or not

DF vs. TF after "Fly-Over" turn
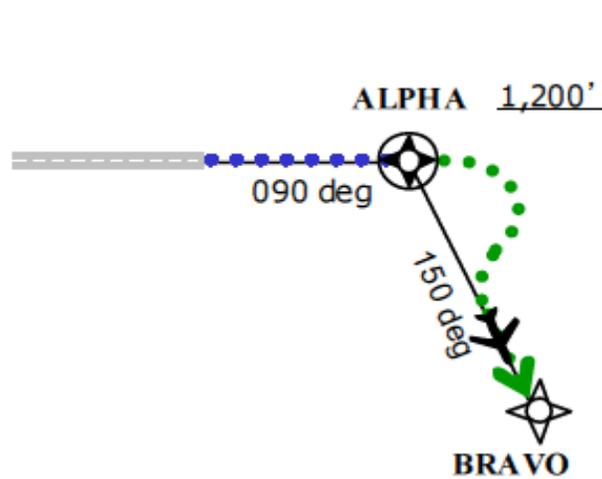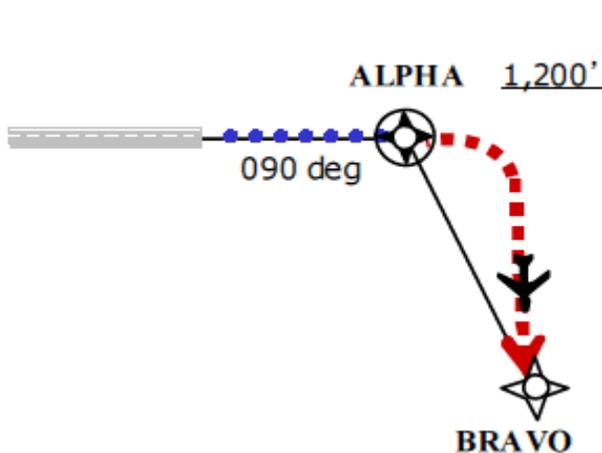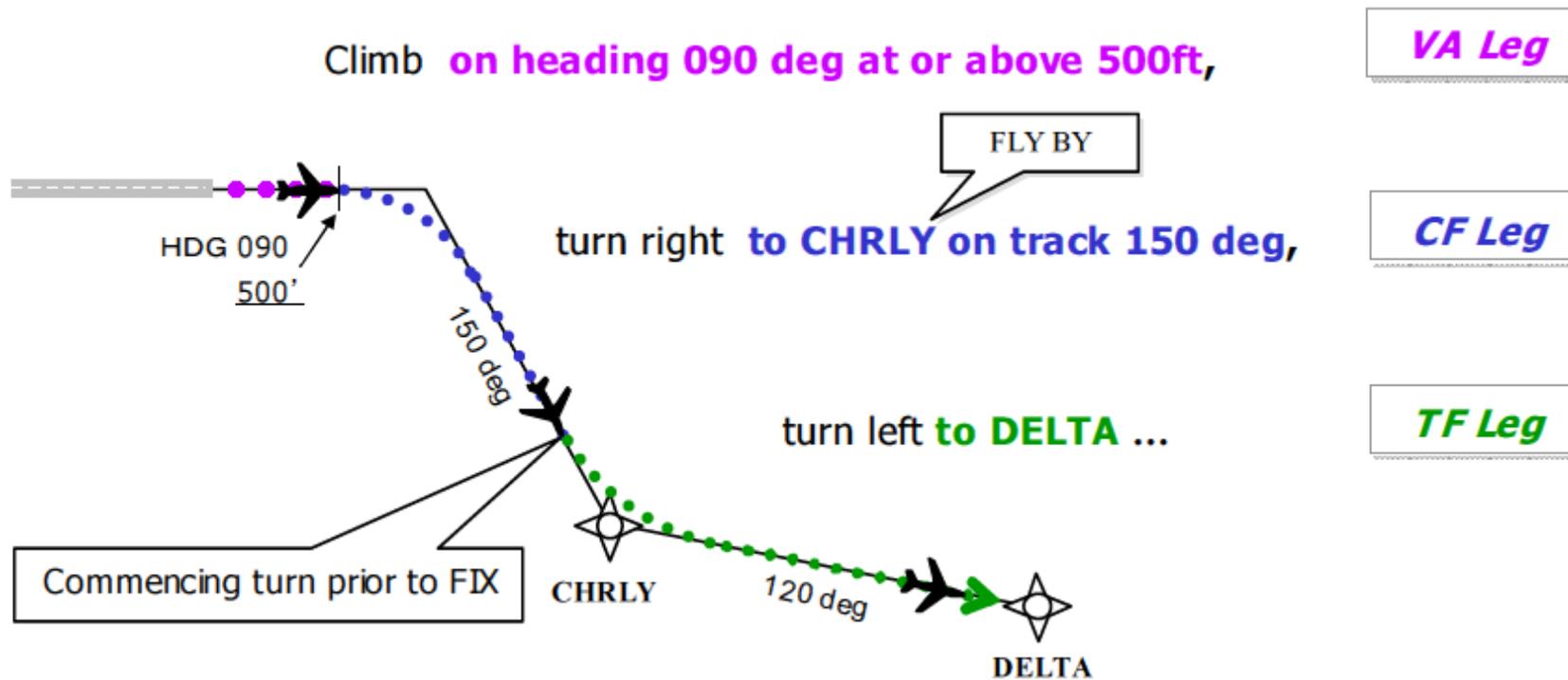
❑Fixed radius paths (FRP) take two forms:

☞**Radius to Fix** (**RF**) when there is a requirement for a specific curved path in a <u>terminal or approach</u> procedure.

☞*Fixed Radius Transition (FRT) is intended to be used in <u>en-route</u> procedures.*

Radius to Fix Transition (RF)

- ❑ Follows an arc of a circle, defined by **radius to a fix**;

- ❑ **RF** is currently only required by the **RNP AR APCH** and **A-RNP Nav Spec**;

- ❑ **RF** be added to **RNP 1** and **RNP APCH.**

RF LEG

NEXT SEGMENT

ARC CENTER FIX

PREVIOUS SEGMENT

Radius to Fix transition (RF)

Figure 4-8. RF turn construction

STEP 1: Apply para 2.2.

Evaluate ± 1 RNP distance from angle bisector as both segments

Segment Terminating Fix

Tangent Points

2 RNP

2 RNP

b

STEP 4

a

STEP 3

r

a=r
b=r+(2xRNP)
c=r-(2xRNP)

c

STEP 5

Segment Initial Fix

STEP 2:
Locate Turn Center

r

r

Tangent Points

2 RNP

2 RNP
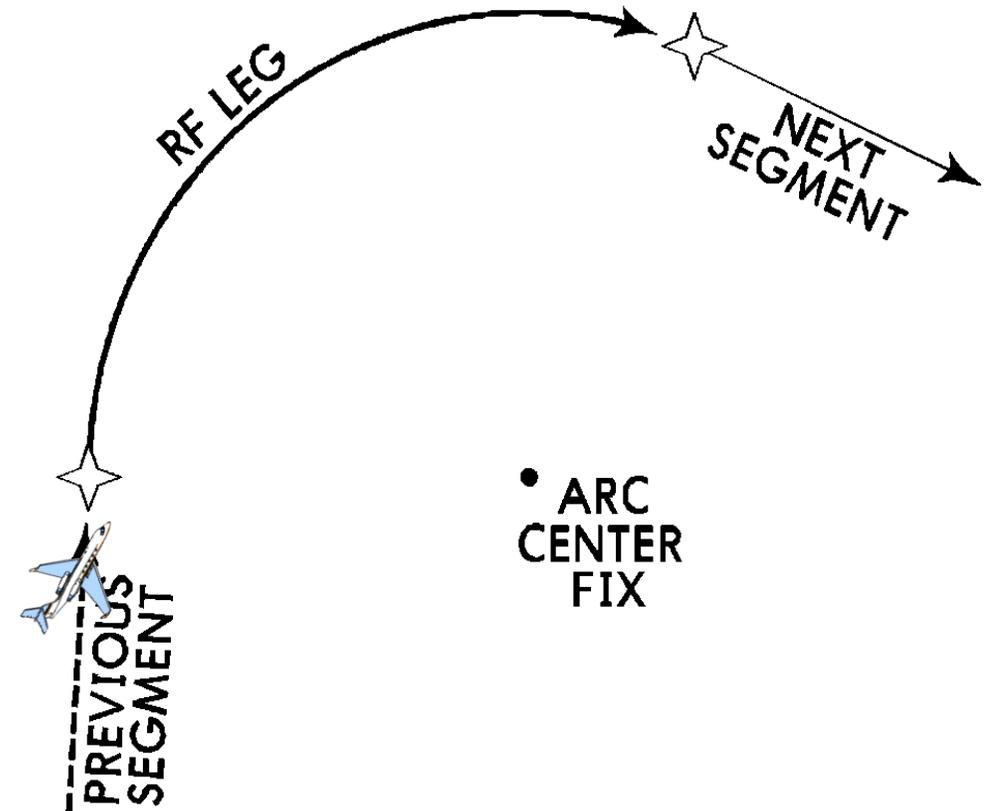
Parallel Offset

- ❑ **First implemented in the NAT OTS to reduce effect of wake turbulence, after RVSM implementation**

- ❑ **Subsequently to reduce risk of collision between aircraft at wrong altitude**

- ❑ **All aircraft with parallel offset capability have to provide parallel offsets trajectories up to 20 NM in increments of 1 NM NM left or right of course.**

Track-angle
change bisector

Off-set route

Offset
Distance

Original route
centreline
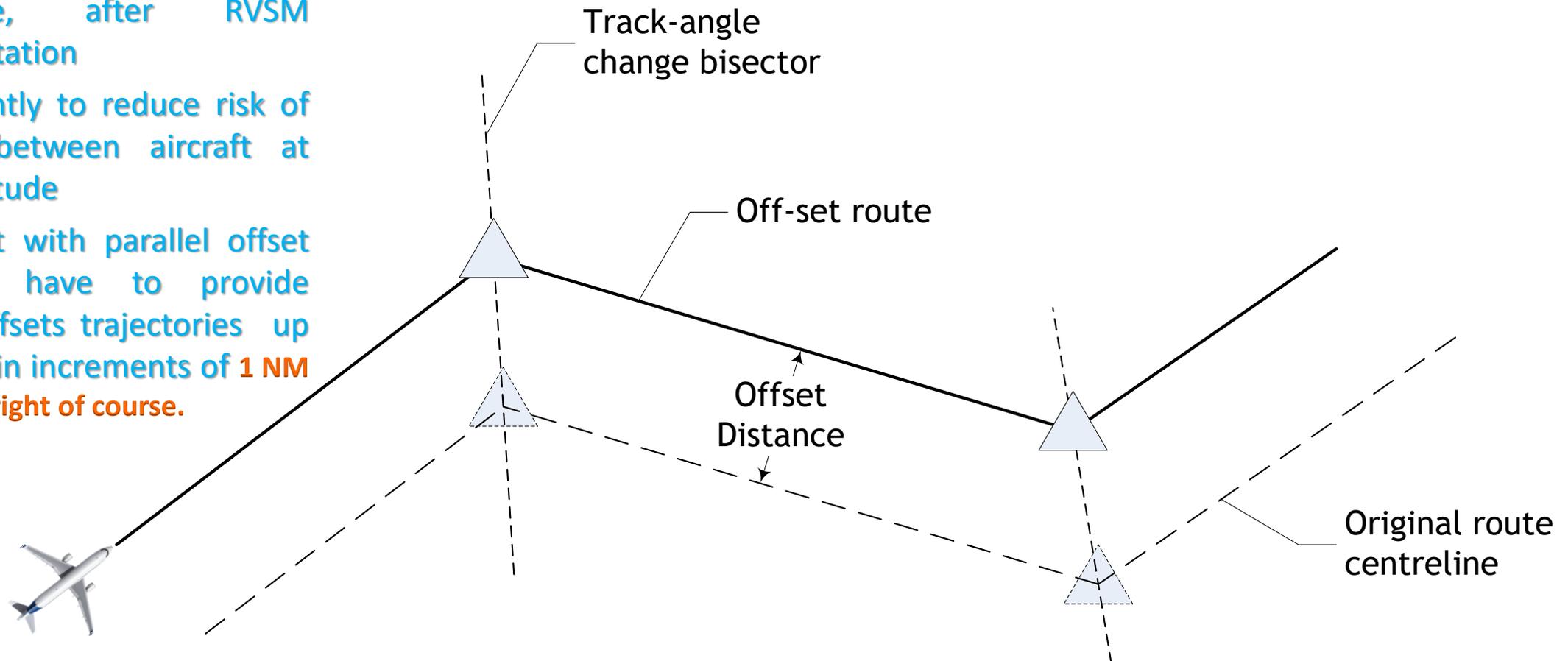
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SUMMARY OF AREA NAVIGATION

Summary

❑ **PBN Area Navigation:**

☞Benefits, RNP 1 with RF transitions.

❑ **Fixes:**

☞Begin and end segments, establish turn and descent points, and change in speed .

❑ **Path Terminators:**

☞Segment of a flight followed by a termination point.

❑ **Transitions:**

☞Fly-by, Fly-over, RF and FRT

UNITING AVIATION

CELEBRATING 70 YEARS OF
THE CHICAGO CONVENTION
70

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NAVIGATION SYSTEMS

PBN Navigation Systems – Need to Know

❑ You need to know about Nav Systems because prior to choosing the correct Nav Spec for implementation, you need to determine aircraft capabilities:

☞ For example in the TMA there is a choice of the following Nav Specs:

- RNAV 1, RNP 1, RNP 1 + RF, A-RNP

❑ And RNAV 1 allows three (3) different types of Nav Systems:

☞ DME/DME, DME/DME/IRU and GNSS

❑ There are five navigation systems which qualify for PBN operations:

☞ These are **GNSS**, **INS**, **DME/DME**, **DME/DME/IRU** and **VOR-DME**

❑ The **green** are ground-based NAVAID **dependent** and the **orange** are **independent** of ground-based NAVAIDs

☞ **GNSS**, **INS** are the only ones that can be used in Oceanic/Remote airspace

☞ **DME/DME**, **DME/DME/IRU** and **VOR-DME** can be used in En-route and Terminal

❑ In PBN, "NAVAID dependent" is different from conventional navigation using individual VOR or DME NAVAIDs.
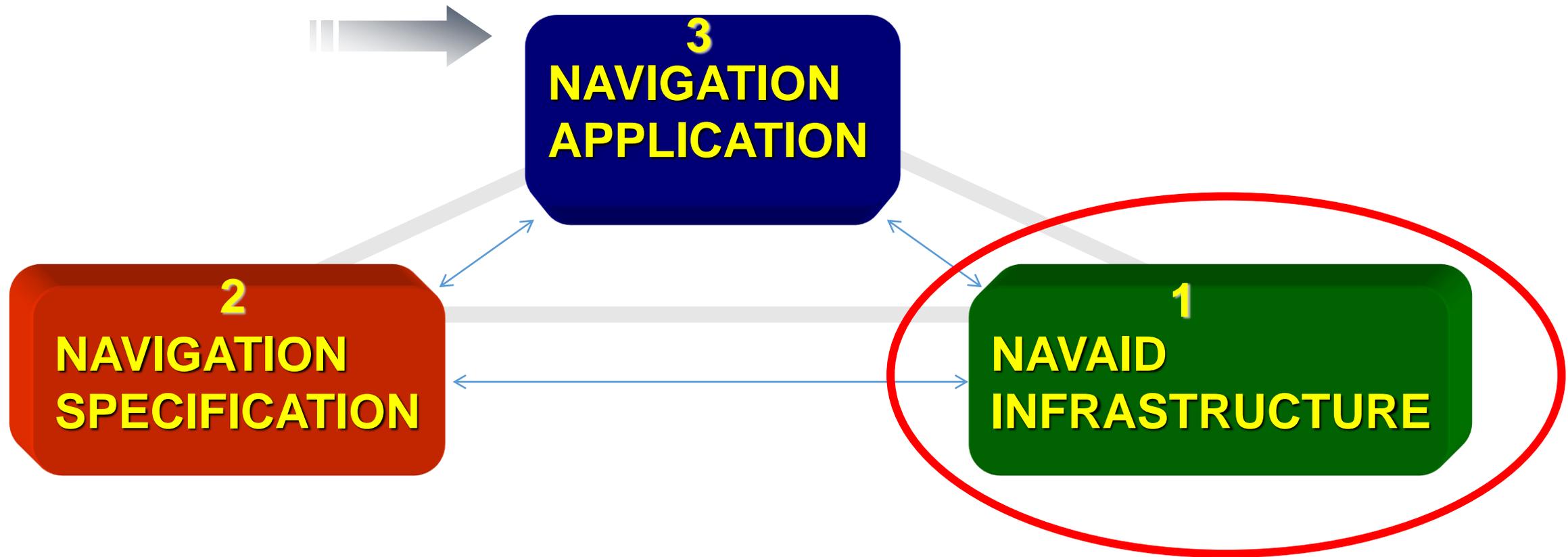
❑ This is **another type** of area navigation system:

☞It adds the inertial functionality to a DME/DME navigation system by coupling IRU with DME/DME to improve the continuity of the navigation system performance.

❑ DME/DME with IRU position updating enables the aircraft's FMS to cross-check its **navigation systems** against each other

❑ It is **not the same** as having **DME/DME** and an **INS** that are **not coupled** but act independently, as two separate navigation sensors

❑ It has the capability to provide navigation through DME/DME gaps, for example through an area 30 to 150 degrees between two DME facilities.

NAVIGATION SENSORS

NAV SPECS	GNSS	INS/IRS	DME/DME	DME/DME/IRU	VOR-DME
RNP (RNAV) 10	X	X			
RNP 4	X				
RNAV 5	X	X	X	X	X
RNAV 1 & 2	X		X	X	
RNP 2	X				
A-RNP	X				
RNP 1	X				
RNP 0.3	X				
RNP APCH	X				
RNP AR APCH	X		(X)		

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SUMMARY OF NAVIGATION SYSTEMS

Summary

❑ Navigation Systems and Sensors:

☞Need to understand navigation systems for aircraft capability assessment to choose the correct Nav Spec for implementation.

❑ PBN approved navigation systems:

☞VOR-DME, DME/DME, DME/DME/IRU, GNSS and INS

❑ NAVAID infrastructure assessment:

☞in TMAs for DME/DME navigation.

❑ INS, IRS, IRU and INS drift;

❑ DME/DME/IRU assessment of gaps.

1. Give three examples of what fixes can be used for.

2. What is the difference between a TF and a CF?

3. Which path-terminators are most commonly used for RNP AR APCH?

4. How are turns designated on charts?

5. When a fly-over fix is followed by a DF leg, does an aircraft rejoin the track leading to the next fix?

6. Why do airspace planners need to understand about navigation systems?

7. Name two types of ground-based NAVAID independent navigation systems.

8. What is the main disadvantage of DME/DME and VOR-DME?

9. What is the advantage of a DME/DME/IRU navigation system?

Questions:

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