



**PBN**

# **AIRSPACE CONCEPT WORKSHOP**

**SIDs/STARs/HOLDS**

**NAV SPEC considerations**



**Federal Aviation  
Administration**





# Overview

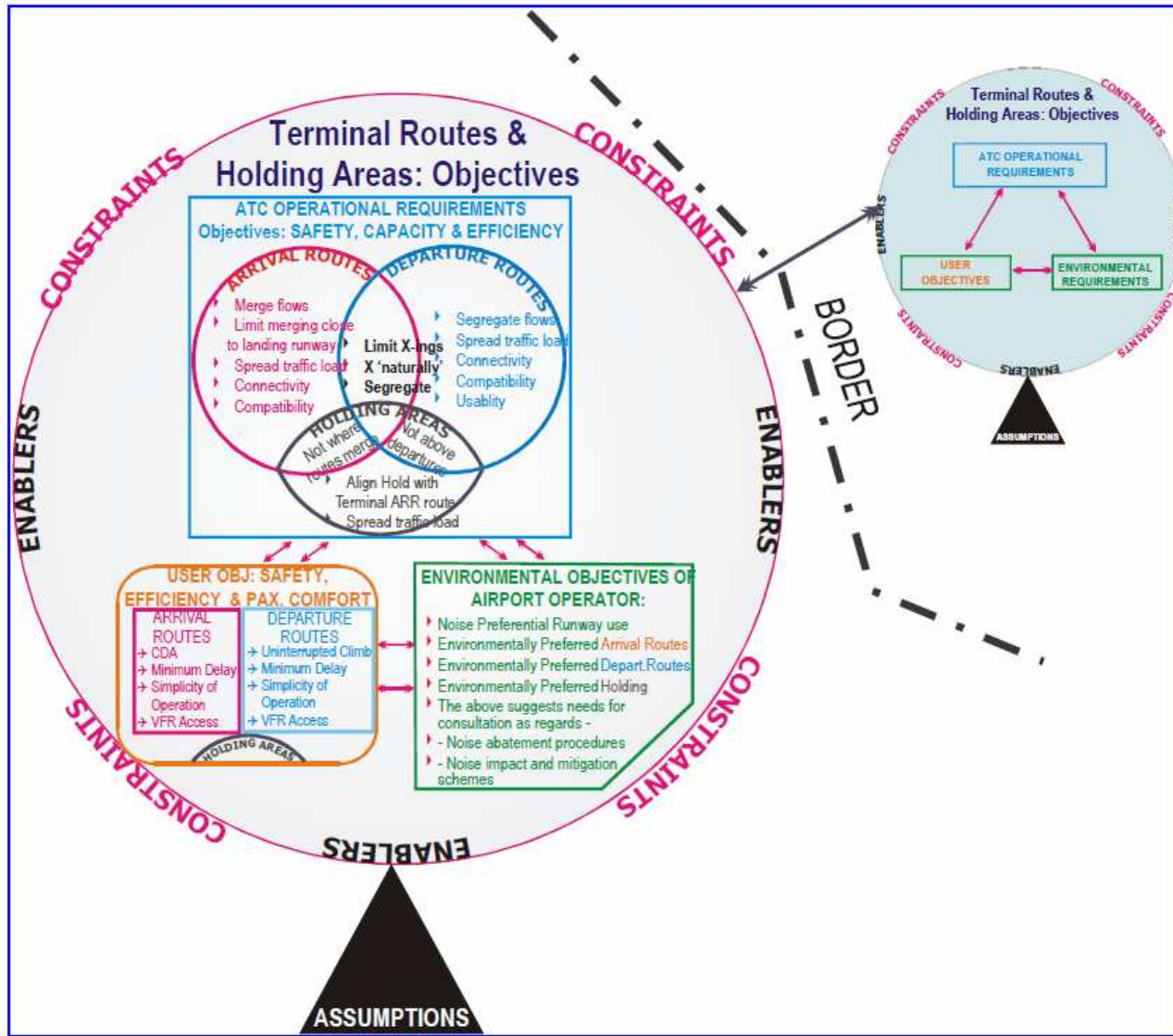
## Objective

This module will provide an insight in the development of routes and holds in support of the Operational requirements



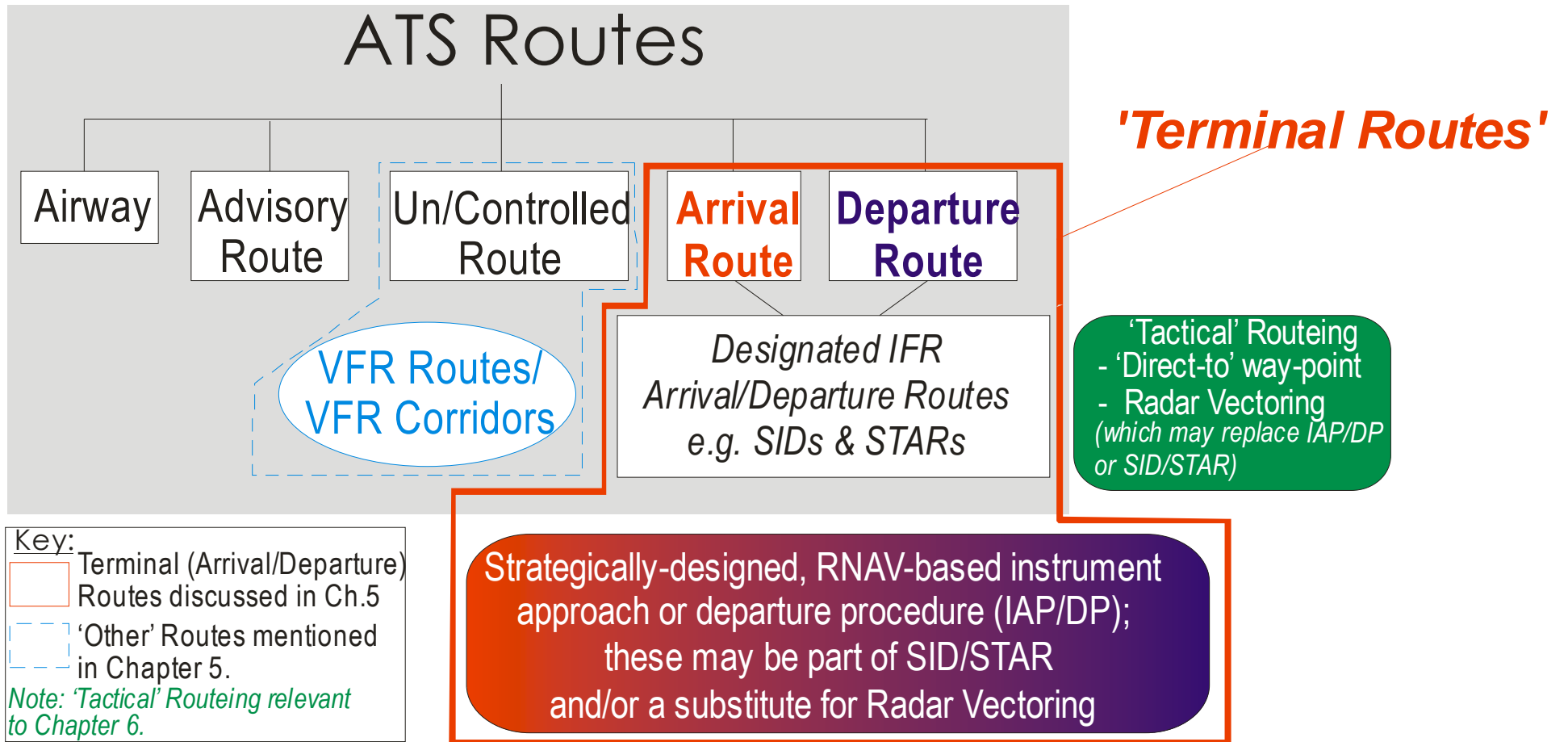


# Competing Interests





# Routes

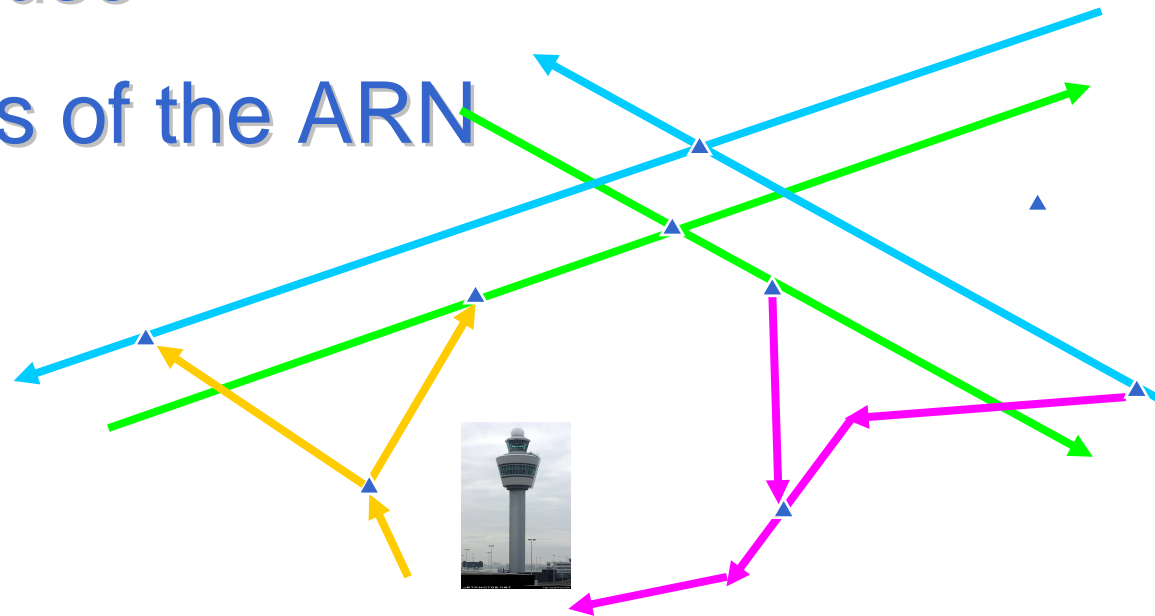




# Terminal Routes

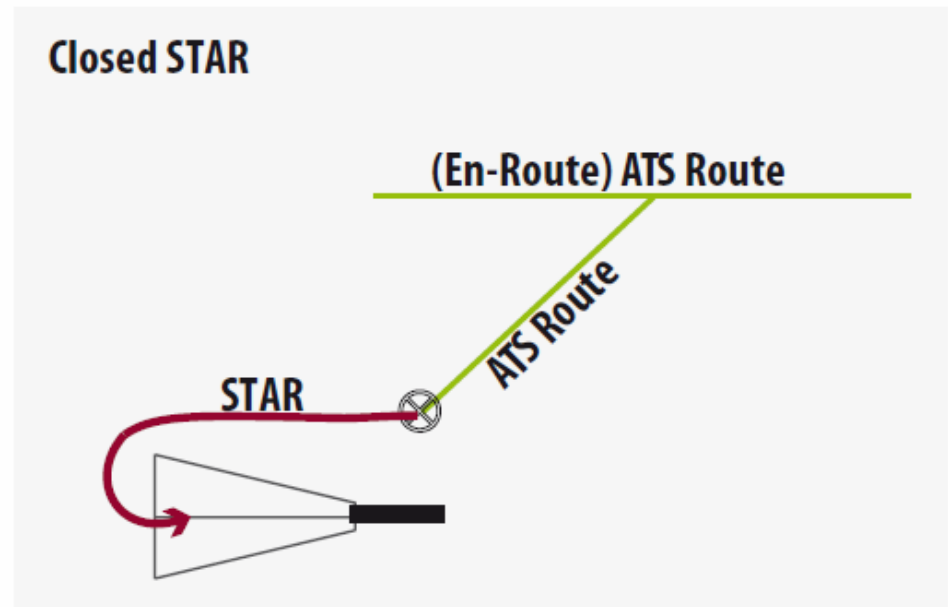
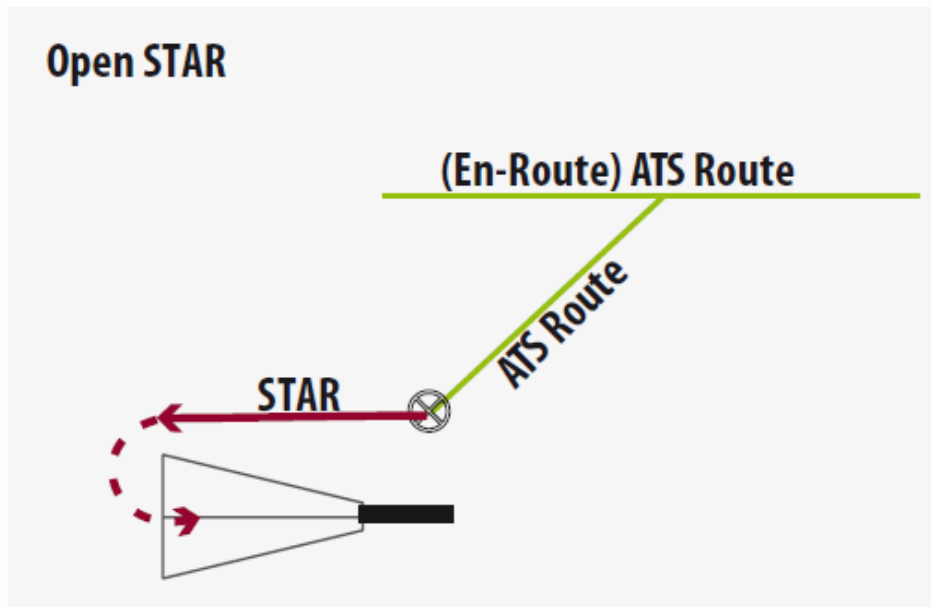
## Routes in Terminal Airspace link...

- Raw demand
- Runway in use
- ATS Routes of the ARN





# Different kinds of STARs

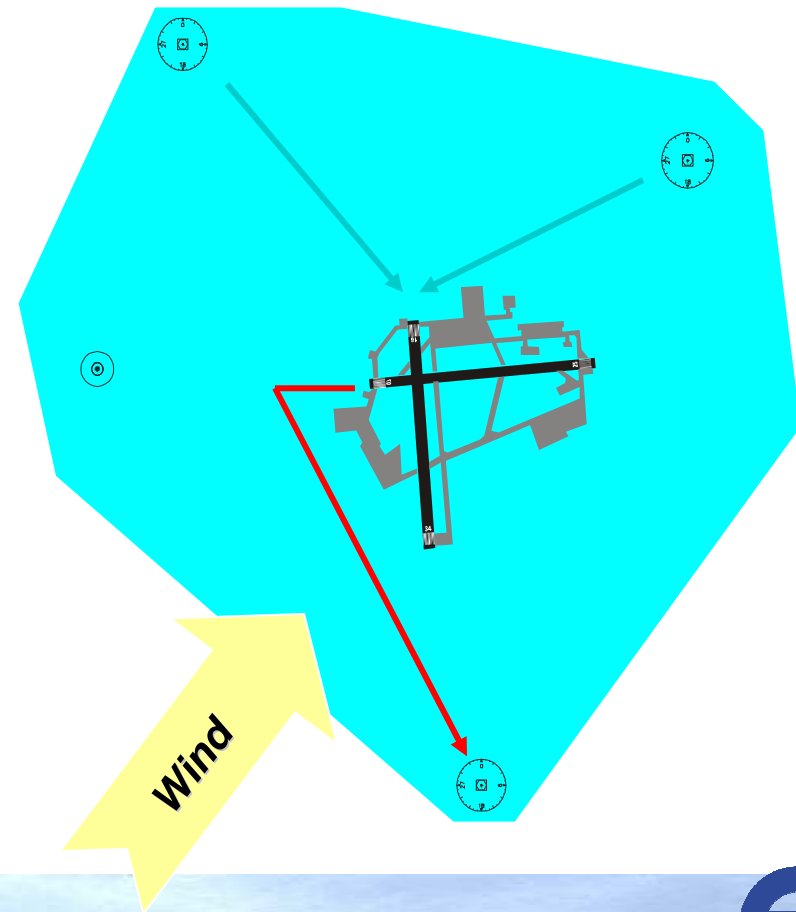


- - - → Tactical Vectors provided by ATC



# SID/STAR Dependence on RWY (1)

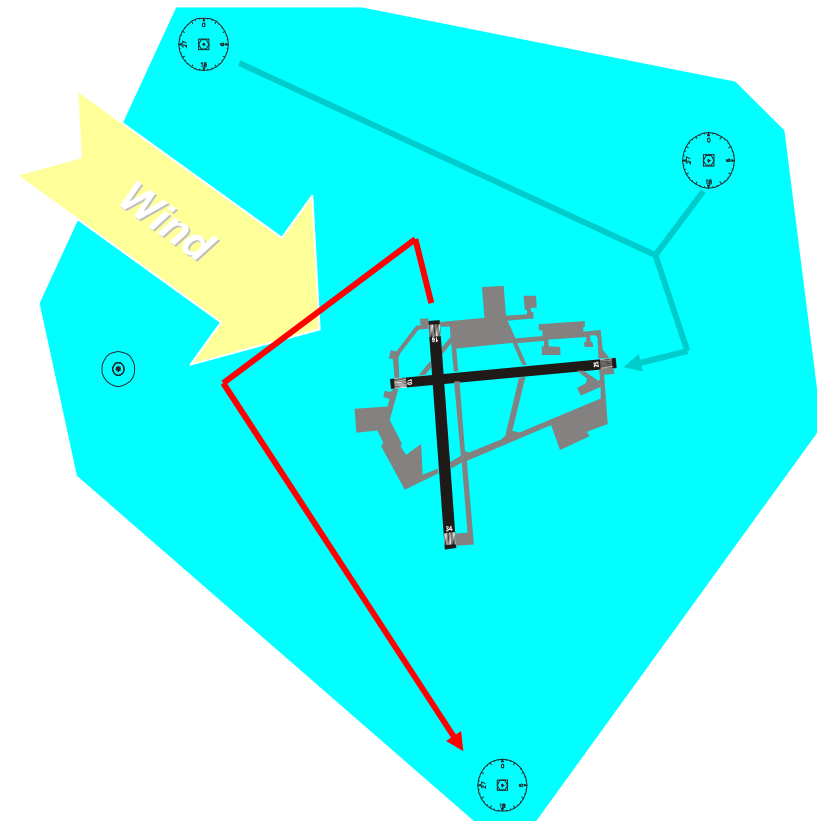
- RWY orientation is given
- Direction of RWY in use depends on wind





# SID/STAR Dependence on RWY (2)

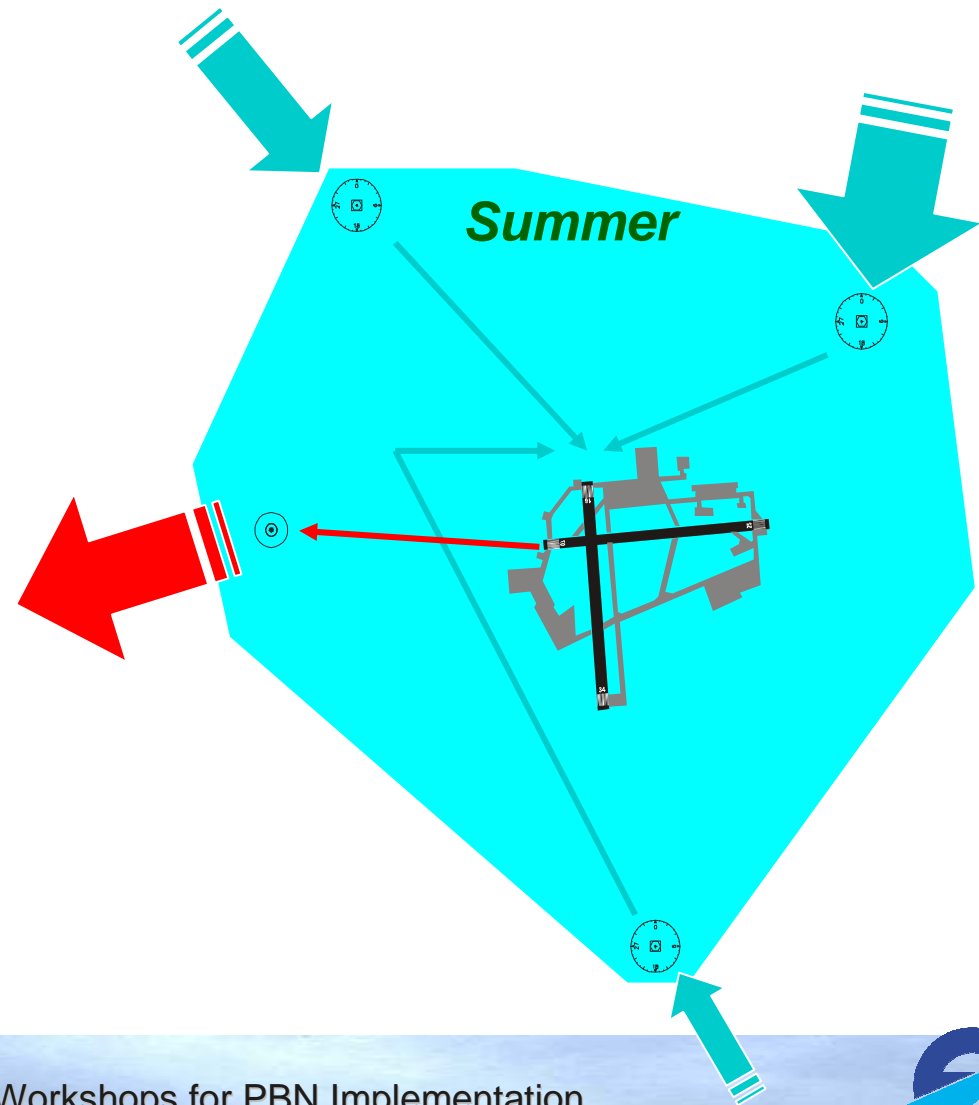
→ Different set of  
SIDs and STARs  
for different  
Runway in use





# Seasonal Effect (1)

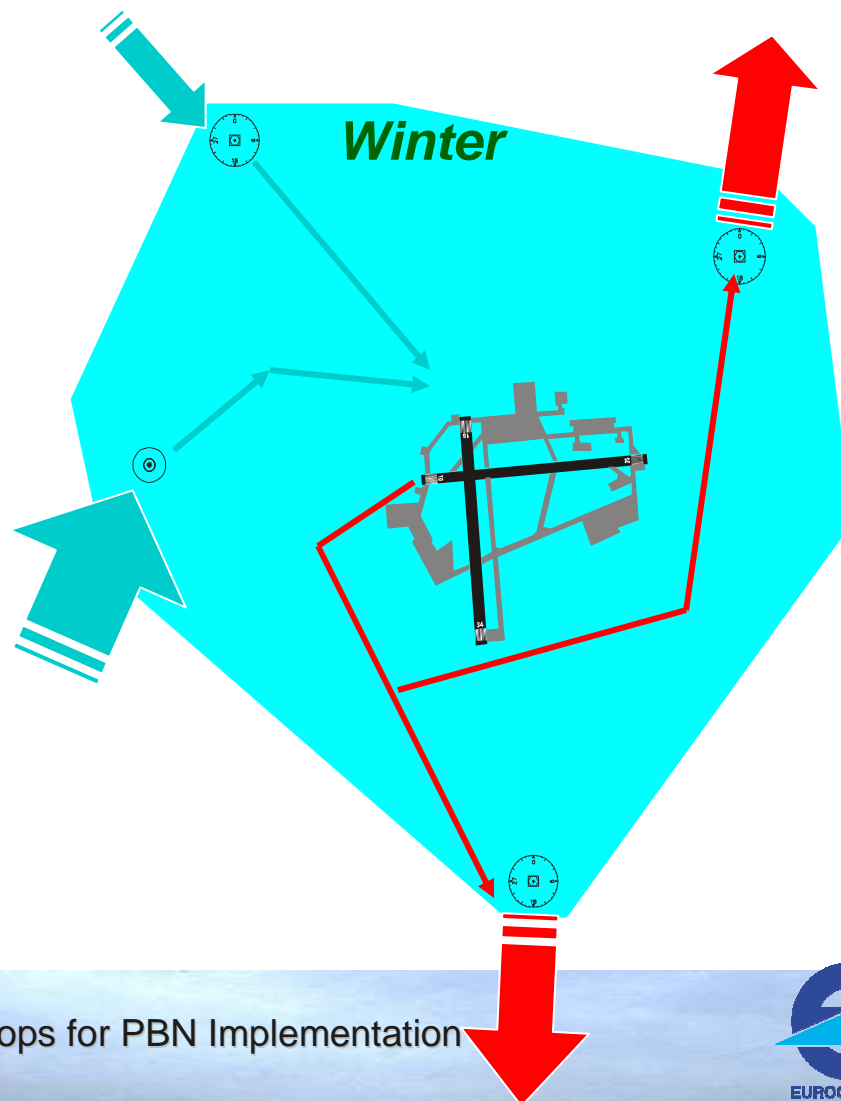
→ Demand and route placement can vary for different seasons





# Seasonal Effect (2)

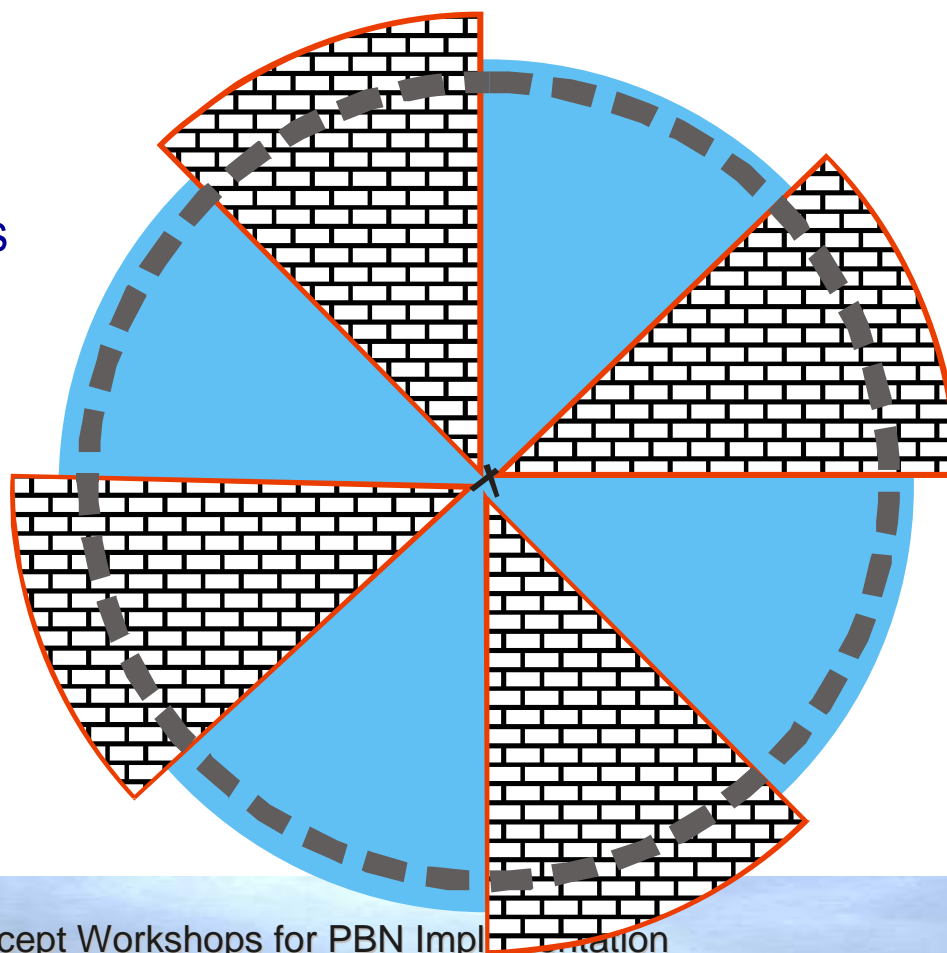
→ Different set of  
SIDs and STARs  
per season



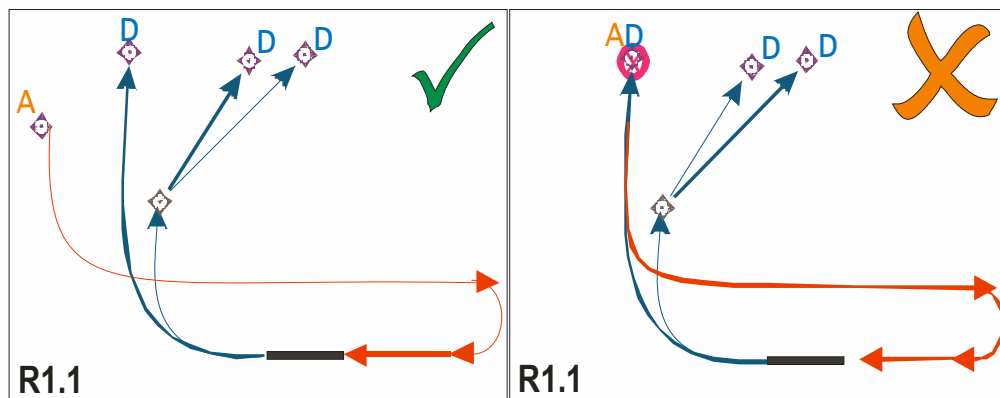


# Good design practice

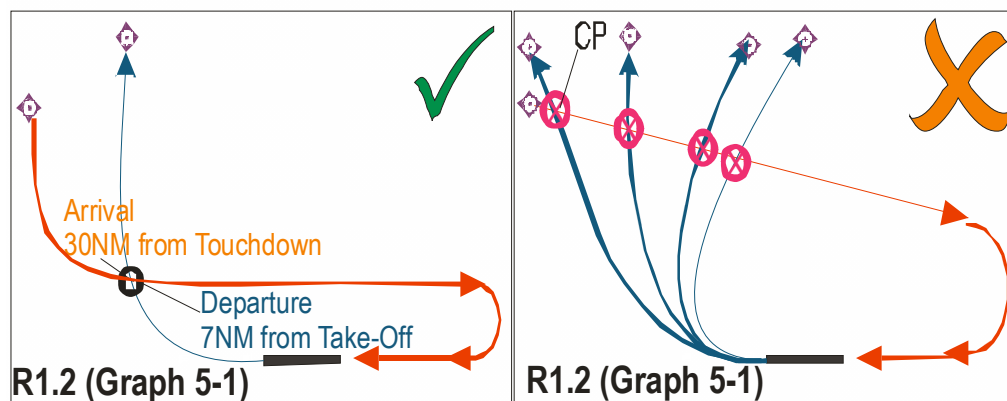
Segregate **Arrivals** from **Departures**  
Both laterally and Vertically



# Good design practice



Segregation of Routes and Entry/Exit point

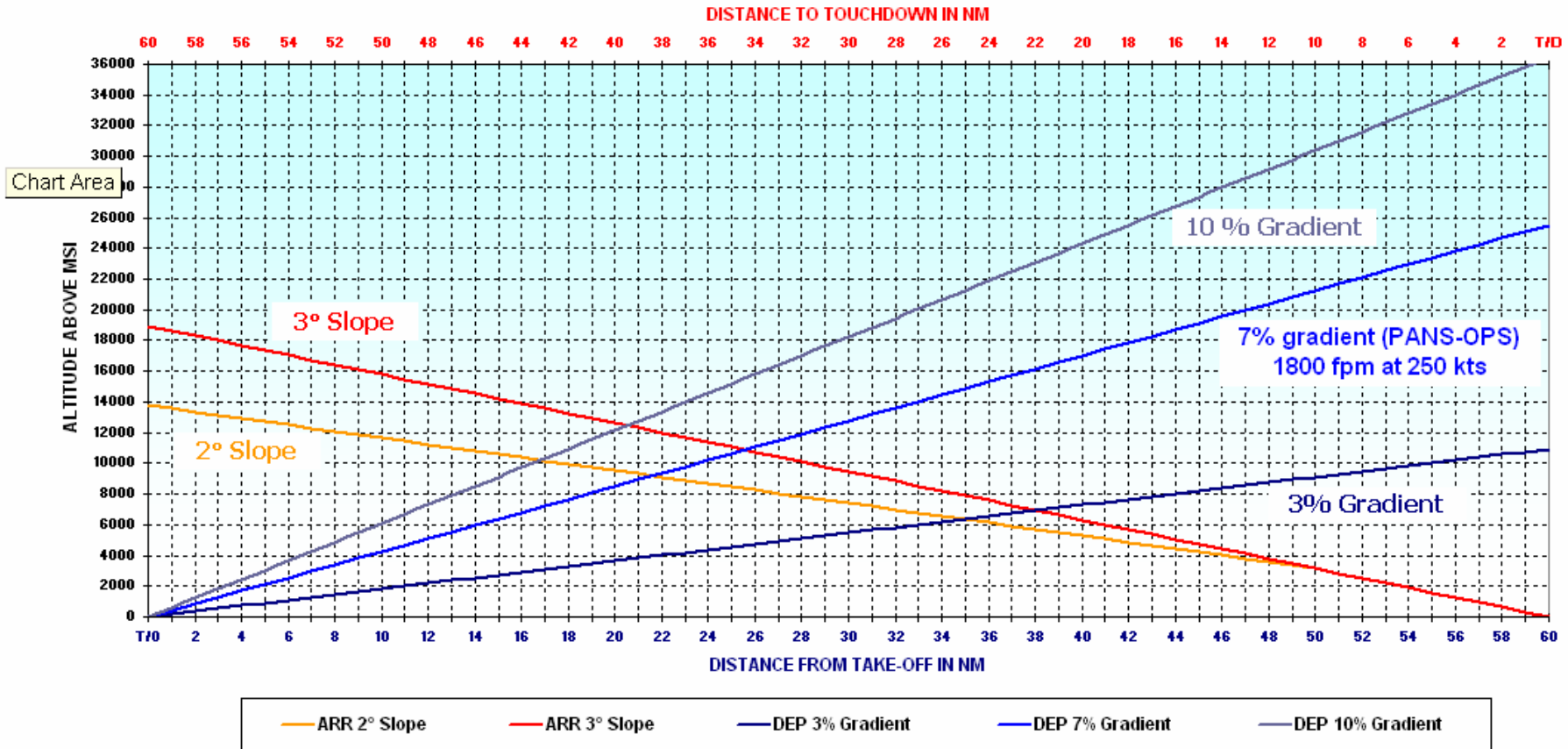


Minimise the number of crossing points  
Plan for vertical separation



# Good design practice

VERTICAL INTERACTION BETWEEN UNCONSTRAINED DEP & ARRIVAL [ELEV. @ MSL]

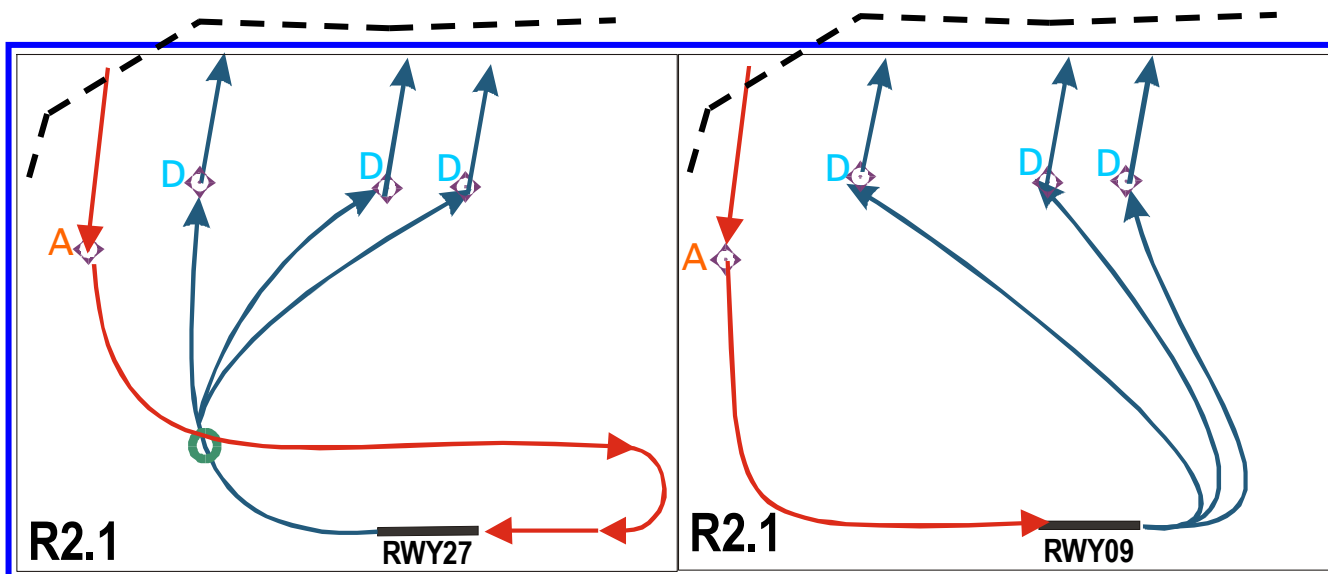




# Good design practice

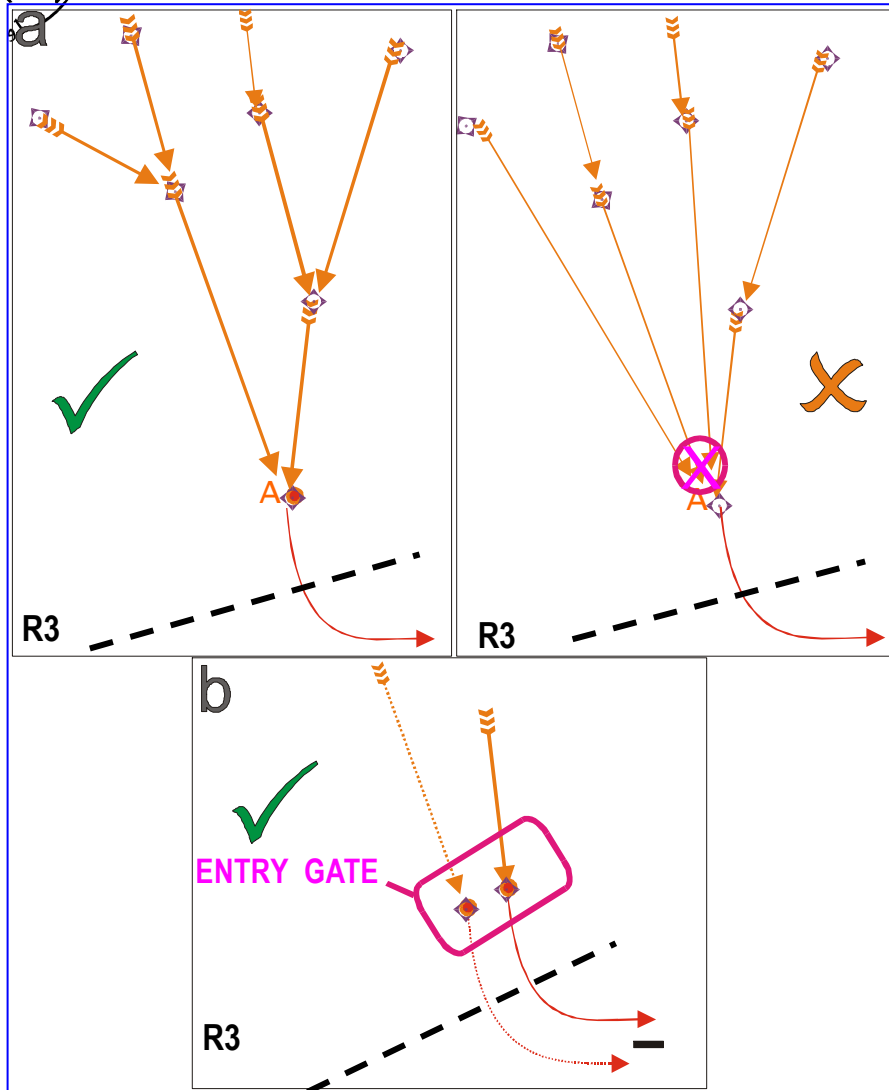
## Fix the same Exit/Entry points for different RWY configurations

(handoff between ACC and APP should not change with RWY configuration)





# Good design practice



Gradually converge inbound flows

Group similar inbound flows in Entry Gates







# The Benefits of RNAV

**PATEON RWY 20**

Transition altitude 6000 feet.

Note: Some chart details have been omitted to aid visual clarity.

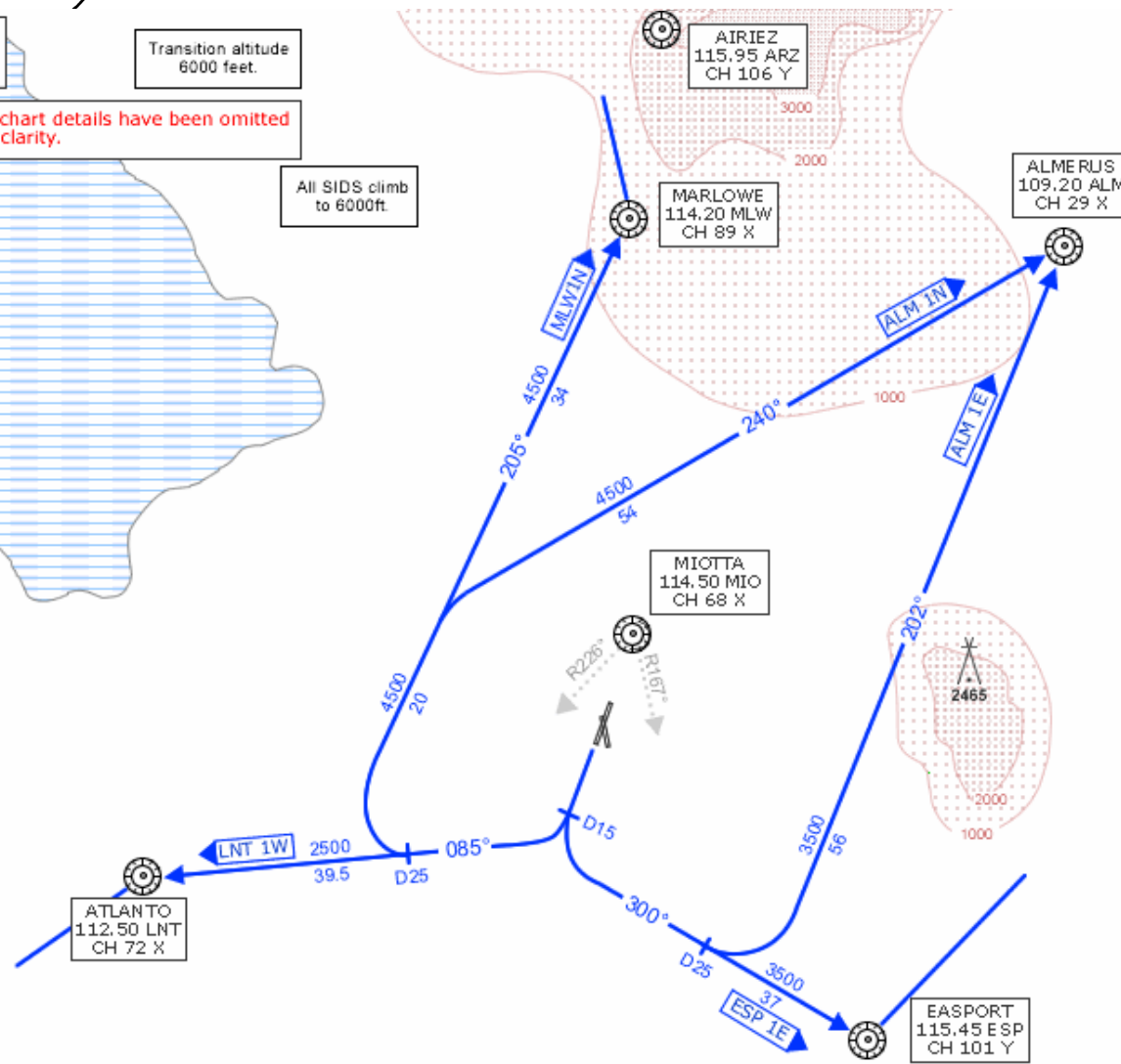
All SIDS climb to 6000ft.

**STANDARD INSTRUMENT DEPARTURES**

MSA ARP 25 NM	VOR/DME	Latitude	Longitude
	AIRIEZ	N54° 01'	E003° 03.1'
	ALMERUS	N53° 48.9'	E003° 25.1'
	ATLANTO	N53° 14.3'	E002° 34.8'
	EASPORT	N53° 05.2'	E003° 14.2'
	MARLOWE	N53° 50.5'	E003° 01.2'
	MIOTTA	N53° 27.7'	E003° 01.6'

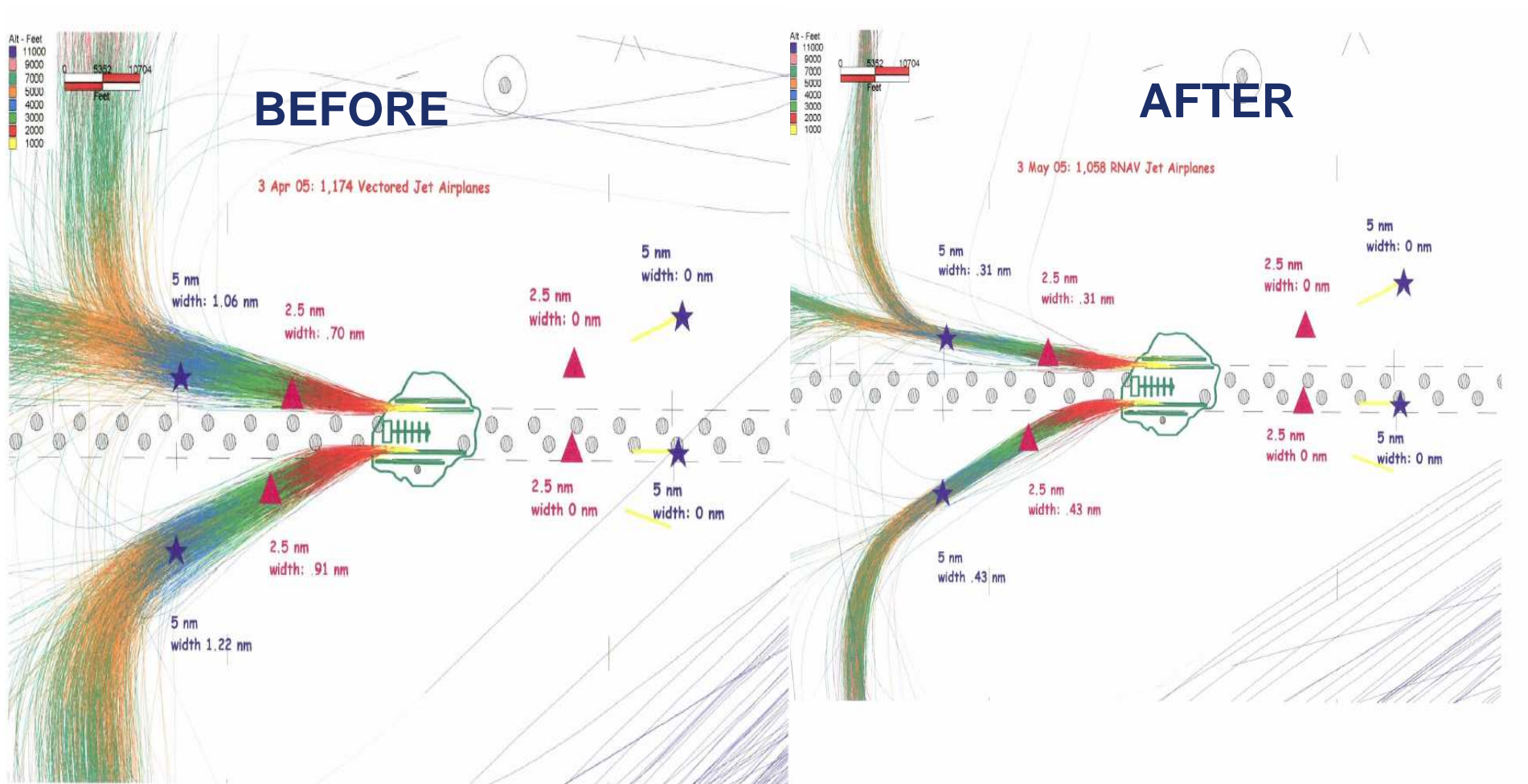
Bearings and tracks are magnetic. Tracks in brackets are true. Altitudes in feet AMSL.

DEPARTURES	ROUTING
ALM 1E	Climb on track 203, at 15D MIO turn left to intercept ESP R300. At 25D MIO turn left to intercept ALM R202 to ALM.
ALM 1N	Climb on track 203, at 15D MIO turn right to intercept LNT R085. At 25D MIO turn right to intercept MLW R205. Intercept ALM R240 to ALM.
ESP 1E	Climb on track 203, at 15D MIO turn left to intercept ESP R300 to ESP.
LNT 1W	Climb on track 203, at 15D MIO turn right to intercept LNT R085 to LNT.
MLW 1N	Climb on track 203, at 15D MIO turn right to intercept LNT R085. At 25D MIO turn right to intercept MLW R205 to MLW.





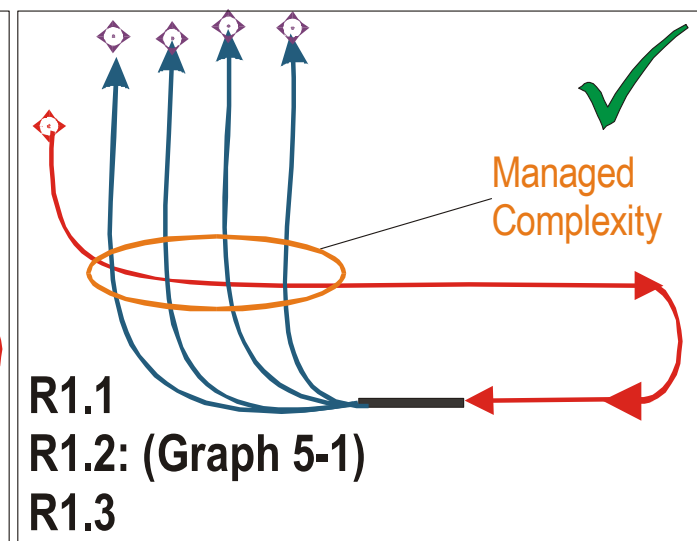
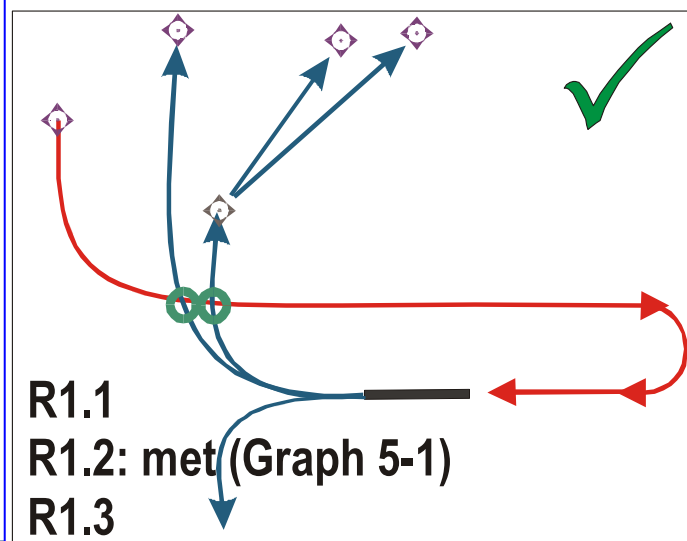
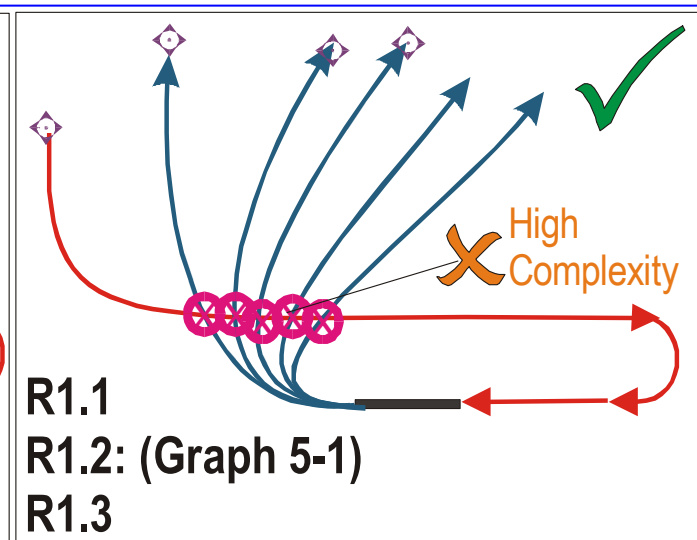
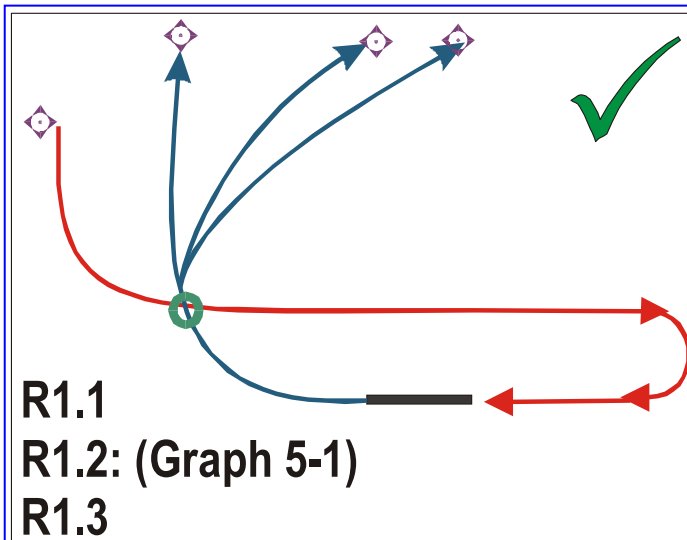
# RNAV Departures at Atlanta USA





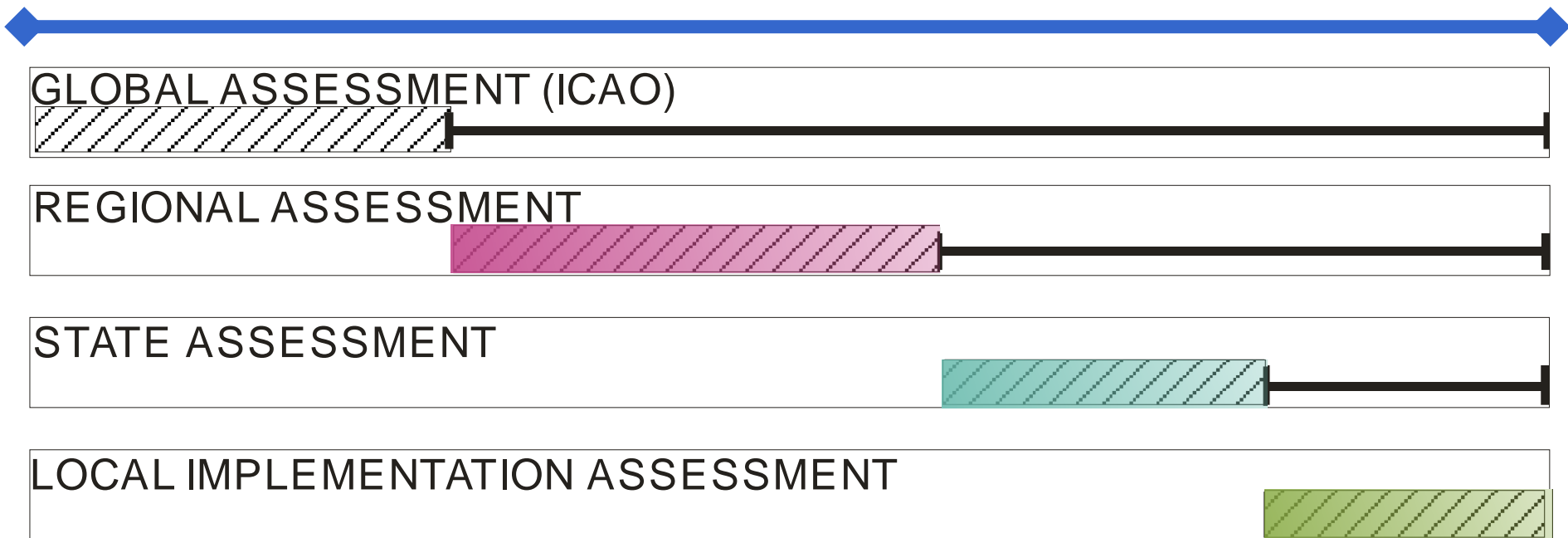
# Good design practice

Minimise Crossing Complexity





# Safety Assessment for Route Spacing



Key



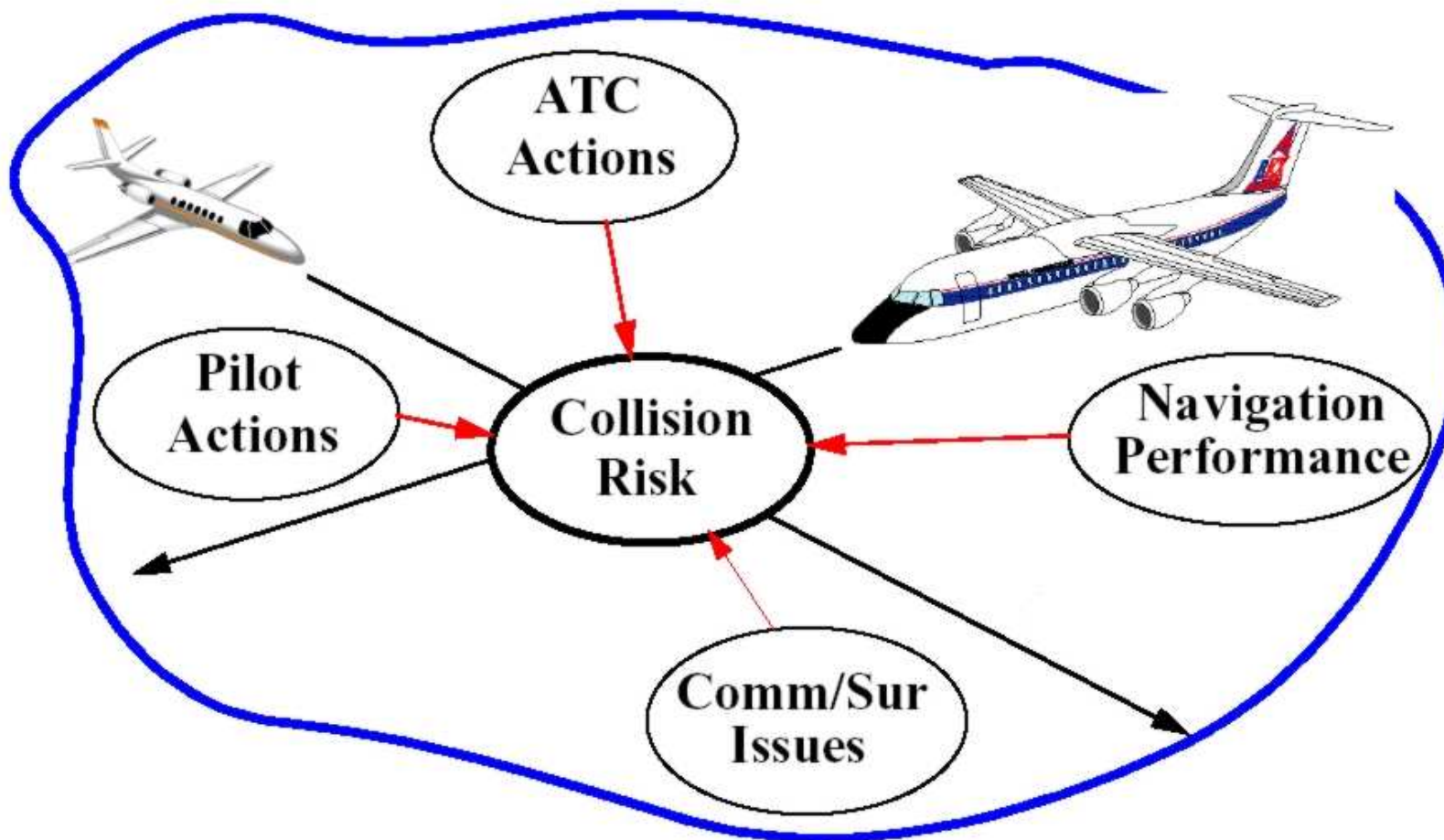
Assessment Scope



Portion of Assessment to be completed at more detailed level (below).

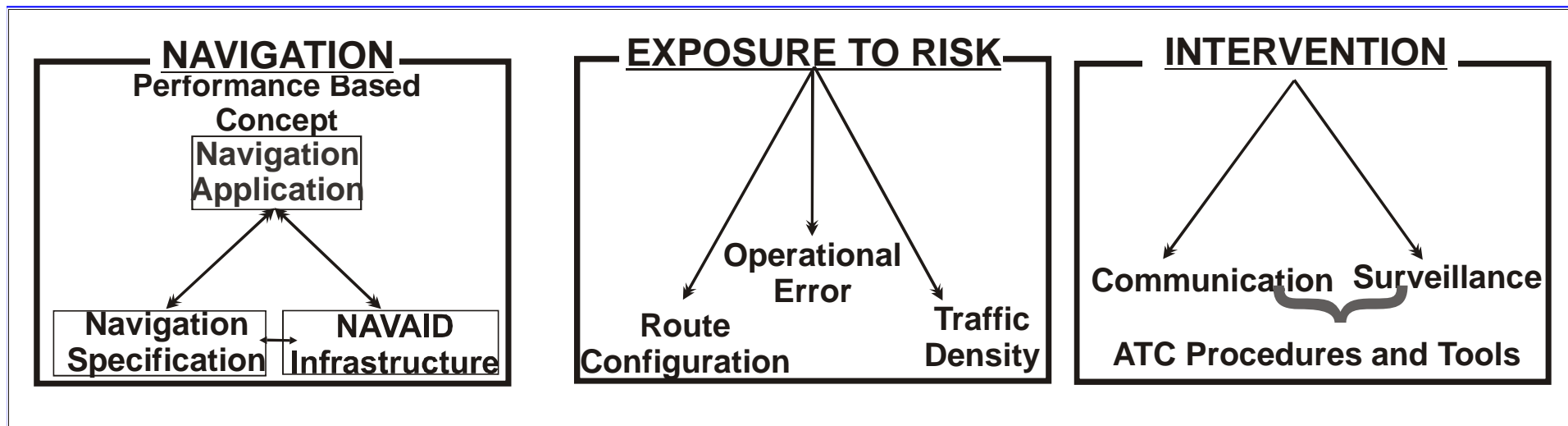


# Route Spacing





# Route Spacing



Generic model used to determine separation and ATS Route spacing



# Route Spacing

<p>PBN</p>	<p><b>NAVIGATION</b> Performance Based Concept Navigation Application</p>	<p><b>EXPOSURE TO RISK</b></p>	<p><b>INTERVENTION</b></p>
<p>Determination of <b>separation minima (1)</b> for tactical use <i>without</i> ATC Surveillance</p>	<p>✓</p>	<p>✓ (2)</p>	<p>✗</p>
<p>Determination of <b>separation minima (1)</b> for tactical use <i>with</i> ATC Surveillance</p>	<p>✗</p>	<p>✗ (2) &amp; (3)</p>	<p>✓</p>
<p>Determination of <b>Route Spacing</b> <i>without</i> ATC Surveillance</p>	<p>✓</p>	<p>✓</p>	<p>✗</p>
<p>Determination of <b>Route Spacing</b> <i>with</i> ATC Surveillance</p>	<p>✓</p>	<p>✓</p>	<p>✓</p>

✓ Relevant; ✗ largely irrelevant; (1) In context, separation minima based on Navaid or Navigation Sensor or PBN; (2) traffic density = single aircraft pair; (3) separation minima determined as a function of performance of ATC surveillance system.



# ECAC Route Spacing Summary for Radar environment

Interpreted results of various EUROCONTROL route spacing studies. The route spacing advantages of Advanced RNP are contrasted to those of P-RNAV and B-RNAV.

↓Parallel Routes / based on →	Advanced RNP		P-RNAV*		B-RNAV
	En Route	Terminal	<i>En Route</i>	<i>Terminal</i>	<i>En Route</i>
Same Direction	7 NM	7 NM	9 NM	8 NM	16.5 NM
Opposite Direction					18 NM
Other					10-15 NM with increased ATC intervention rates
Spacing on turning segments	As above		Larger than above because no FRT		Larger than above because no FRT

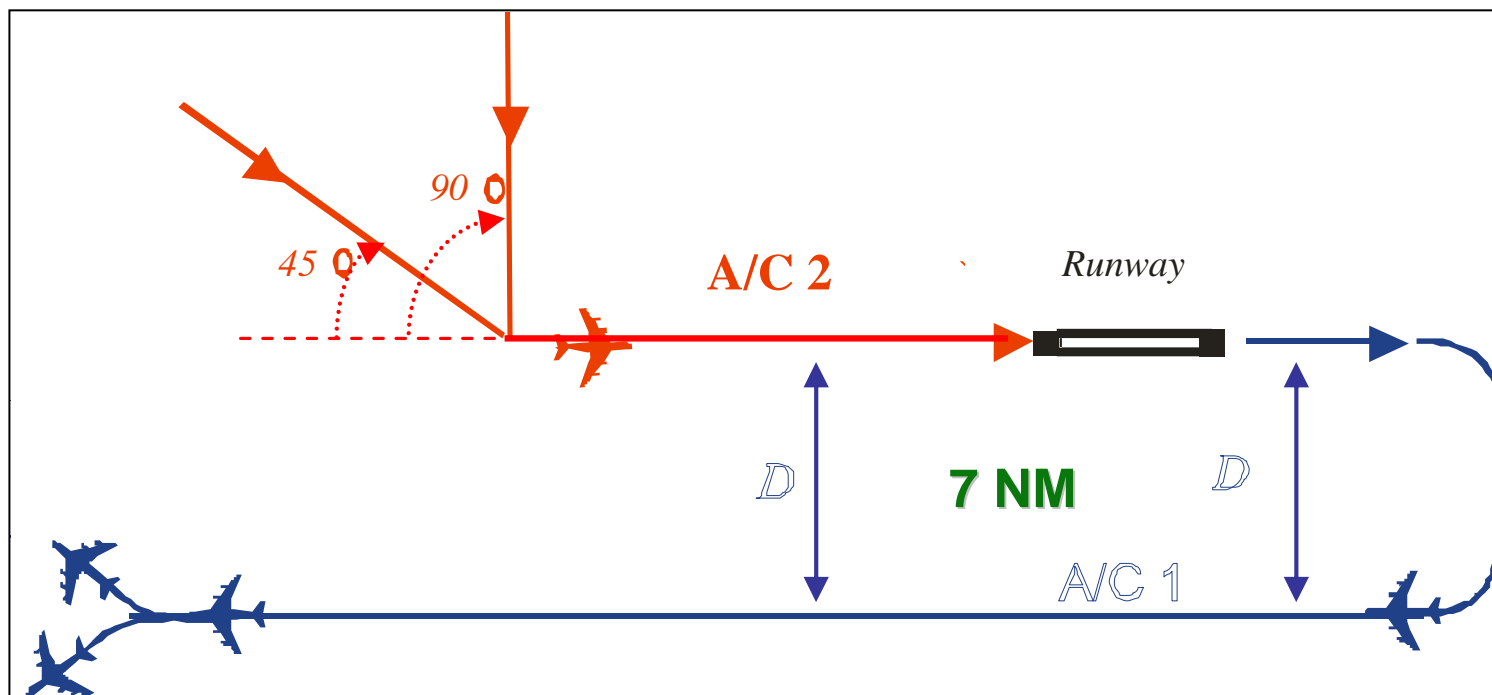
Assumption is that all aircraft in same ATC sector

\* In 2000, a spacing of 7 NM was considered possible in a specific study undertaken for the Paris-London tracks south of CBA 1. This finding does not suggest that 7 NM spacing is generally possible with P-RNAV. This particular spacing is to be seen in the context of the Paris-London tracks and depends on the situation studied and associated assumptions viz. the specifics of the route configuration, the navigation performance of the aircraft operating on those tracks at the time and the traffic characteristics, etc.



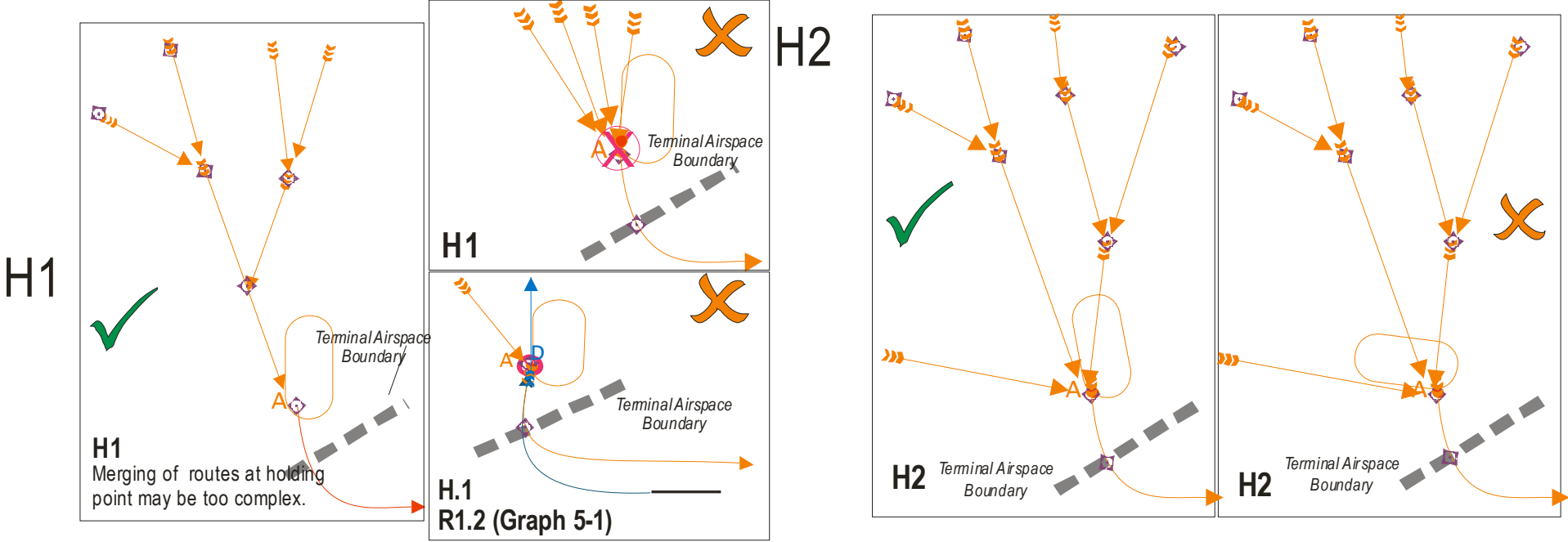
# PANS-ATM Route Spacing Procedural Terminal for PBN

Up to 400  
Movements  
Per day

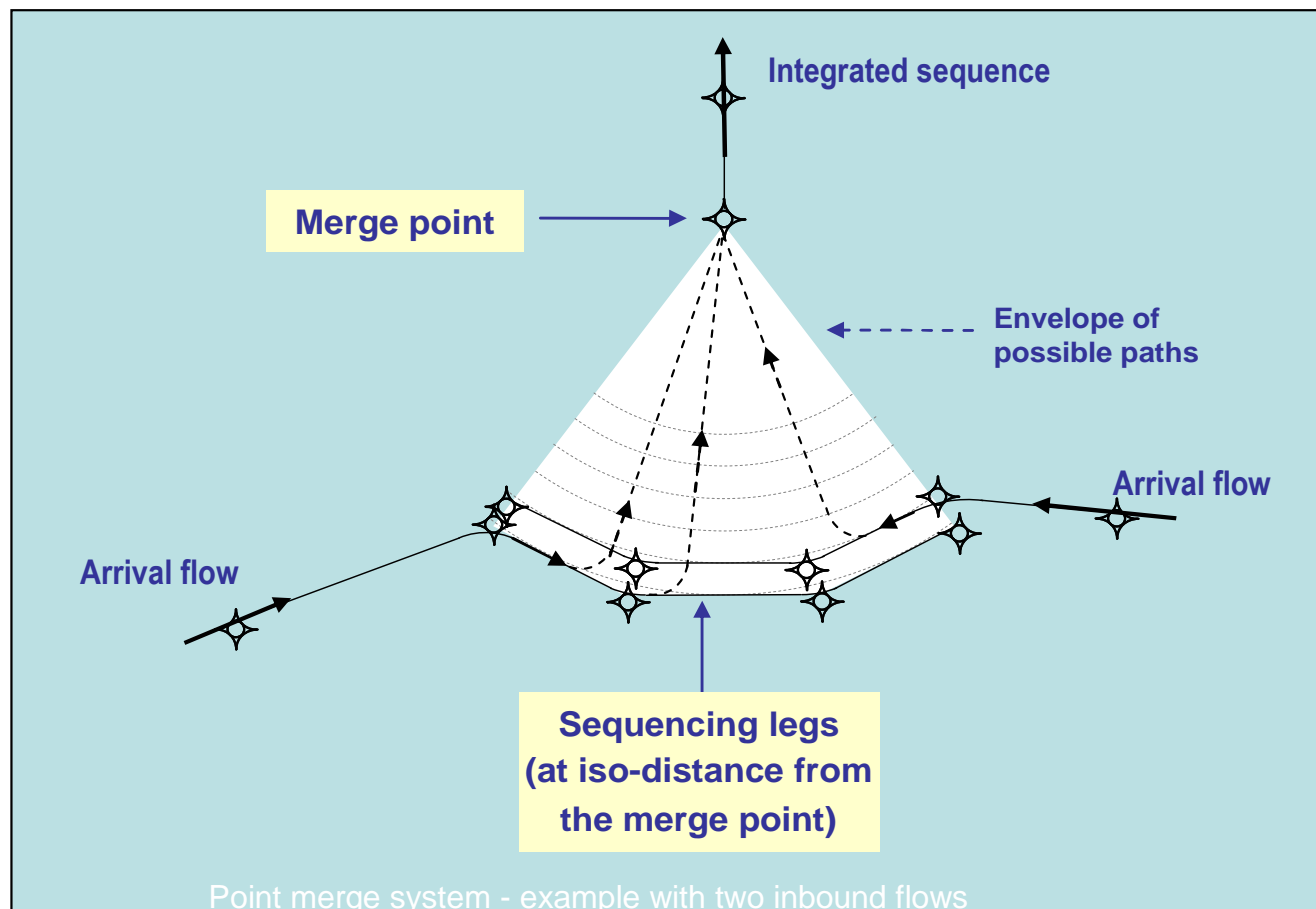


# Good design practice

## Holds

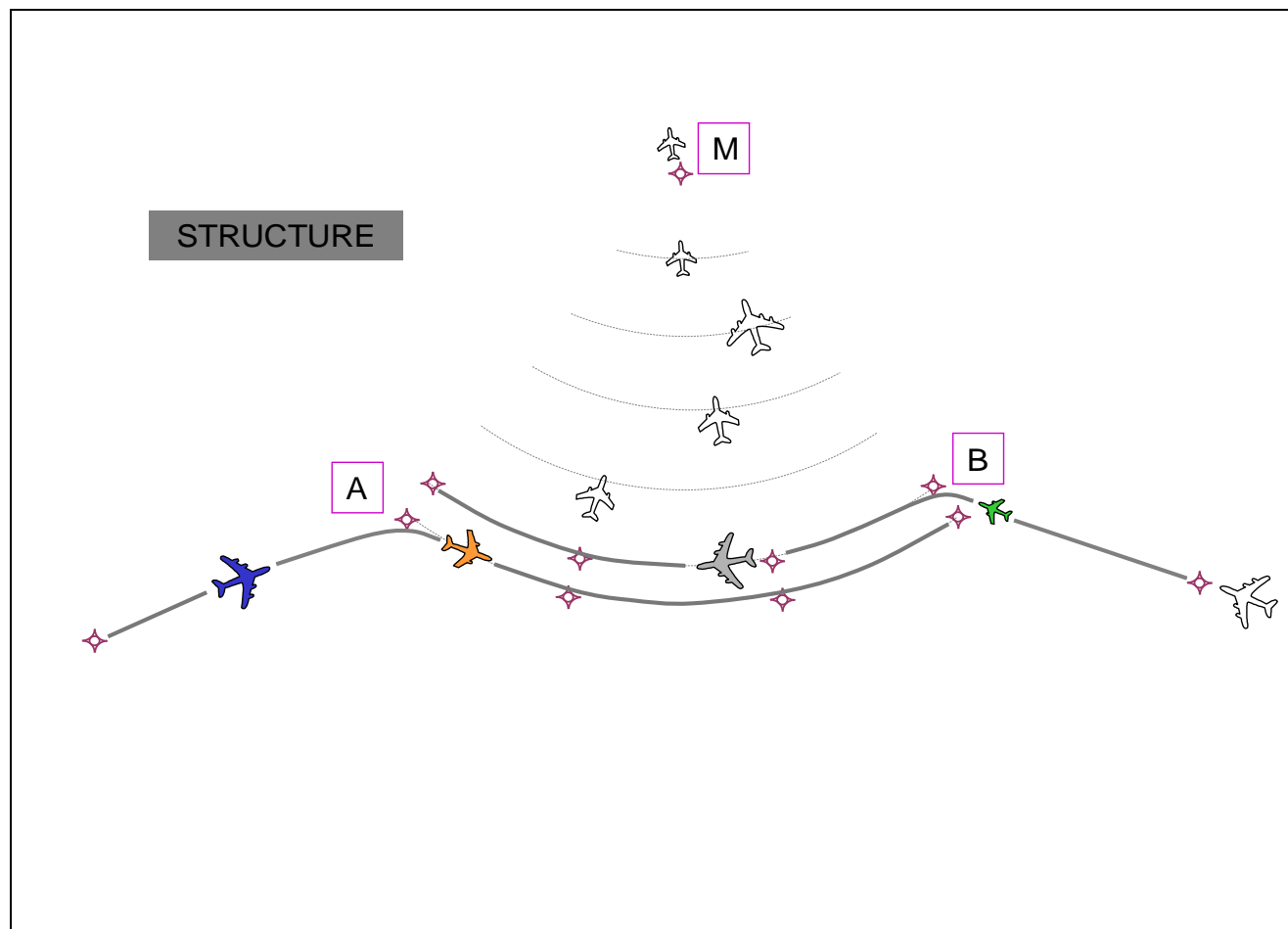


# Point Merge System (PMS)



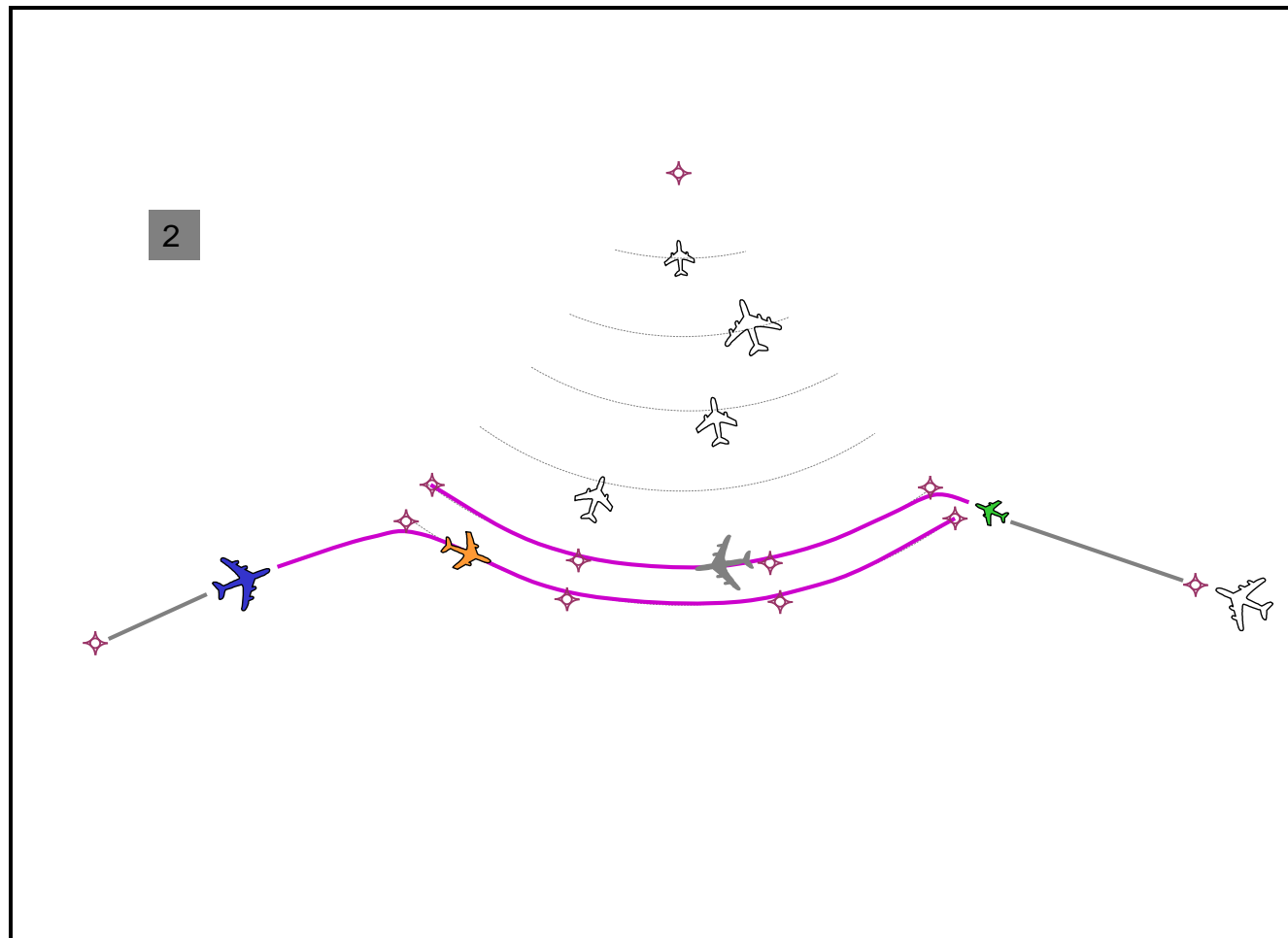


# Scenario “talk-through” (1/5)



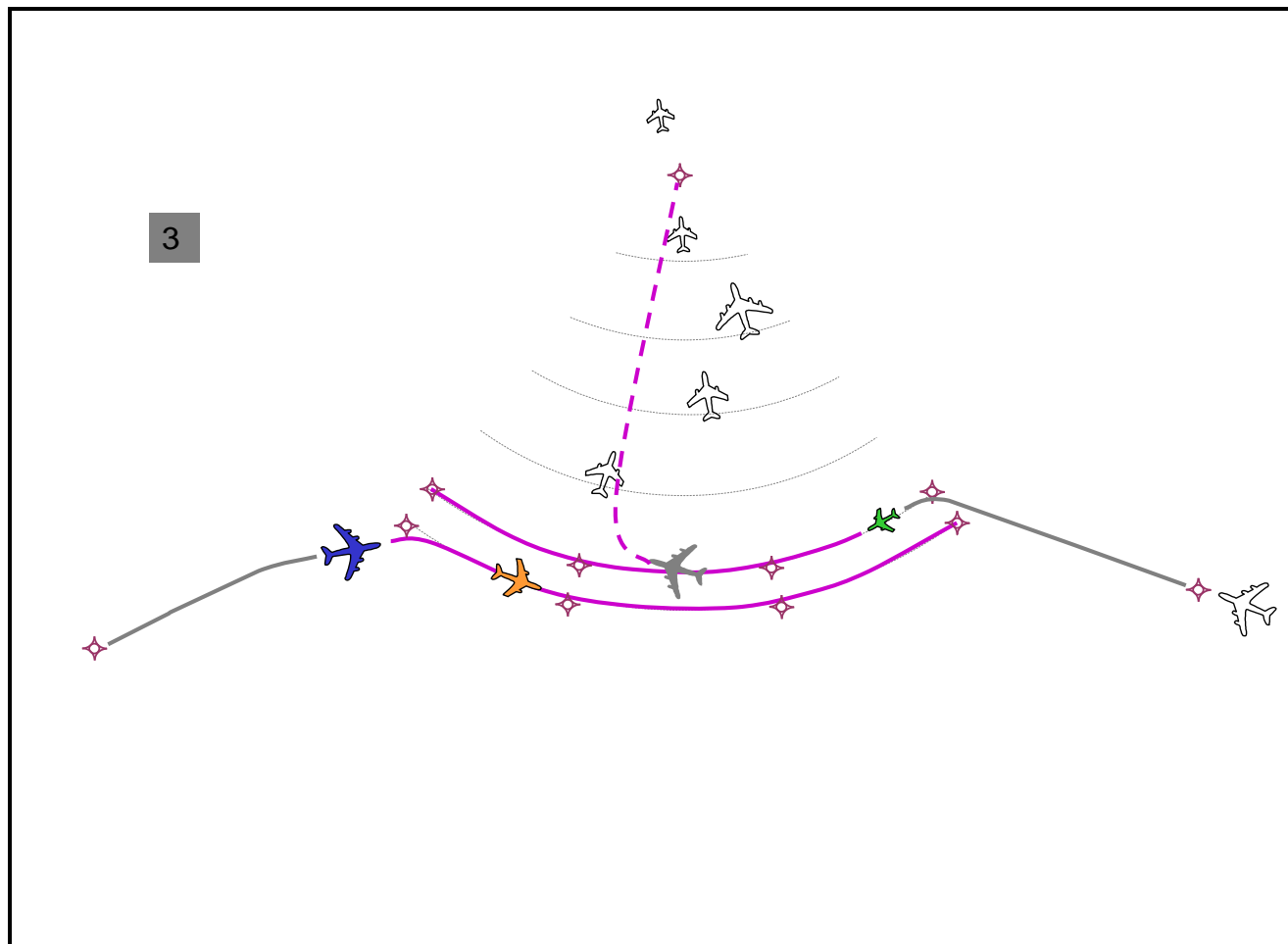


# Scenario “talk-through” (2/5)





# Scenario “talk-through” (3/5)

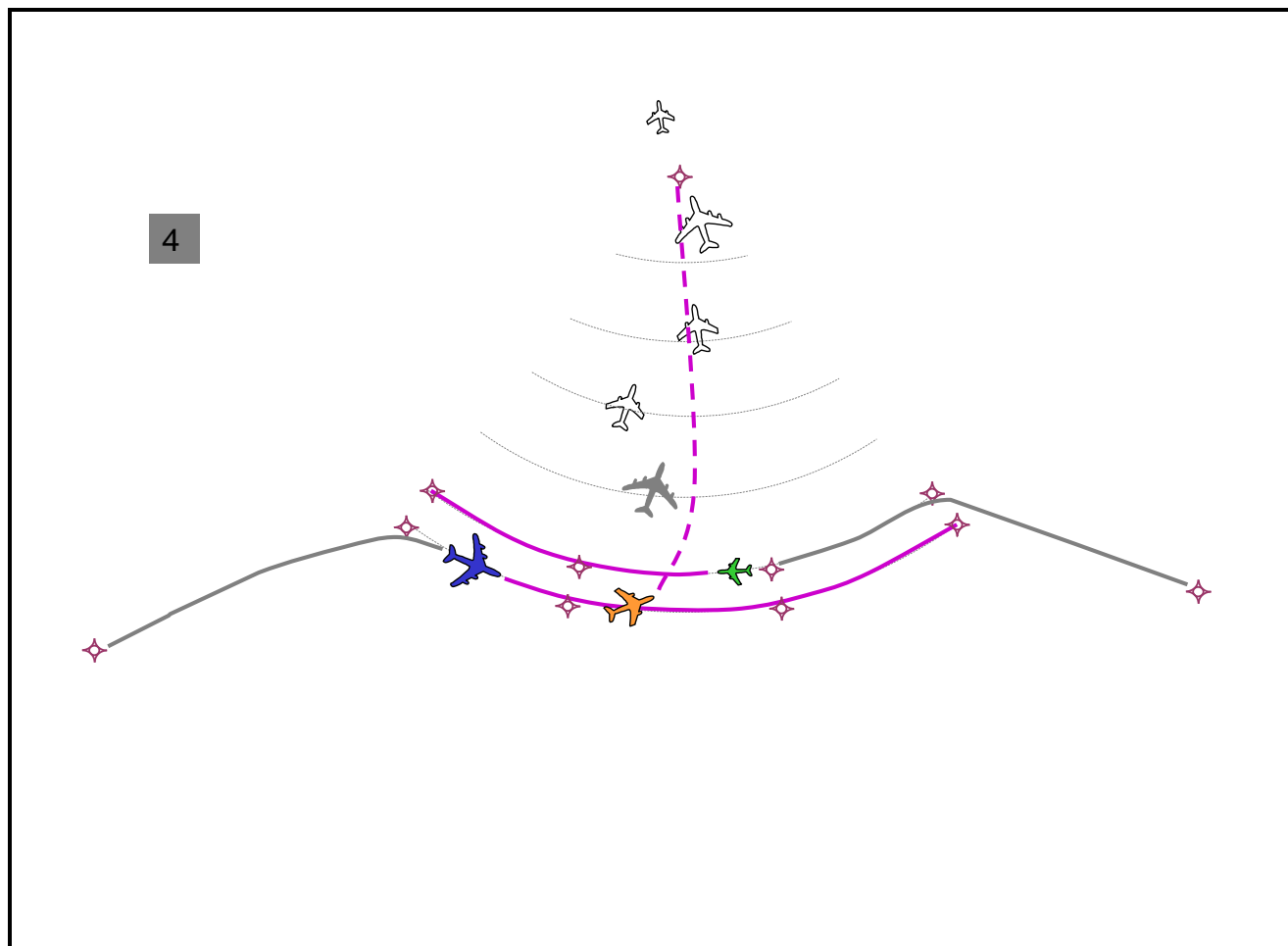


Controller determines when to issue the "Direct to merge point" instruction to the lead aircraft so that WTC spacing behind the preceding aircraft will be achieved.





# Scenario “talk-through” (4/5)



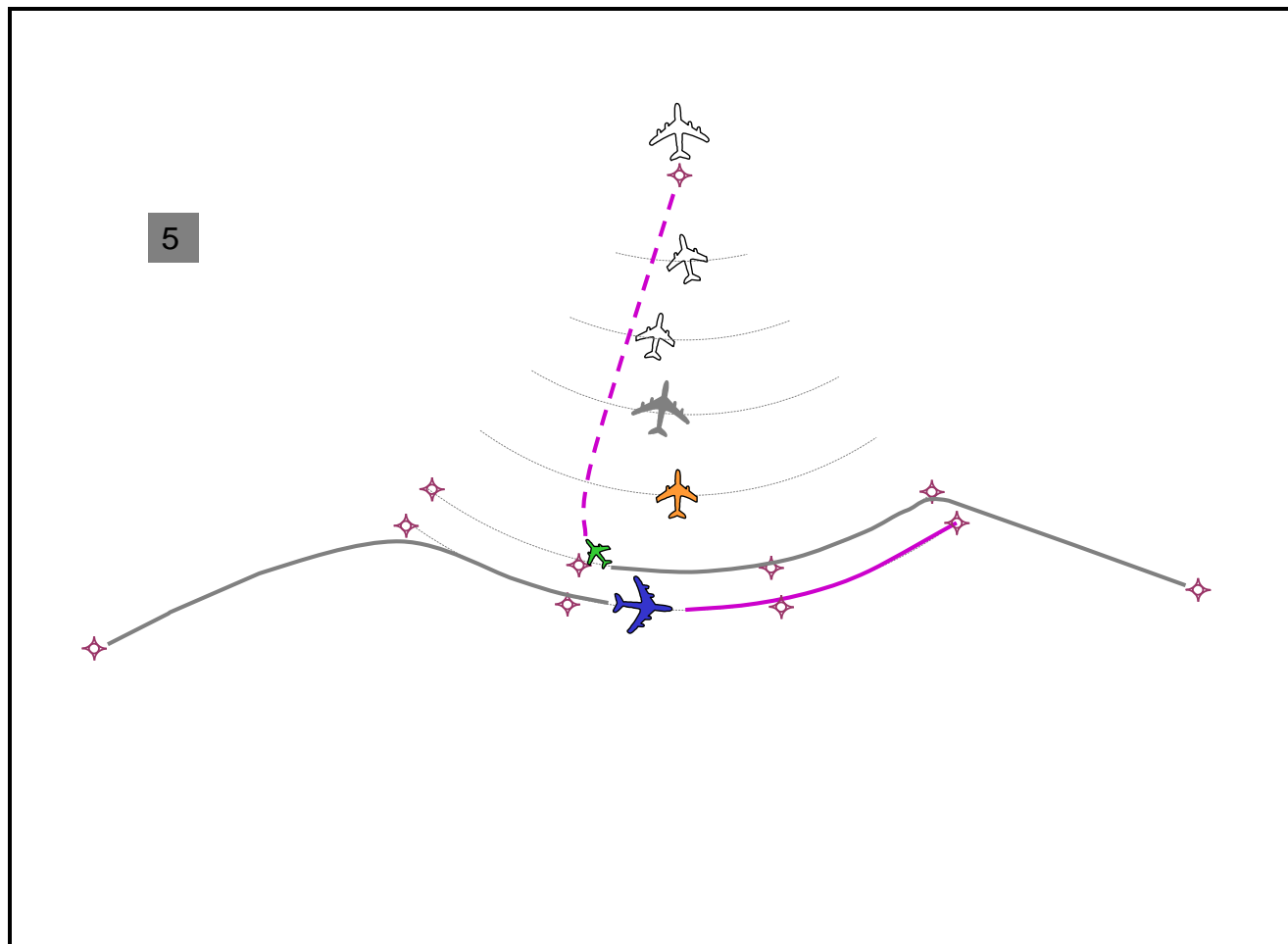
4

to the Gold aircraft using the range ring arcs to assess  
the appropriate spacing for FBN implementation



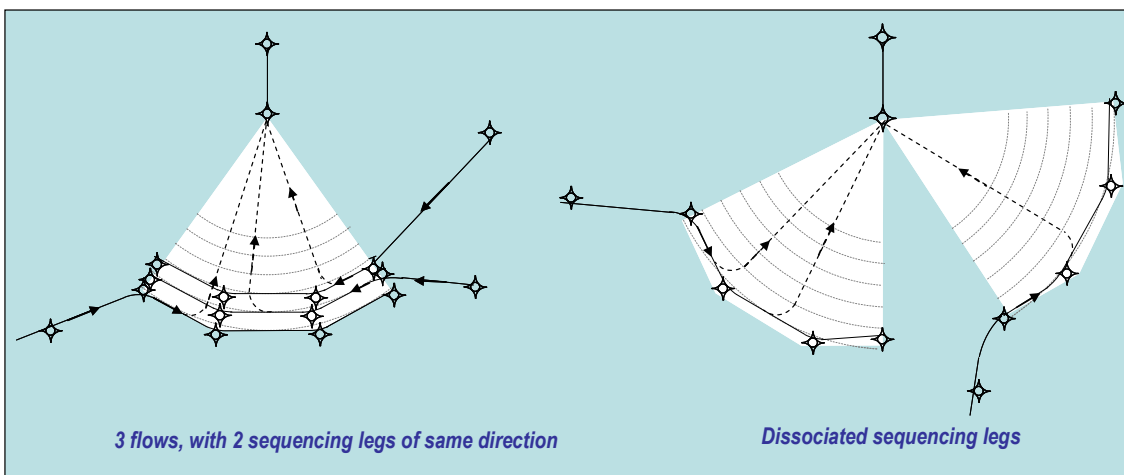
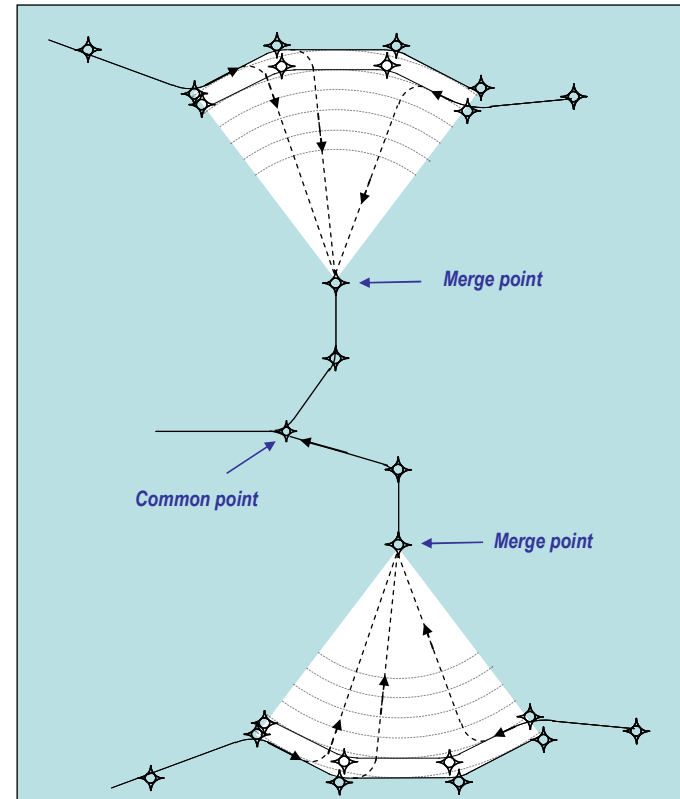
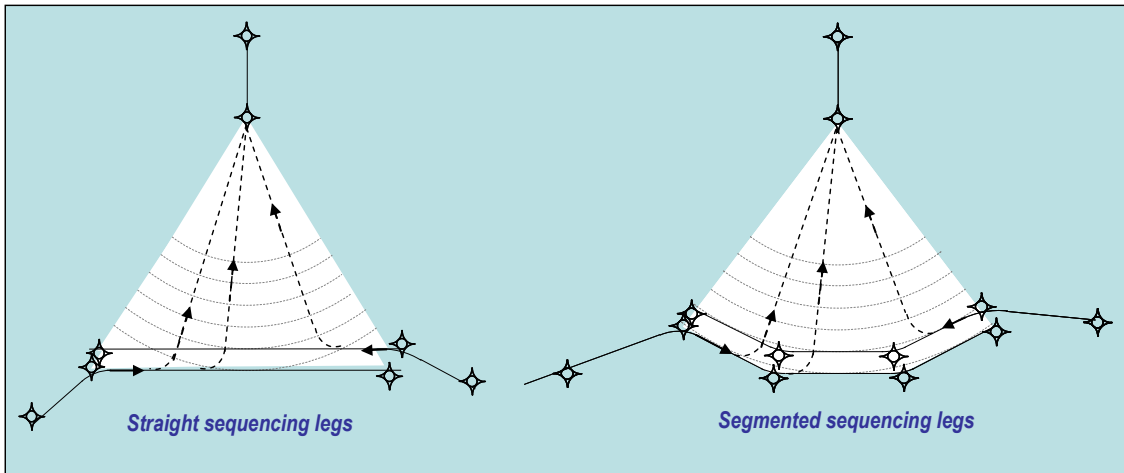


# Scenario “talk-through” (5/5)



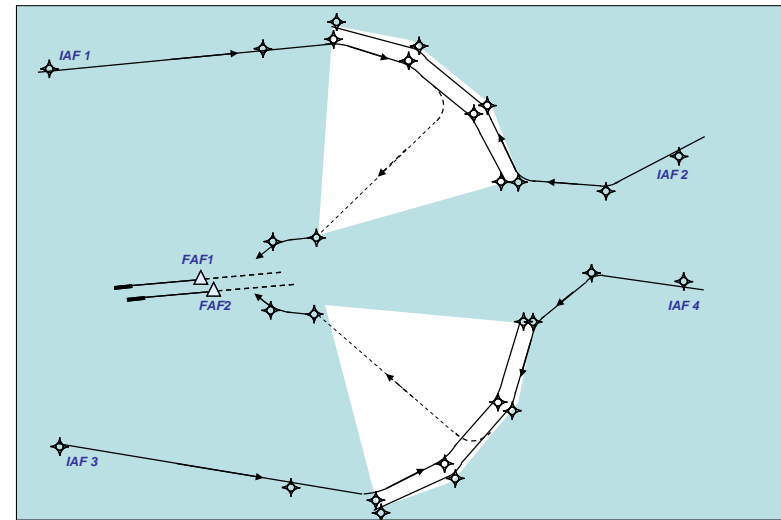
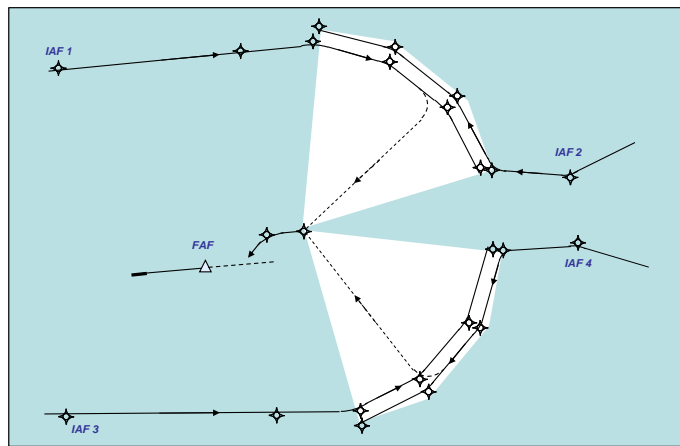
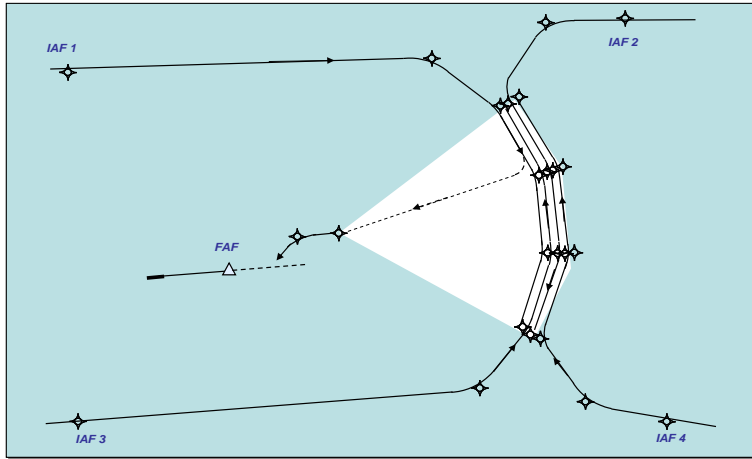


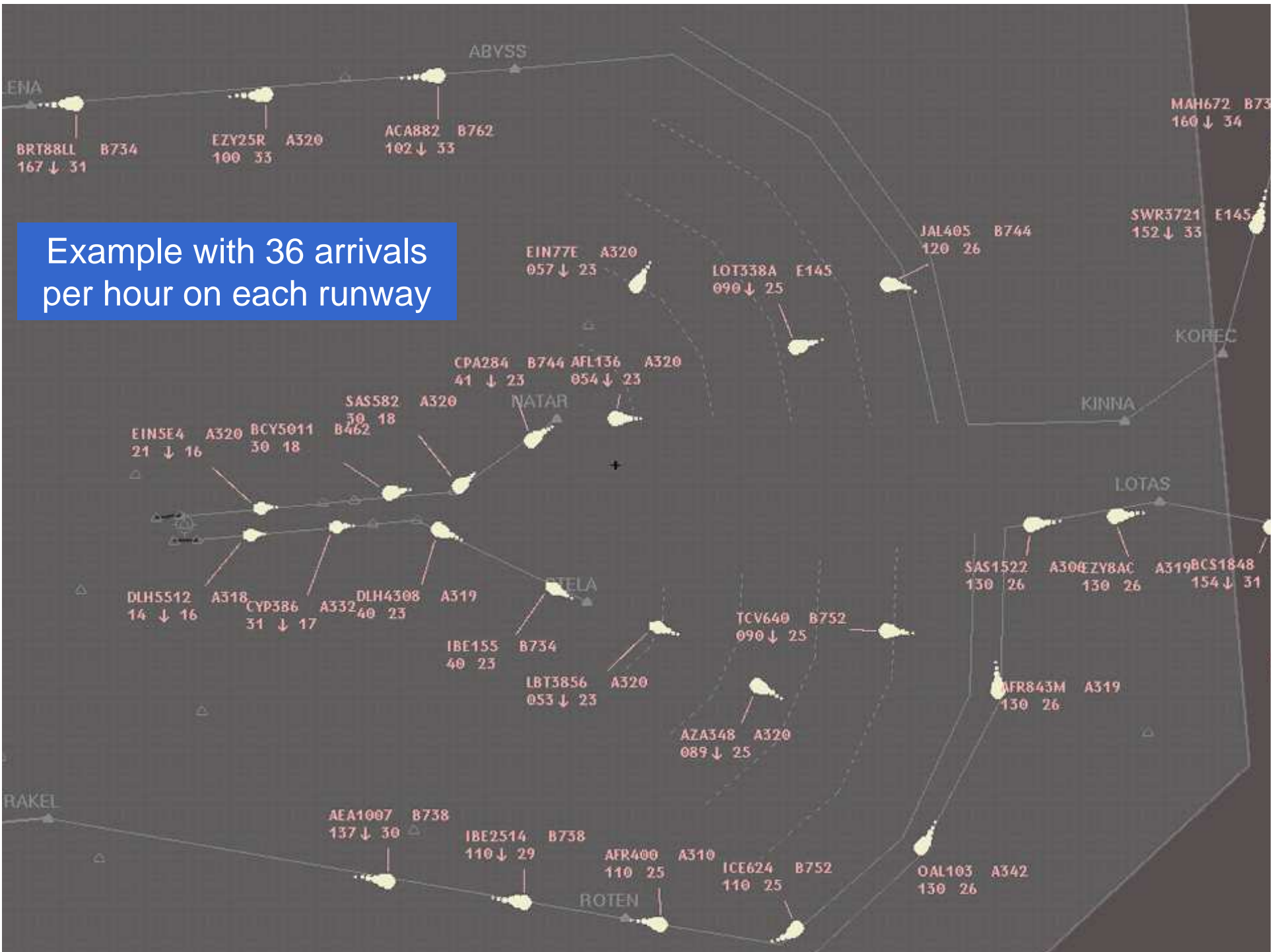
# Configurations tested (1/2)





# Configurations tested (2/2)



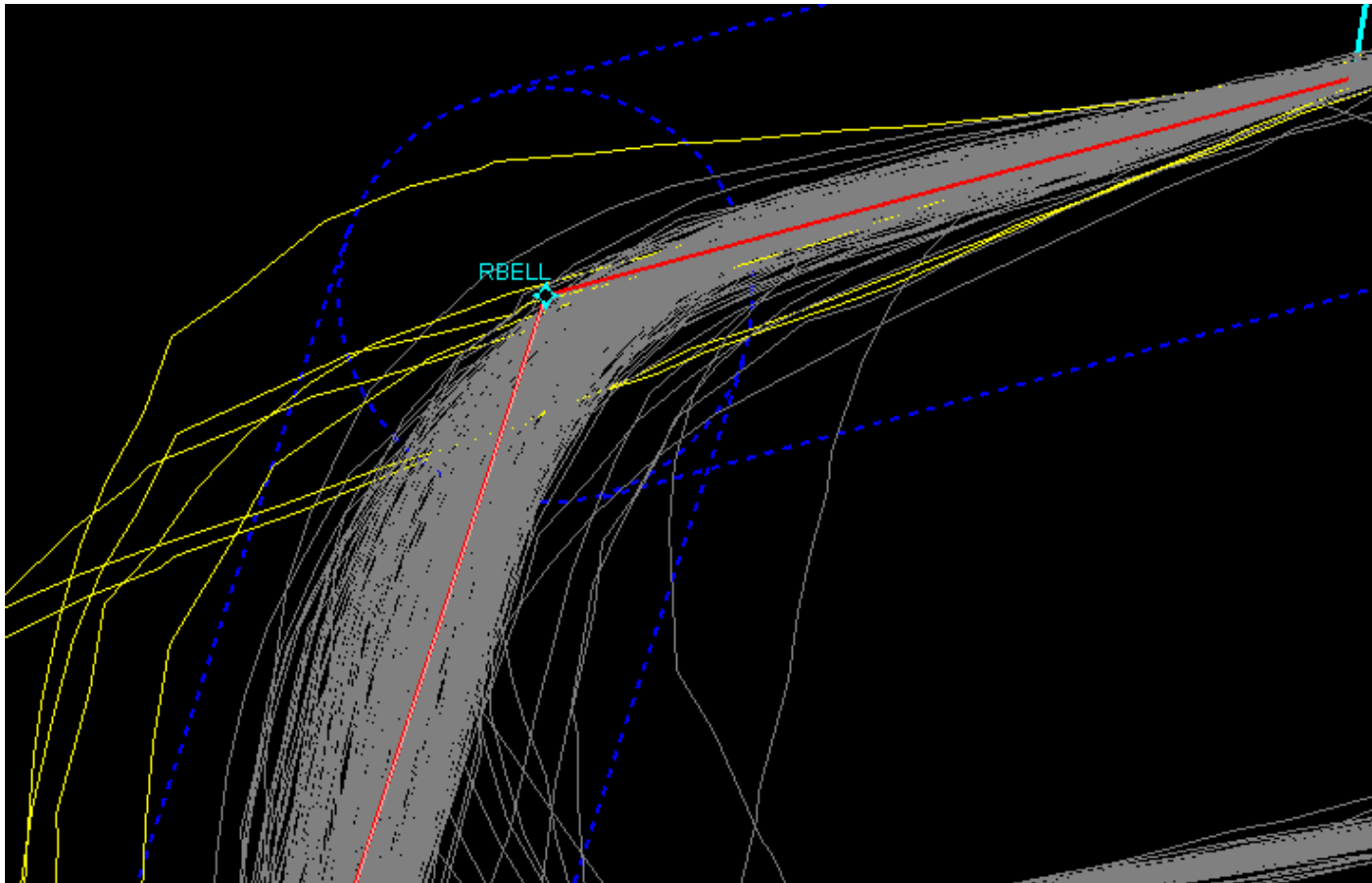




# Lessons Learned

## Turn Anticipation:

variable for ambient conditions, altitude, angle of turn, phase of flight, avionics, and aircraft





# Impact of Turn Performance RNAV 5 in en route without FRT

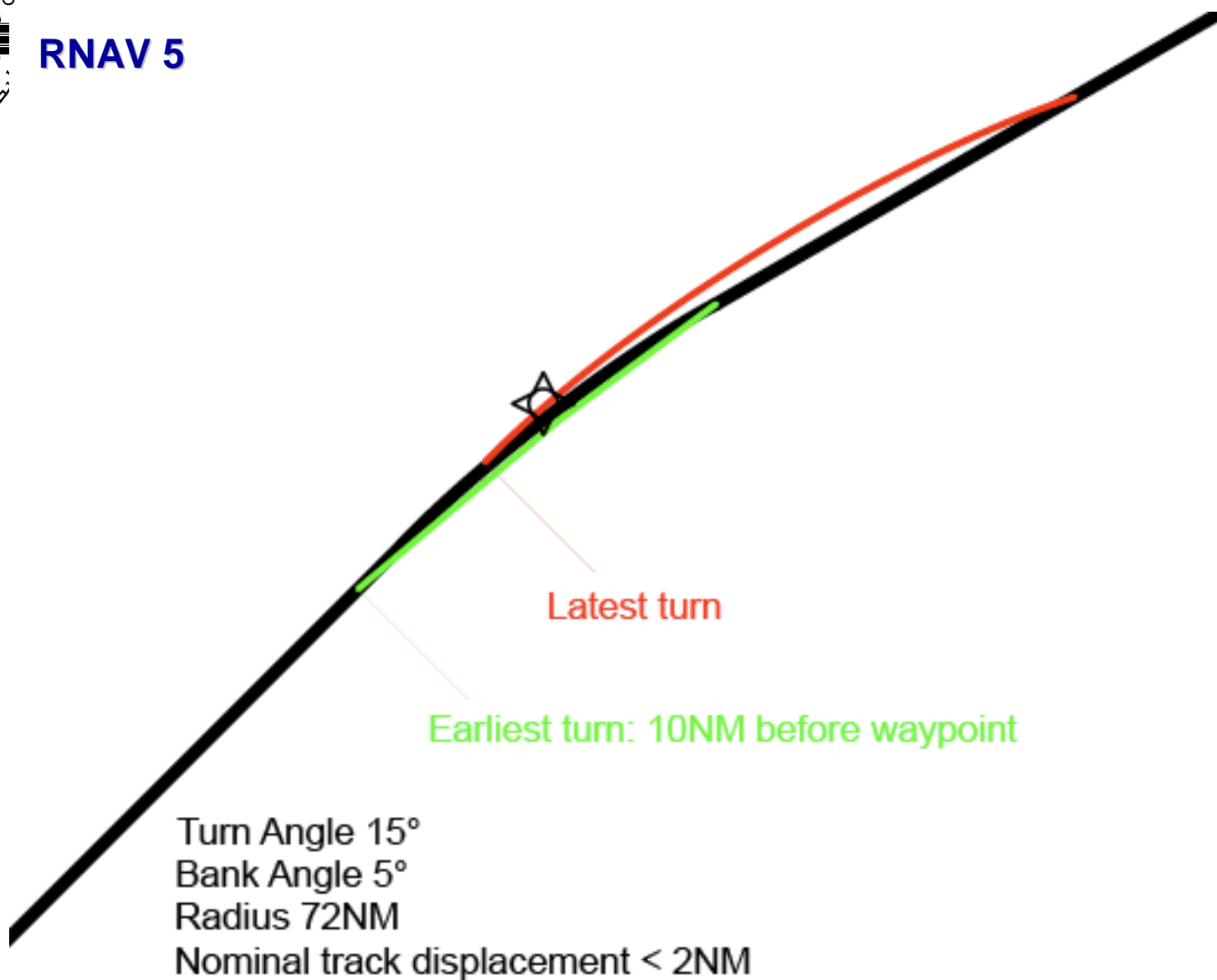
## Assumptions:

- FL340;
- 655kts ground speed (includes wind);
- ISA+10
- Minimum bank angle applied (5°) within max turn initiation distance of 20NM from waypoint
- Assumes a  $\pm 2.5$  NM along track error (B-RNAV with GNSS)
- Assumes a fly-by turn at the waypoint (B-RNAV also allows fly-over although few aircraft systems expected to employ it)
- This is just the nominal track and takes no account of across track error.
- Suggest adding route spacing value and including VOR fly-over figures for track on inside of turn

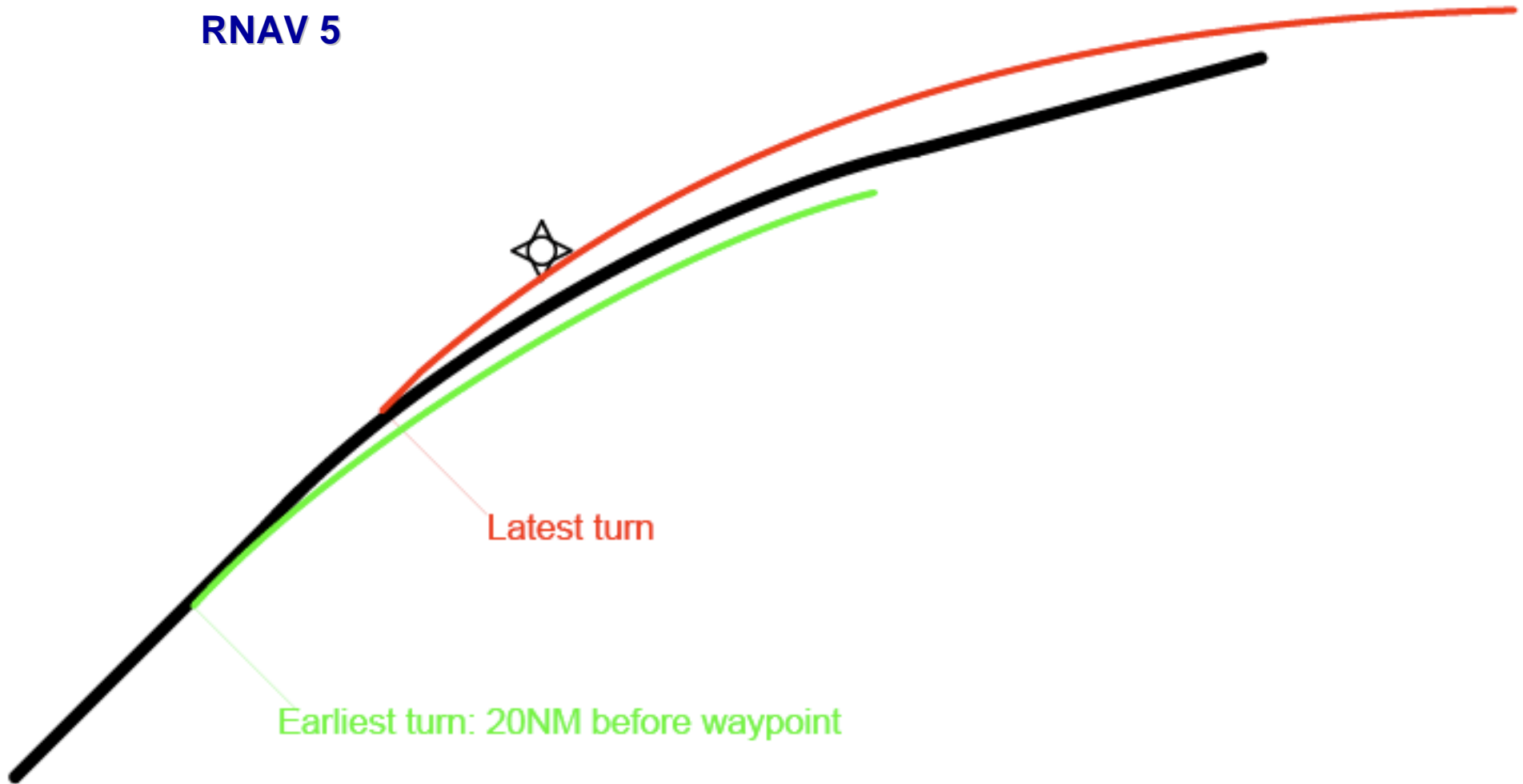




# RNAV 5

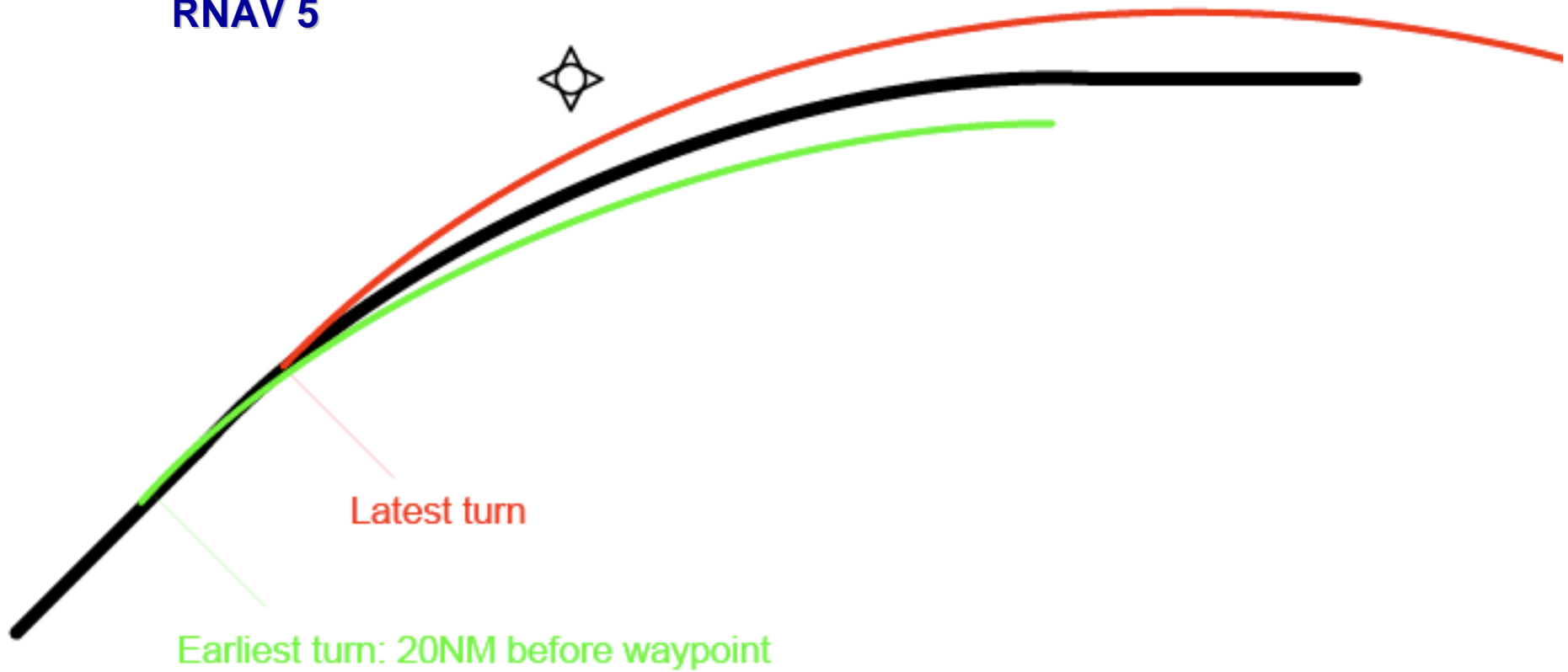


# RNAV 5



Turn Angle 30°  
 Bank Angle 5°  
 Radius 72NM  
 Nominal track displacement <3NM inside turn, <2NM outside turn

# RNAV 5



Turn Angle 45°

Bank Angle 8°

Radius 48NM

Nominal track displacement <4.5NM inside turn, <2NM outside turn



# Sample Checklist: Routes and Holds

## Checklist ROUTES & HOLDS (ref. Part C, Ch.5)

### 1. General

- Is there a general consensus on the "geographic" location of a STAR in the flight profile i.e. what is the general approach on where STARS begin and end in relation to the Terminal Airspace?
- Are the STARS in the design to be considered Open or Closed?

### 2. Terminal Routes (ref. Part C 5.4.2)

- Are all Arrival and Departure routes as much as possible laterally segregated?
- Are all Arrival and Departure routes as much as possible vertically segregated as a function of aircraft performance?
- Are all Arrival and Departure routes as much as possible laterally segregated as soon as possible after departure?
- Are the missed approach tracks segregated as much as possible from each other and of terminal departure routes?
- Are all terminal routes consistently connected with the ATS route network?
- Are all terminal routes consistently connected with the ATS route network irrespective of the runway in use?
- Are all terminal routes compatible with routes in adjacent terminal airspaces (where applicable)?
- Are all terminal routes compatible with routes in adjacent terminal airspaces (where applicable) irrespective of the runway in use?
- Is the impact of a change of the runway in use on the operational complexity to the terminal route structure as minimal as possible?
- Are the terminal routes merged progressively as they approach the terminal airspace?

### 3. Holding Areas (ref. Part C 5.4.3)

- Are the holding patterns, serving a terminal airspace, located either at an entry point or outside the terminal area?
- Are the locations of the holding patterns as such that they create minimum operational complexity for both En-route and terminal airspace and where applicable for adjacent terminal airspaces?
- Do the locations of the holding patterns remain constant irrespective of the runway in use?
- Are the inbound tracks of the holding patterns closely aligned with the subsequent arrival routes?



# QUESTIONS?

- Develop STARs/SIDs/HOLDs
- 2 hrs
- Both teams present results and provide rationale

