Design Airspace
(Routes, Approaches and Holds)

Module 11 – Activity 7

European Airspace Concept Workshops
for PBN Implementation

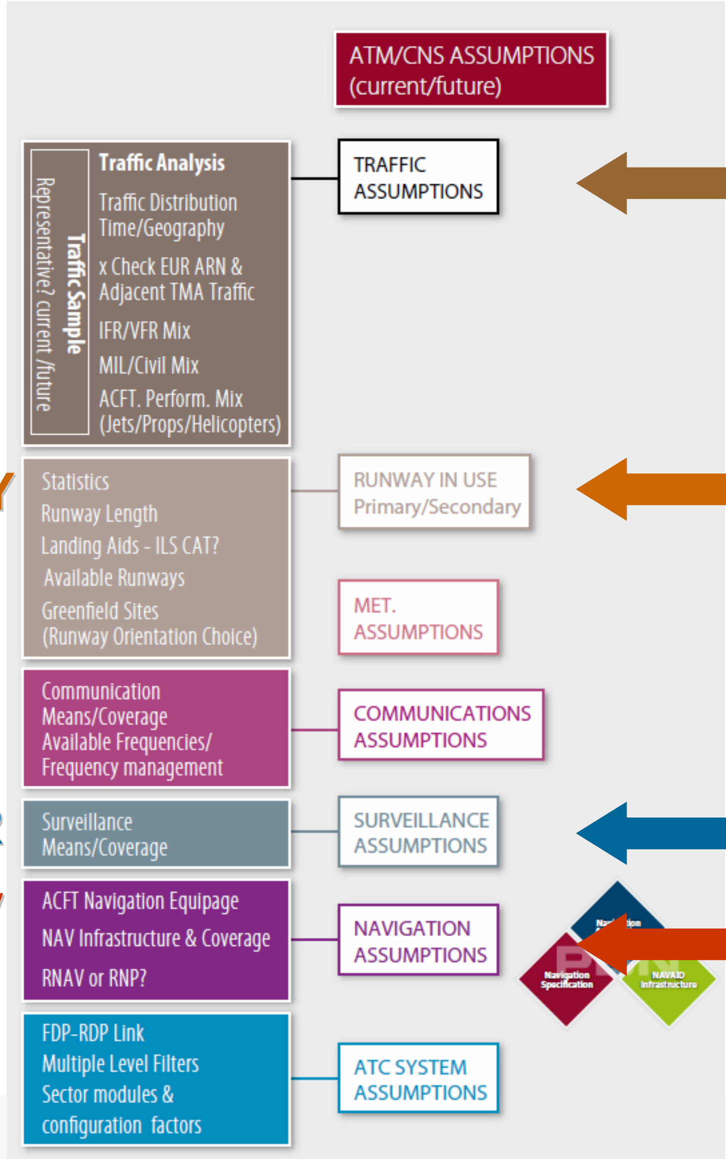
Design in Context

TFC

RWY

SUR

NAV



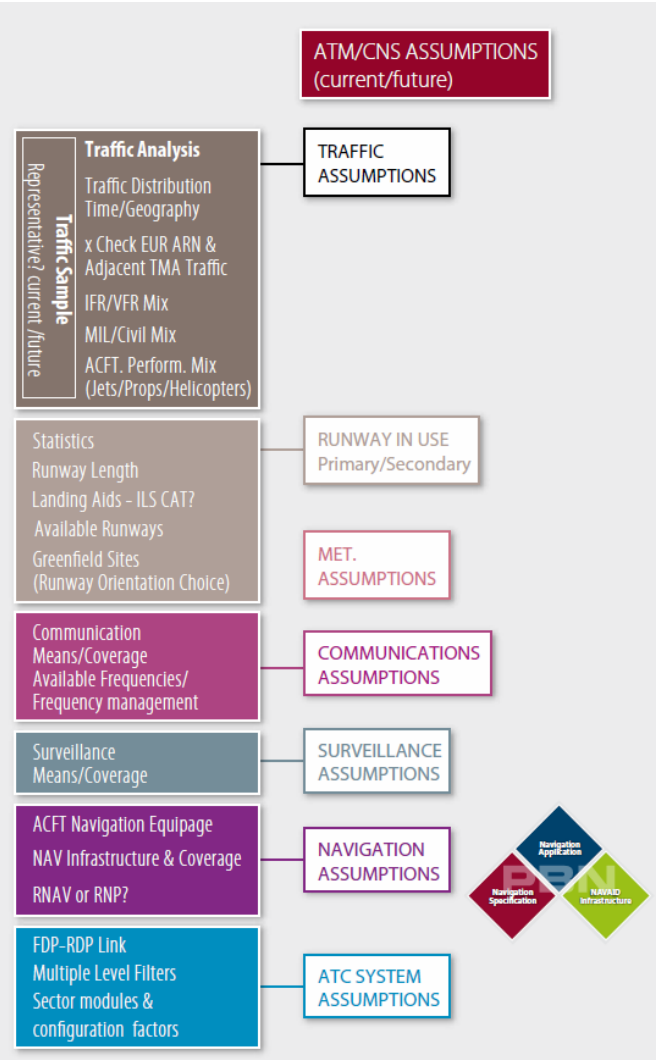
Where does the traffic come from? And when?

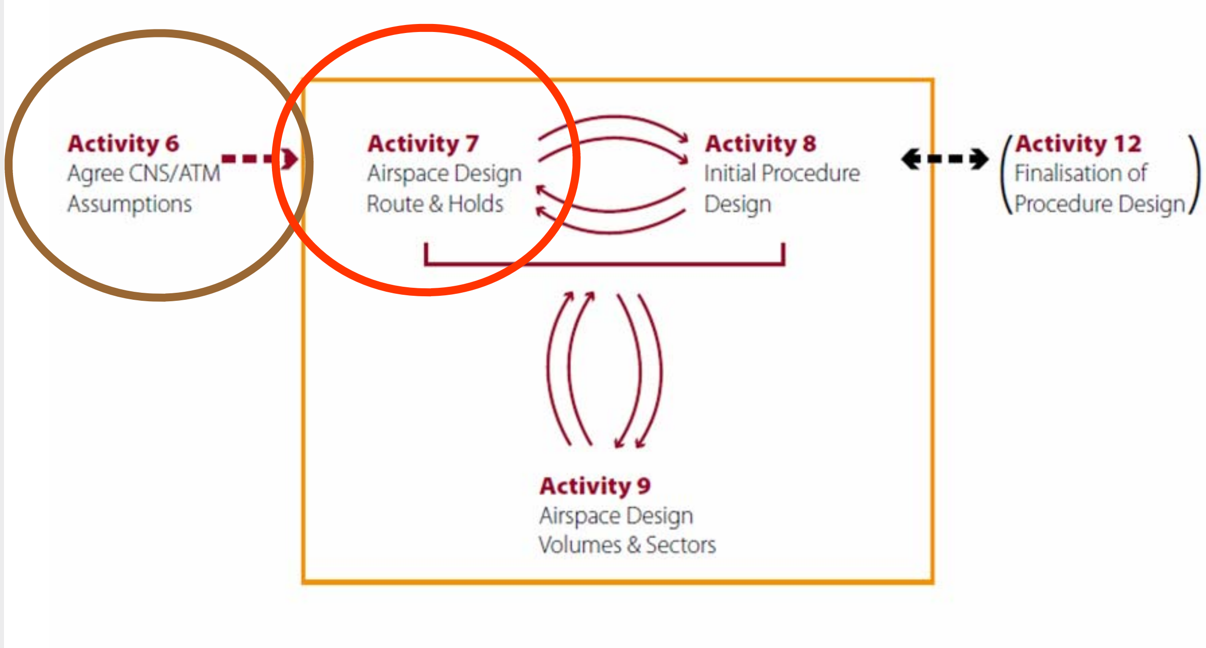
Which Runway(s)?

Is there Radar?

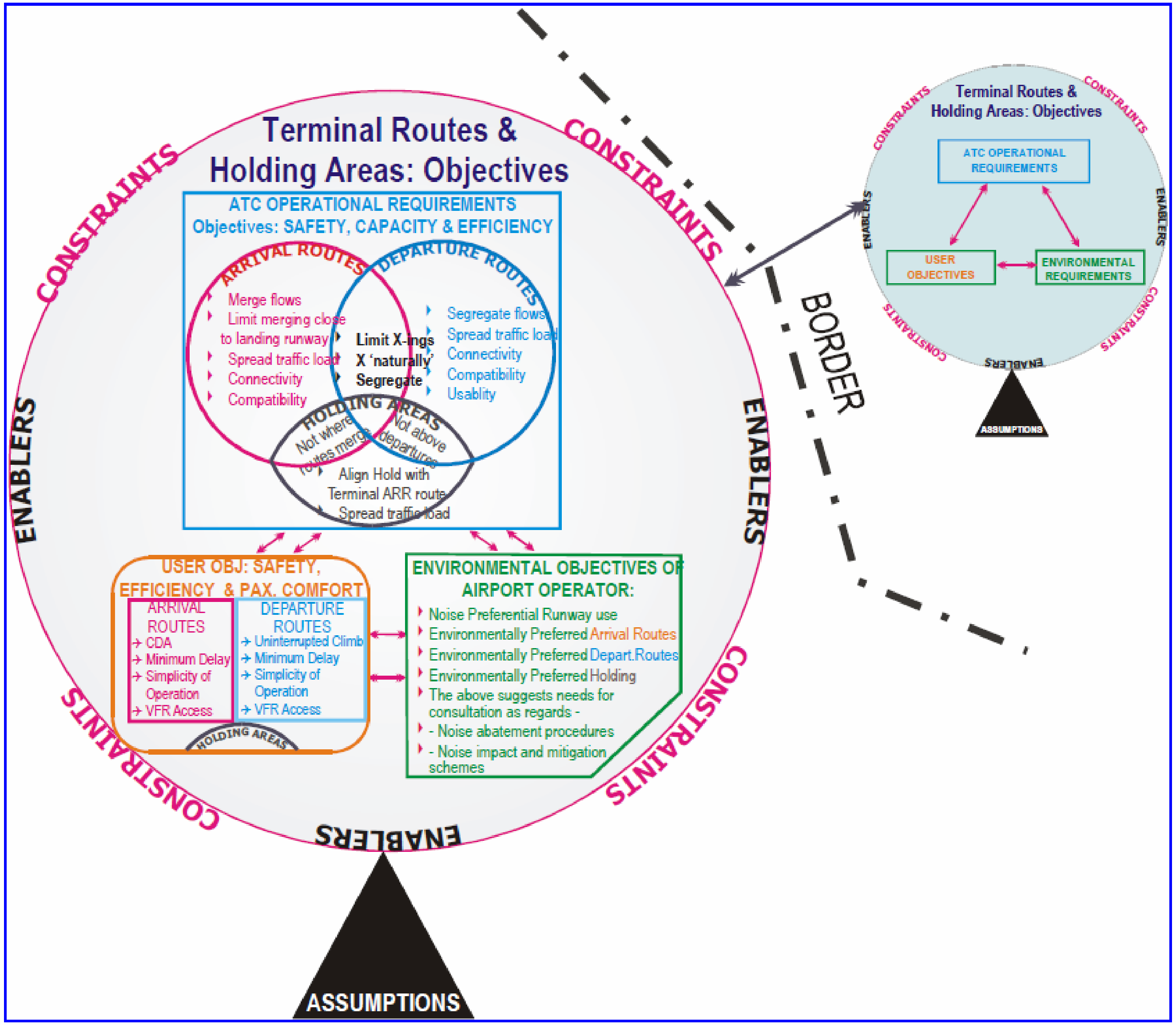
Which equipage? How many aircraft ?

Design in Context

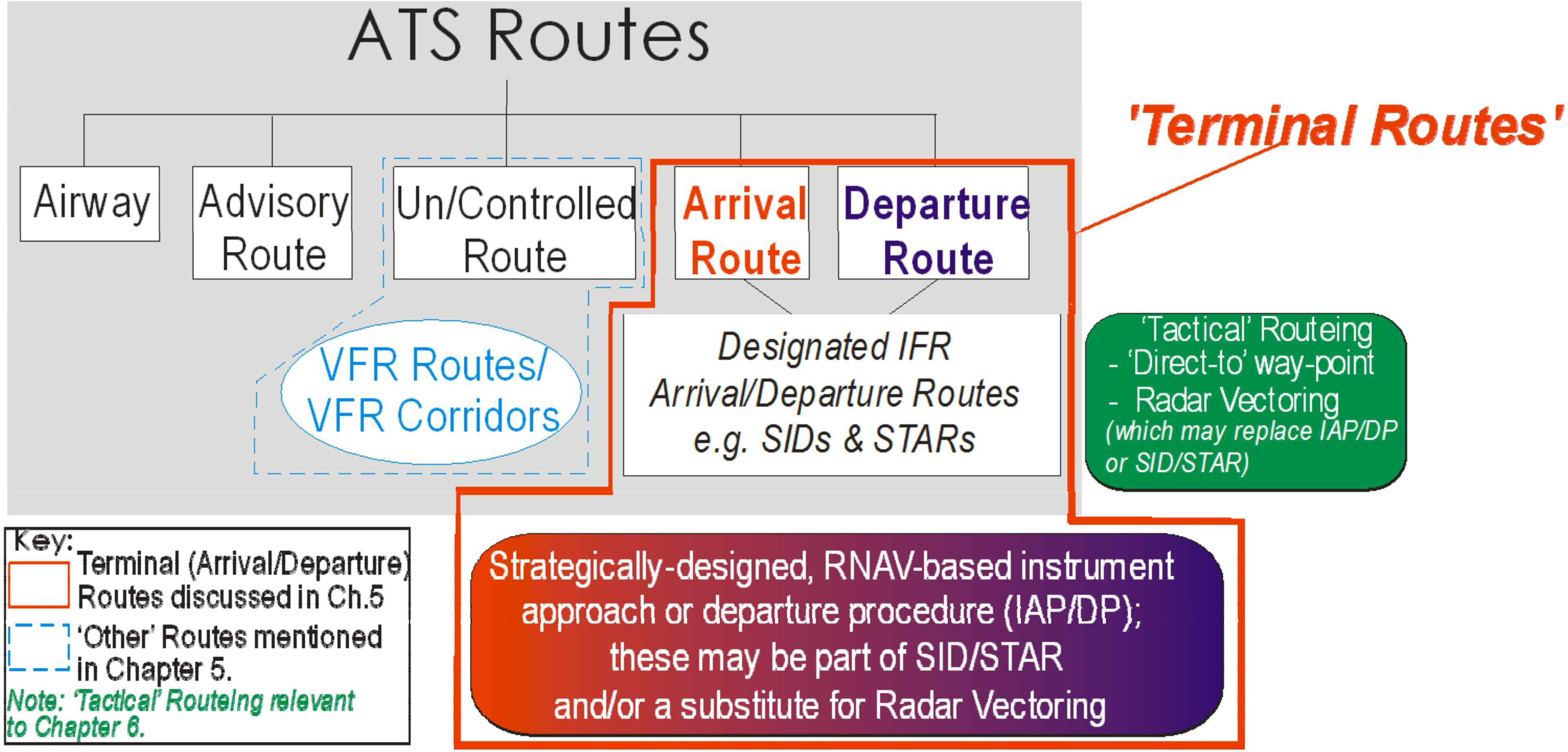




Competing Interests



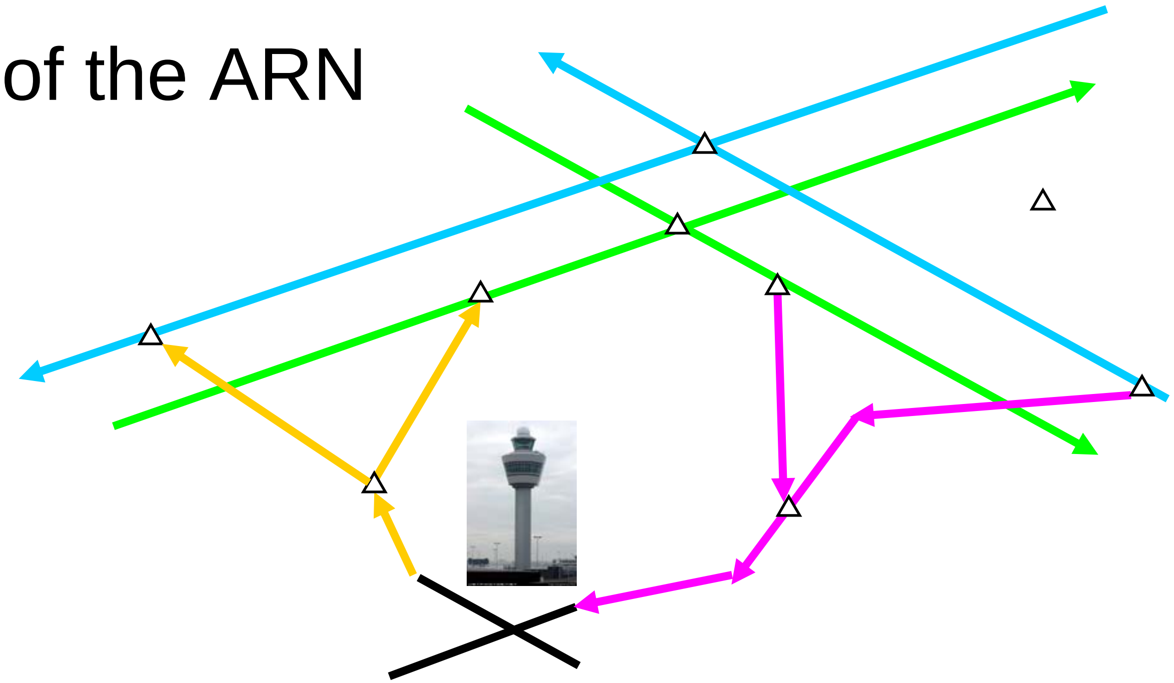
Routes


ATS Routes
Airway
Advisory Route
Un/Controlled Route
Arrival Route
Departure Route
'Terminal Routes'
VFR Routes/ VFR Corridors
Designated IFR Arrival/Departure Routes e.g. SIDs & STARs
'Tactical' Routeing
- 'Direct-to' way-point
- Radar Vectoring
(which may replace IAP/DP or SID/STAR)
Strategically-designed, RNAV-based instrument approach or departure procedure (IAP/DP); these may be part of SID/STAR and/or a substitute for Radar Vectoring
Key:
Terminal (Arrival/Departure) Routes discussed in Ch.5
'Other' Routes mentioned in Chapter 5.
Note: 'Tactical' Routeing relevant to Chapter 6.

Terminal Routes

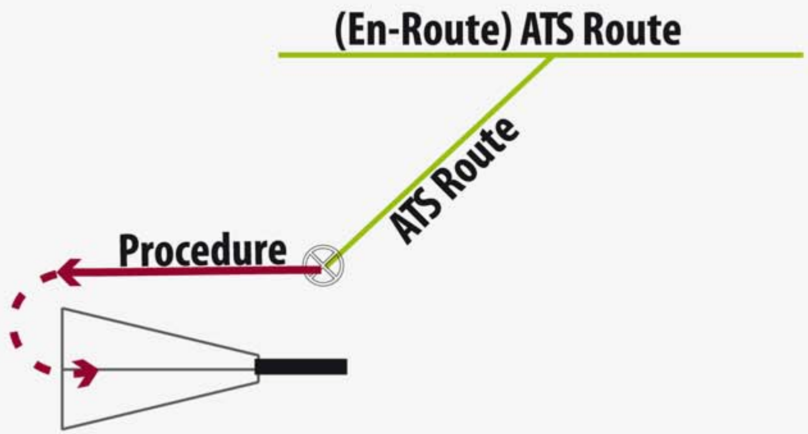
Routes in Terminal Airspace link…

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



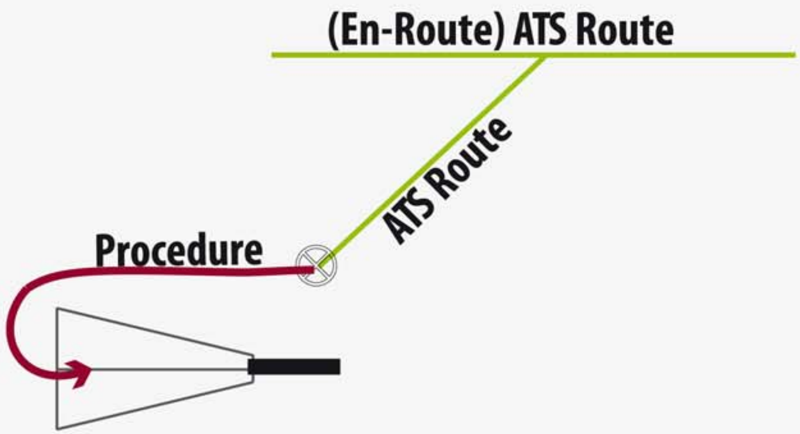
Different Kinds of IFP

Open Path



- - - ➔ Tactical Vectors provided by ATC

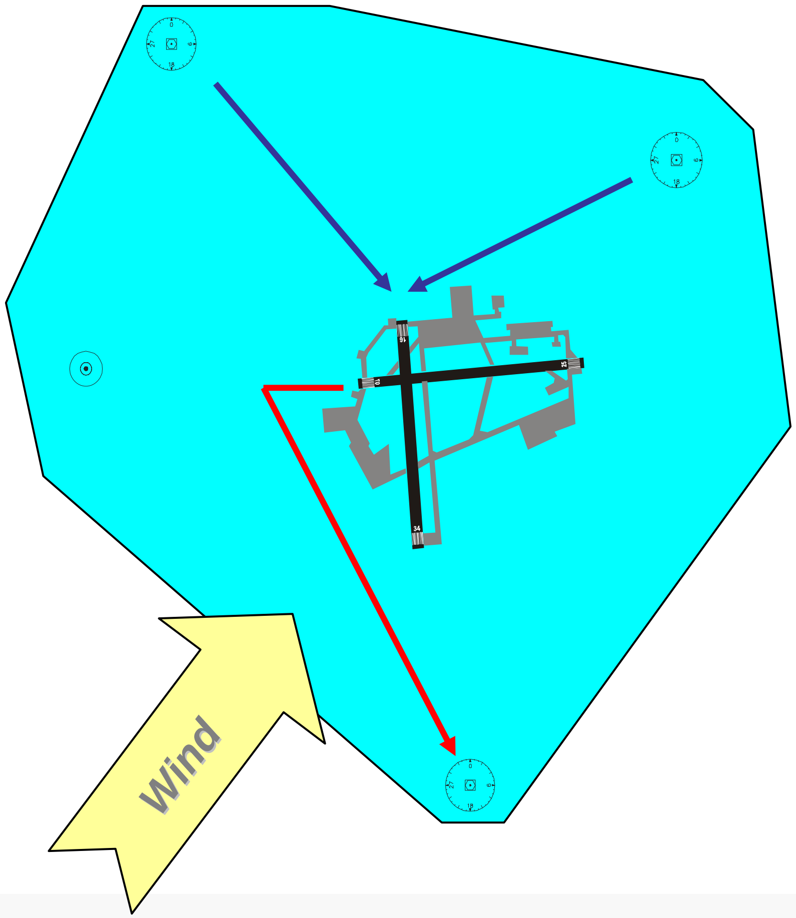
Closed Path



- - - ➔ Tactical Vectors provided by ATC

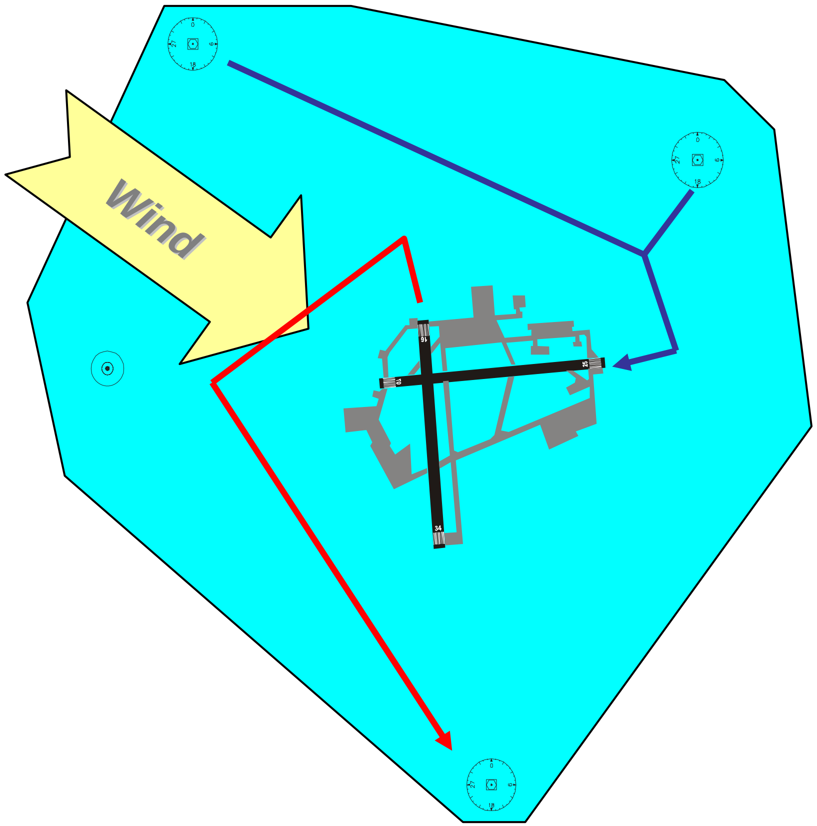
SID/STAR Dependence on RWY (1)

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



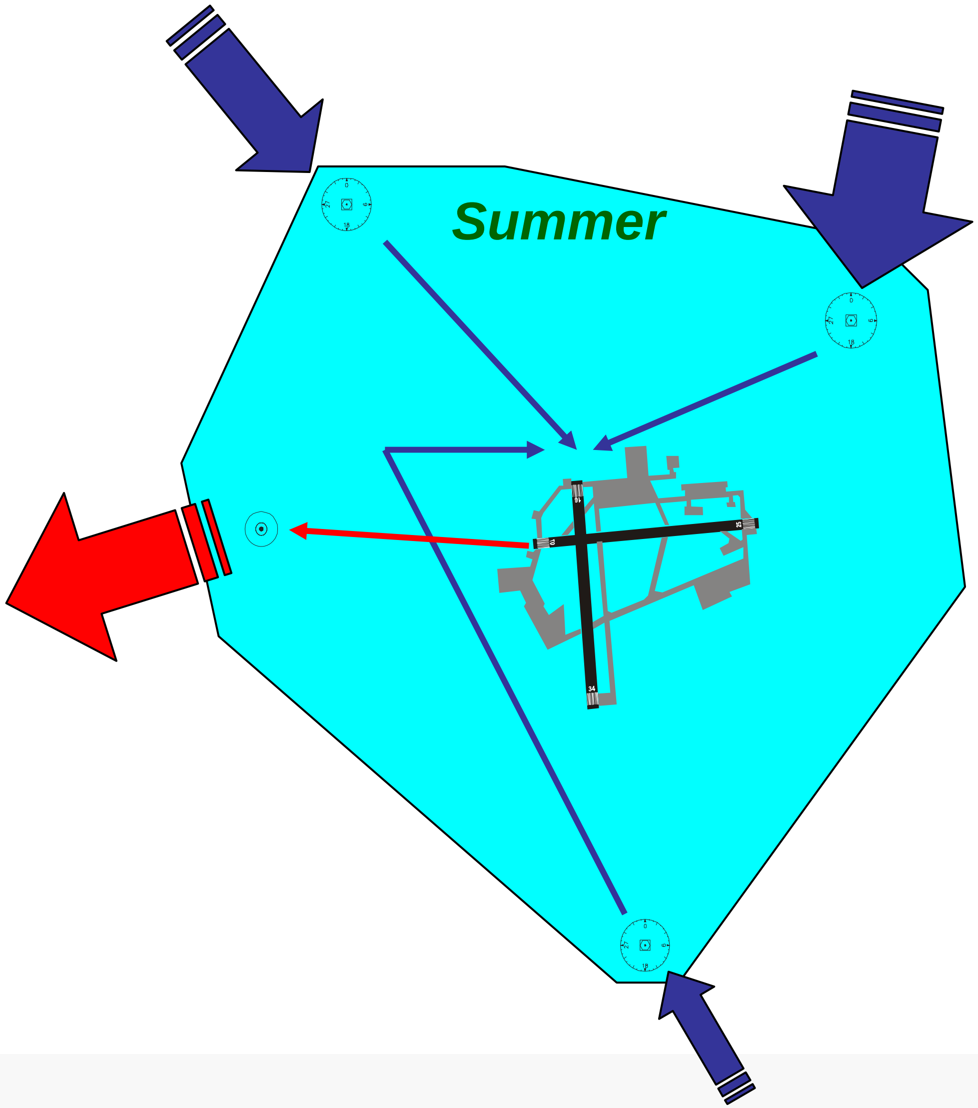
SID/STAR Dependence on RWY (2)

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



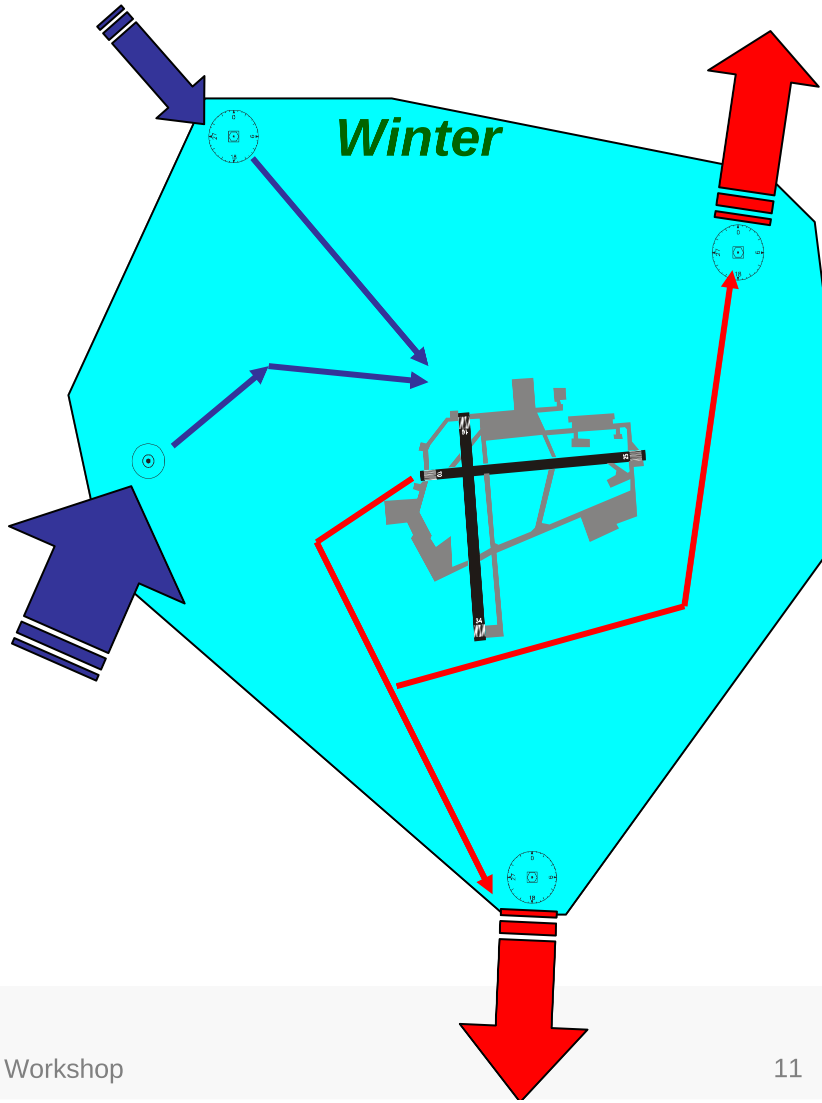
Seasonal Effect (1)

- Demand and route placement can vary for different seasons



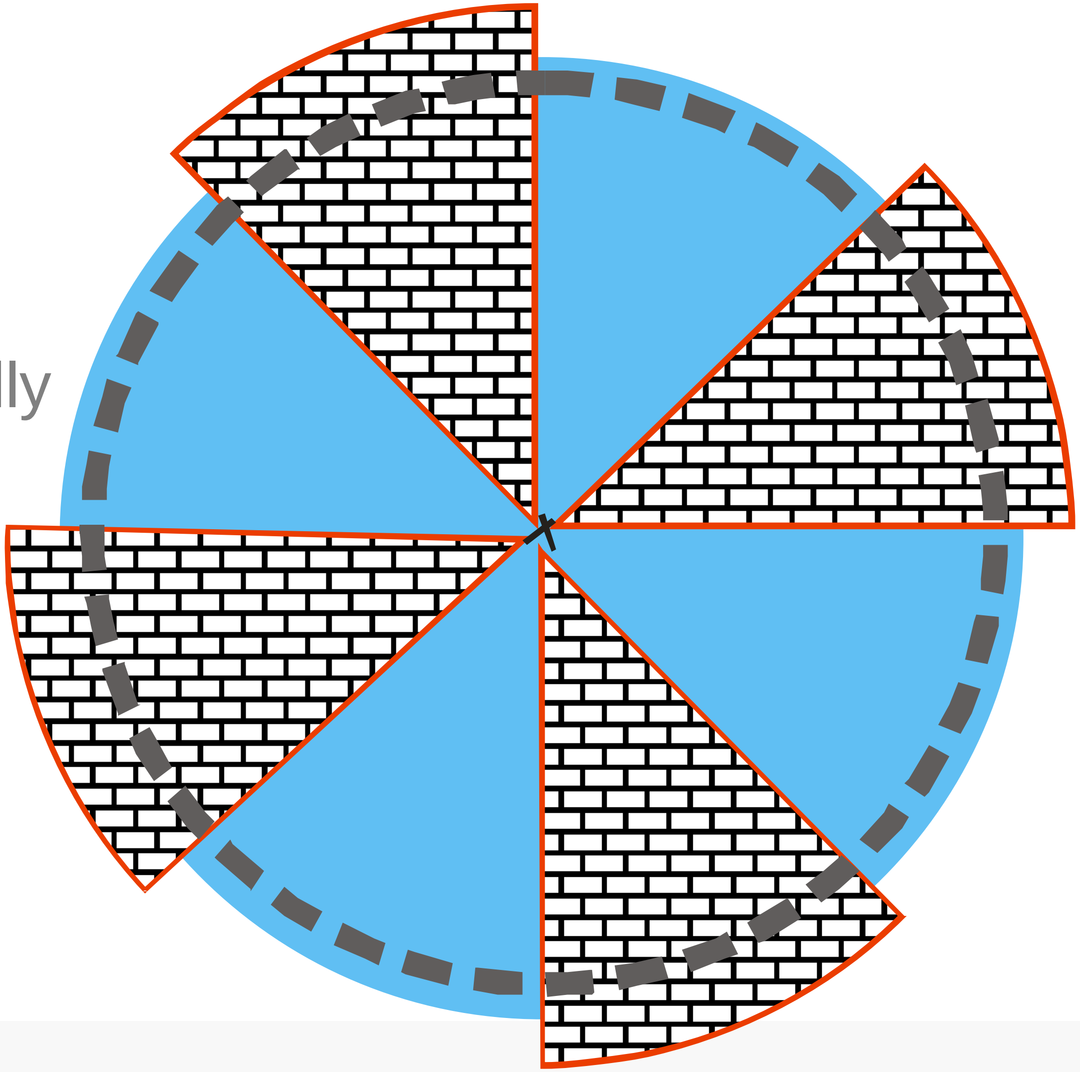
Seasonal Effect (2)

- Different set of SIDs and STARs per season



Good Design Practice

Segregate Arrivals from
Departures
Both Laterally and Vertically

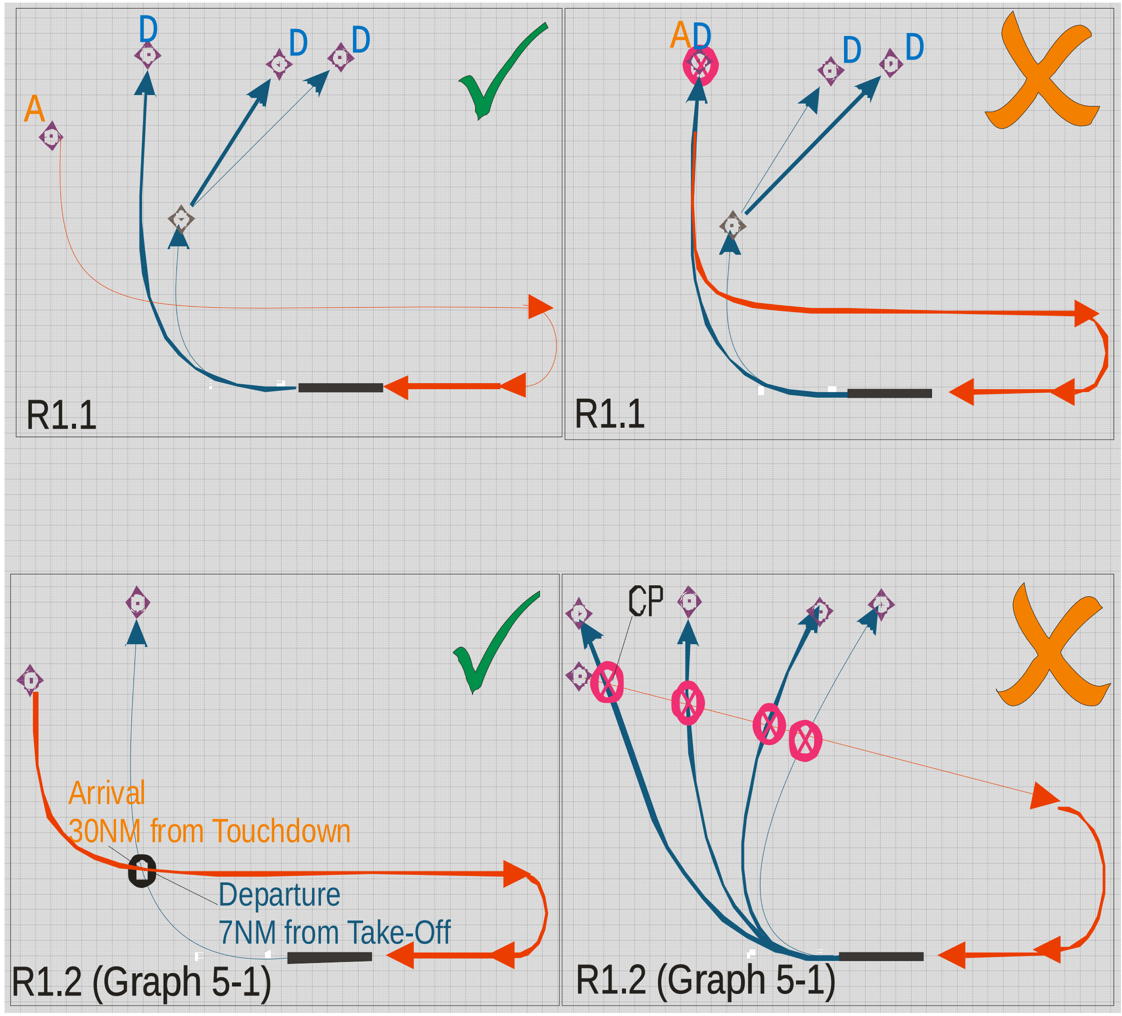


Good Design Practice

Segregation of Routes and Entry/Exit point

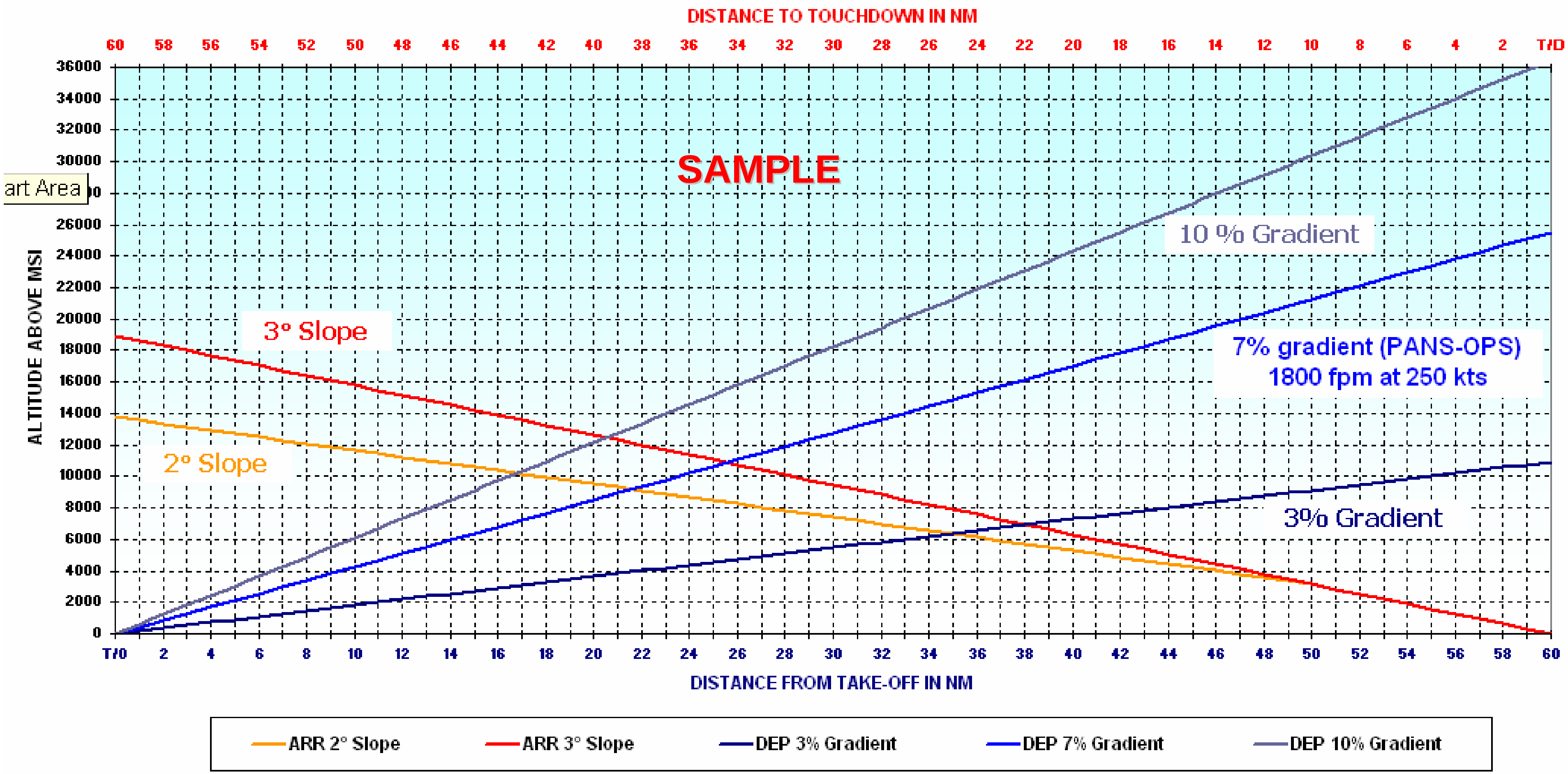
Minimise the number of crossing points

Plan for vertical separation



Good Design Practice

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

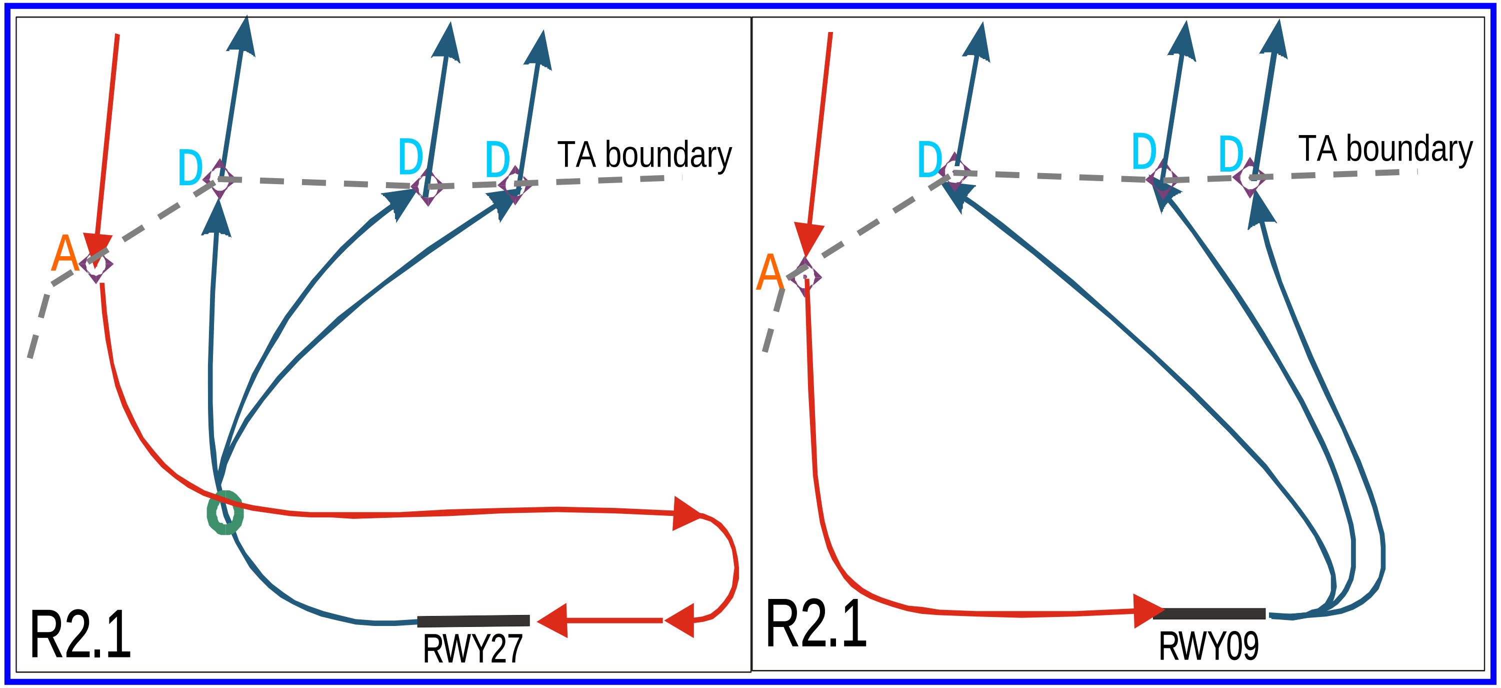


SAMPLE CHART ONLY: SIMILAR GRAPHS SHOULD BE DEVELOPED FOR EACH IMPLEMENTATION DEPENDING ON FLEET

Good Design Practice

Fix the same Exit/Entry points for different RWY configurations

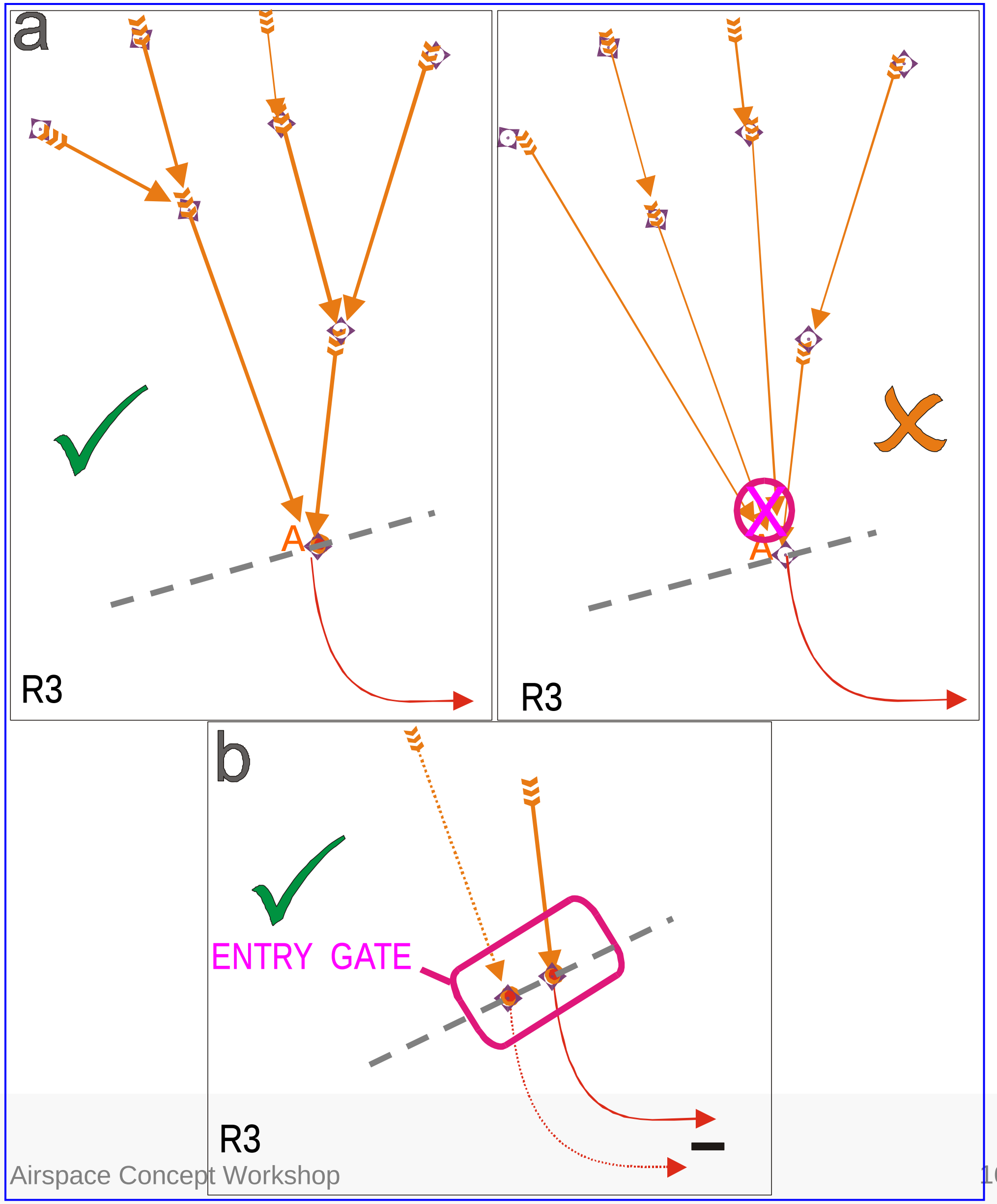
(handoff between ACC and APP should not change with RWY configuration)



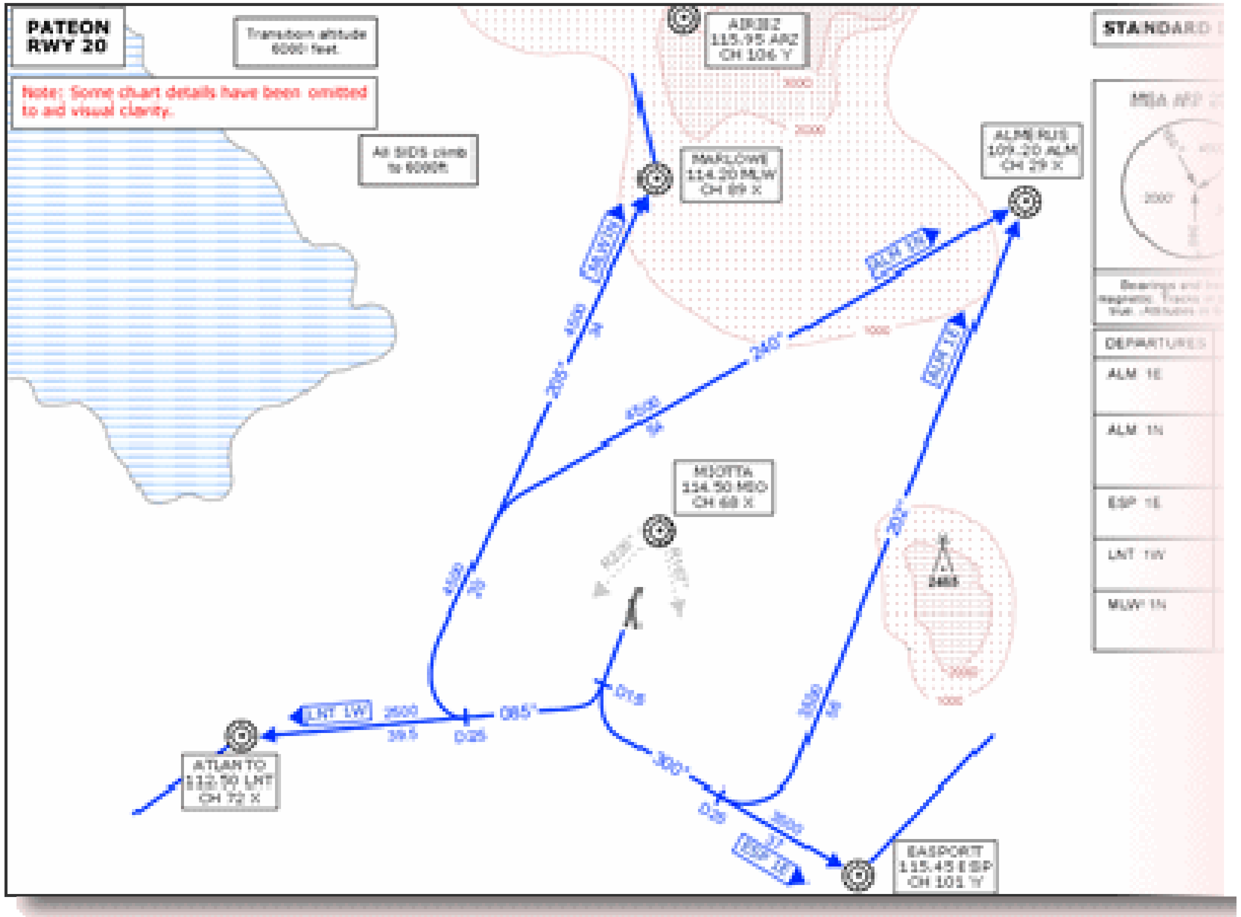
Good Design Practice

- Gradually converge inbound flows

- Group similar inbound flows in Entry Gates



Conventional SID



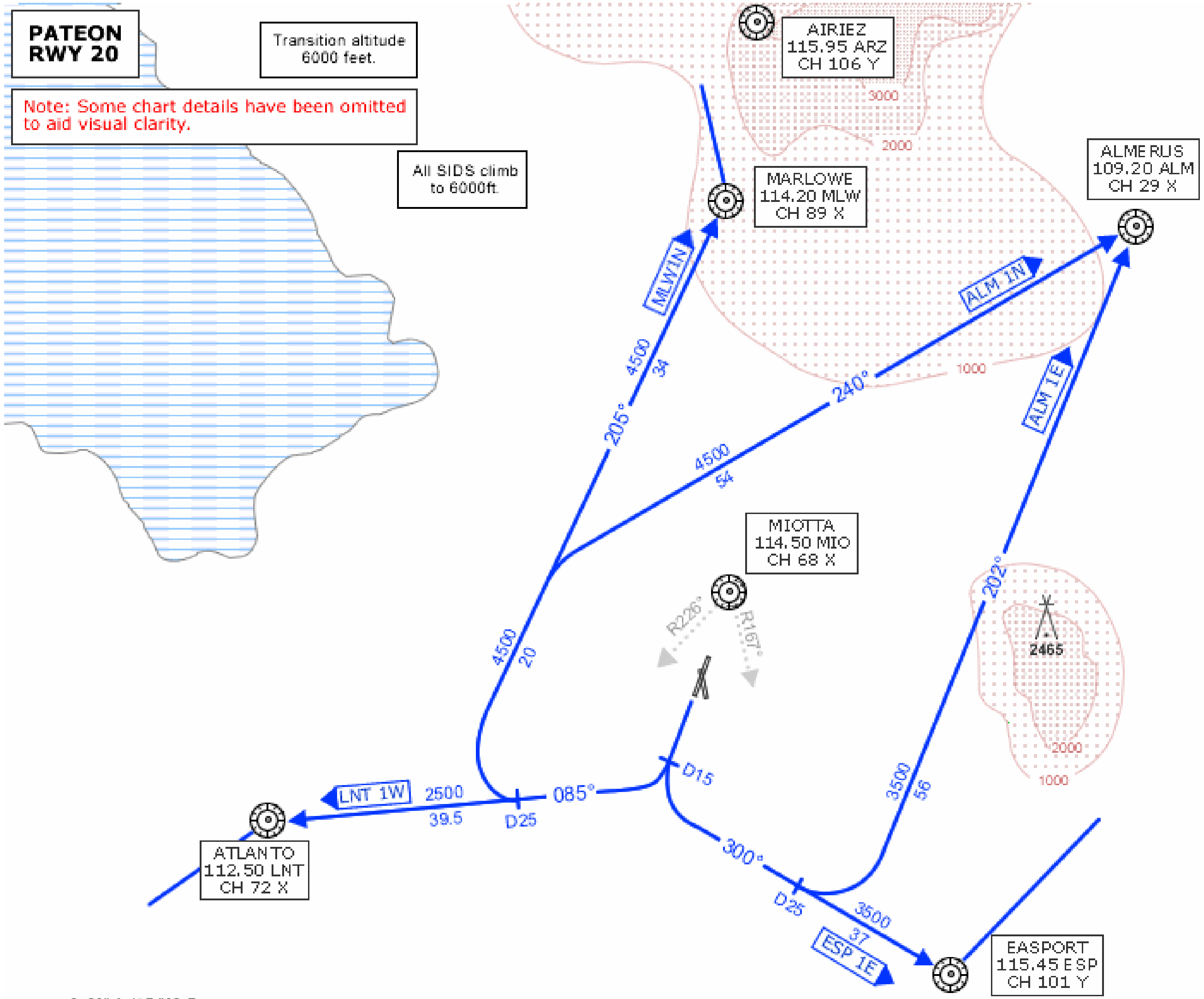
Limitations:

- Inflexible SID/STAR design:
  - constraint to airspace optimisation
- Track accuracy performance cannot be stipulated
- Inconsistent track-keeping performance
- Require the use of VOR/DME and/or NDB

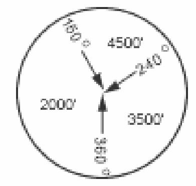
Advantages:

- All aircraft operating under IFR are suitably equipped
- Defined by NAVAIDs

The Benefits of RNAV



STANDARD INSTRUMENT DEPARTURES

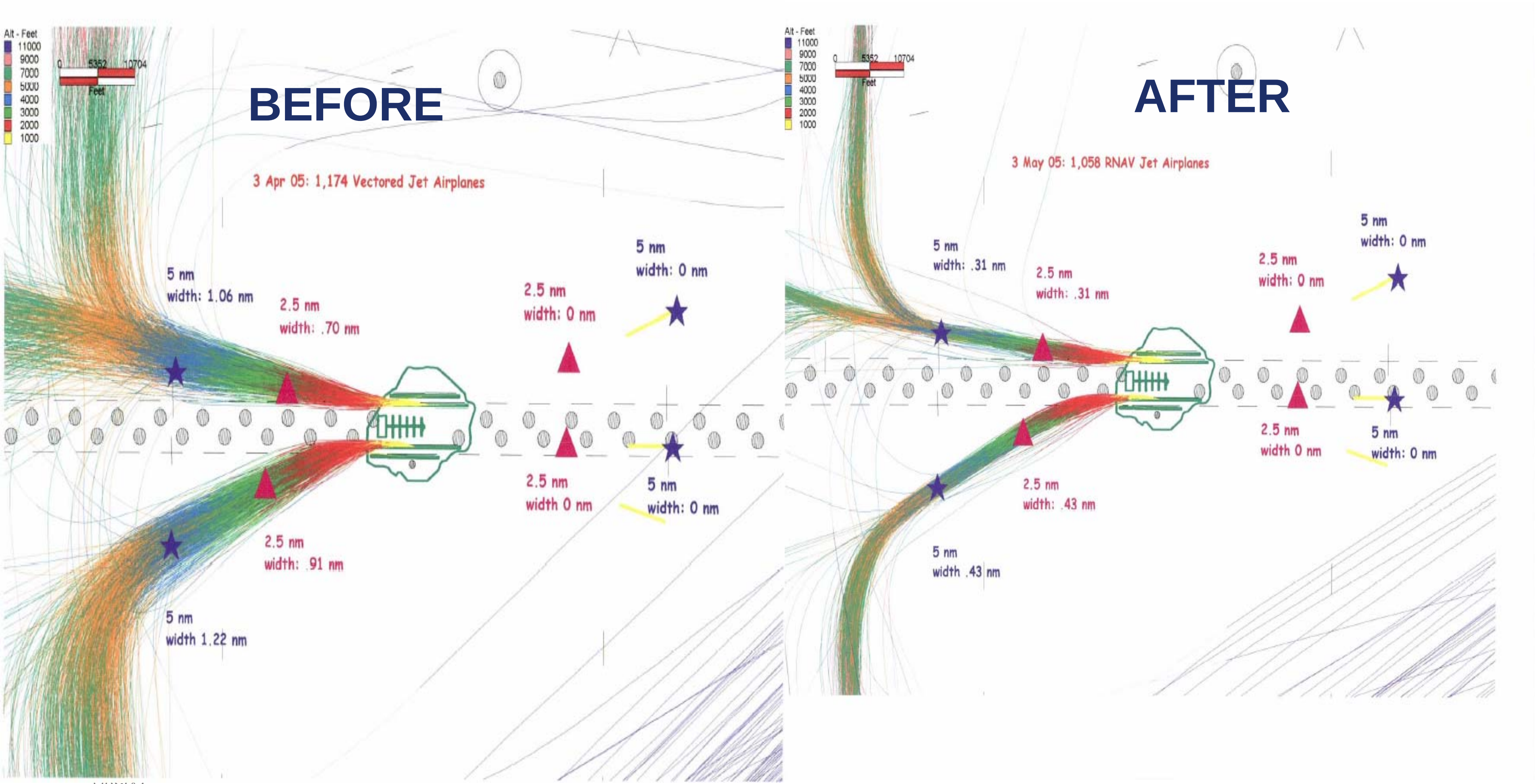


Bearings and tracks are magnetic. Tracks in brackets are true. Altitudes in feet AMSL.

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'

DEPARTURES	ROUTEING
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.

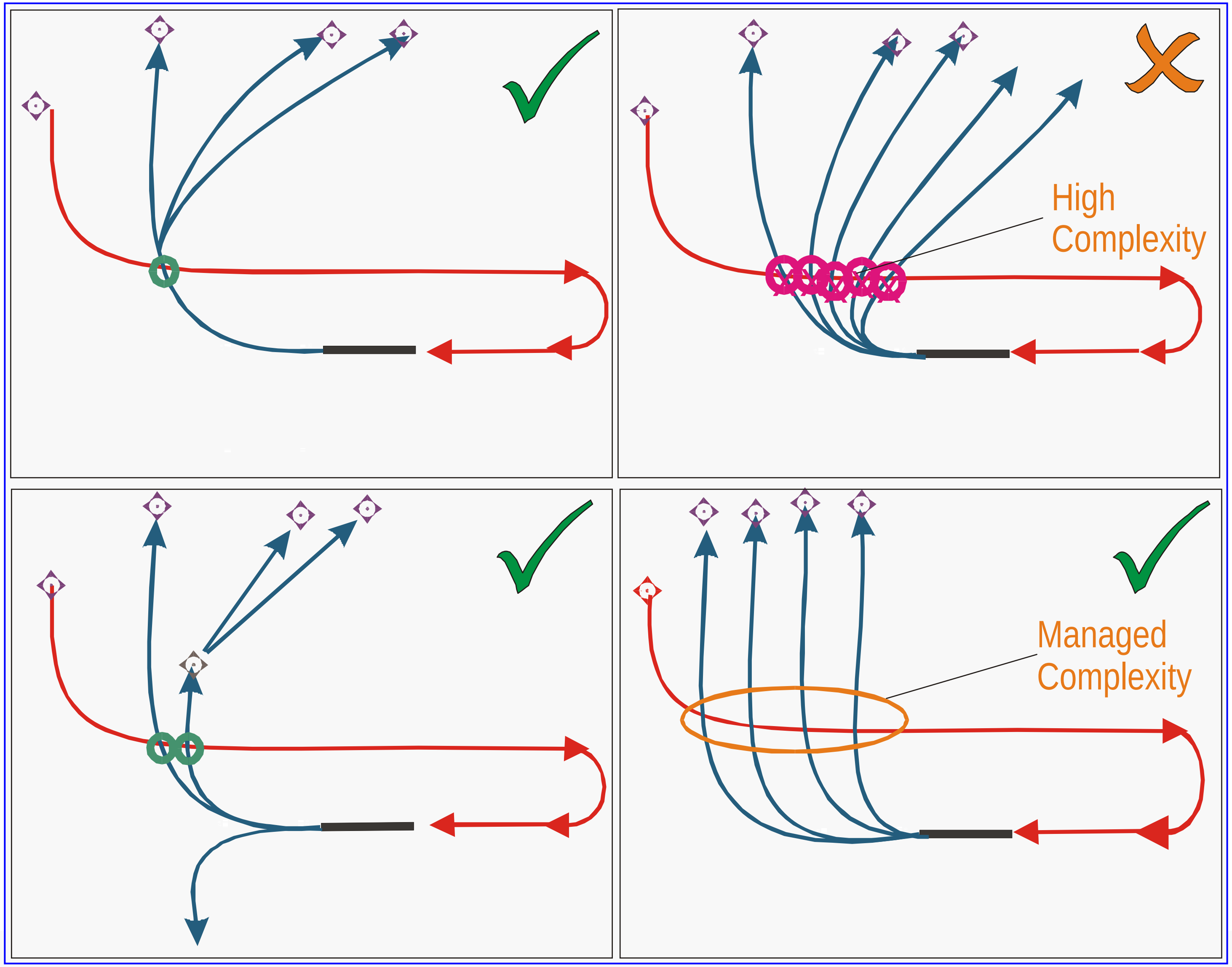
RNAV Departures at Atlanta USA



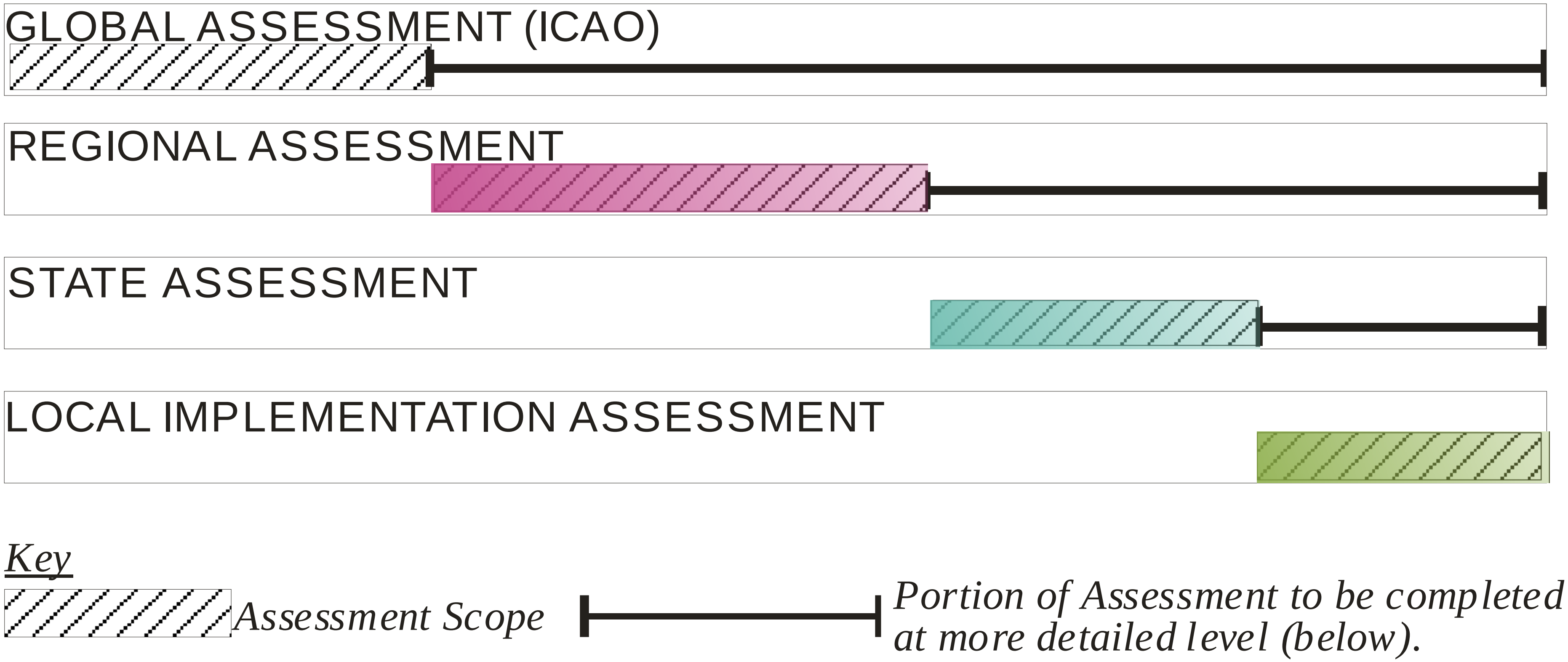
Slide from ICAO PBN Seminar

Good Design Practice

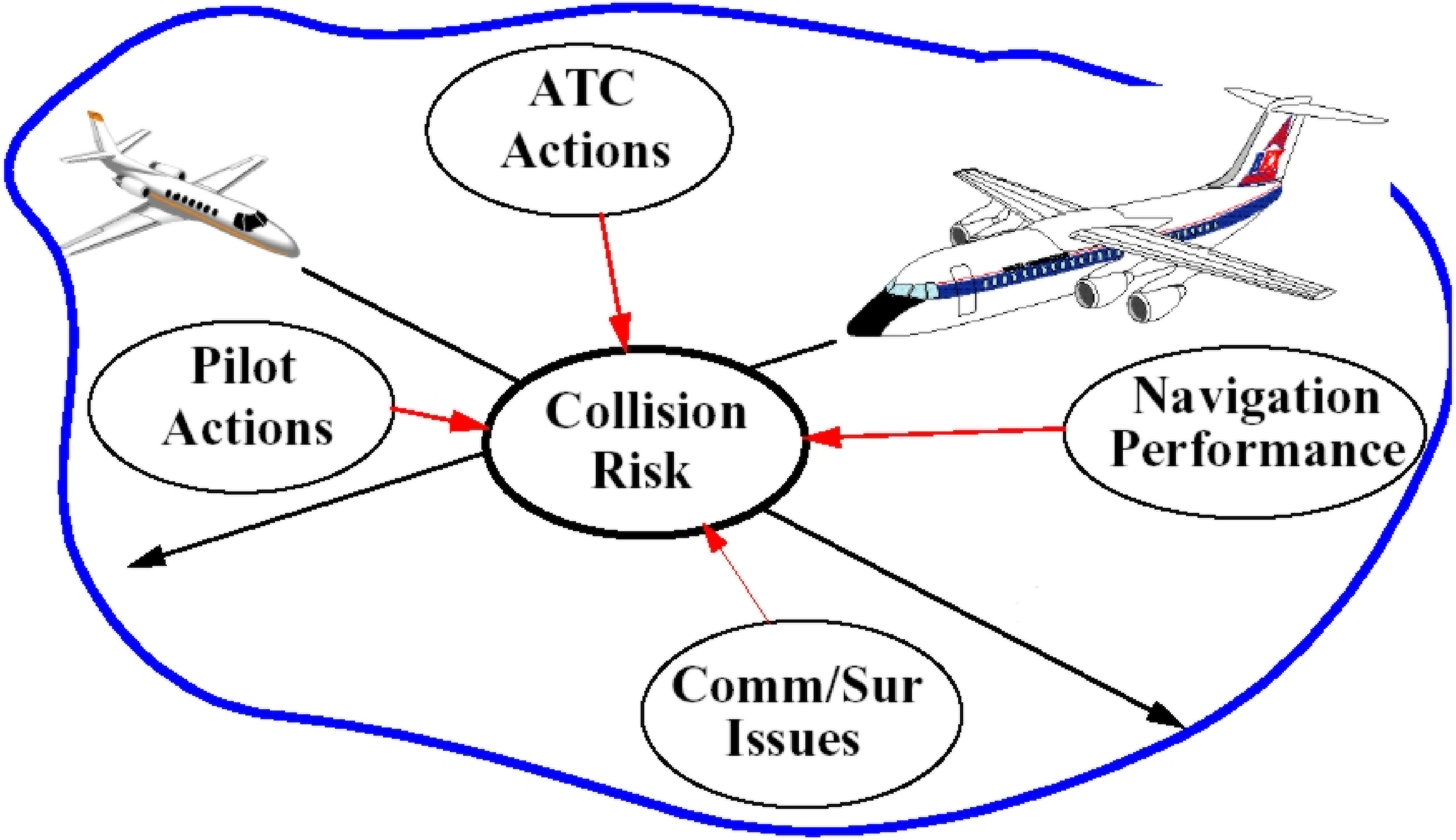
Minimise Crossing Complexity



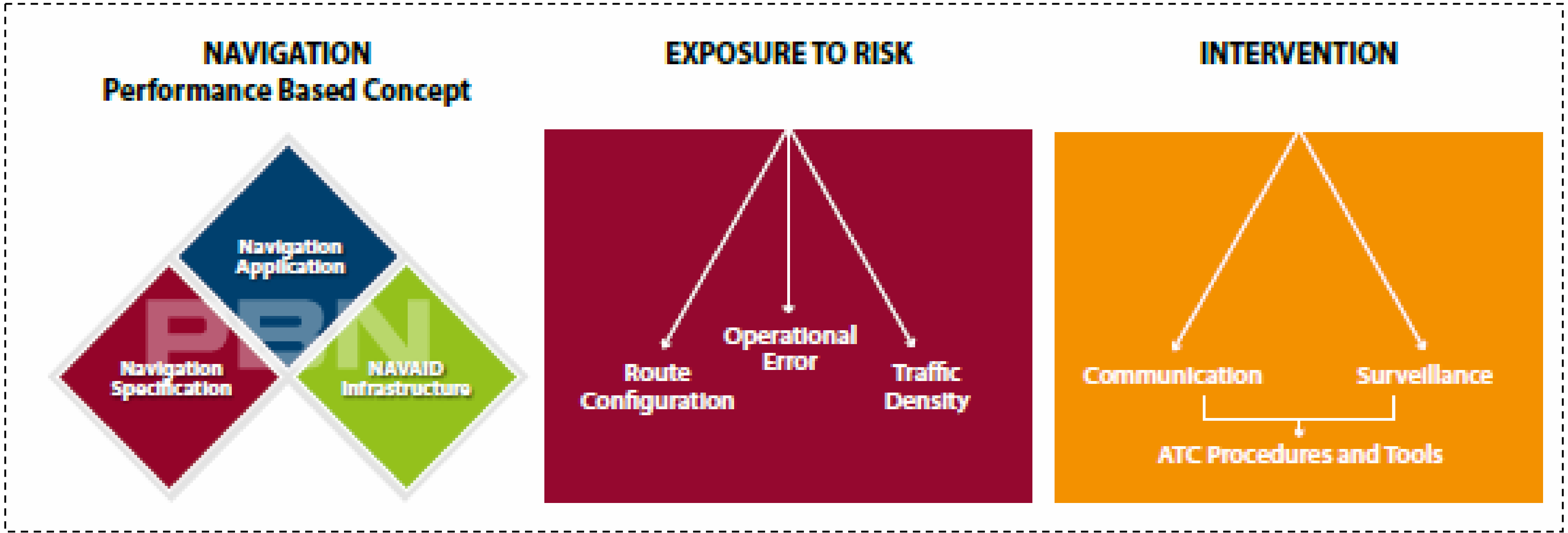
Safety Assessment for Route Spacing



Route Spacing

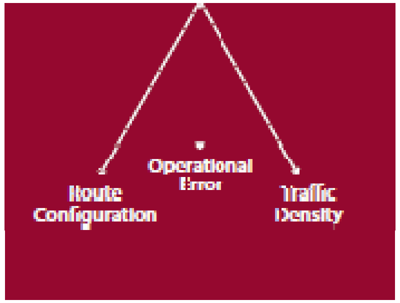


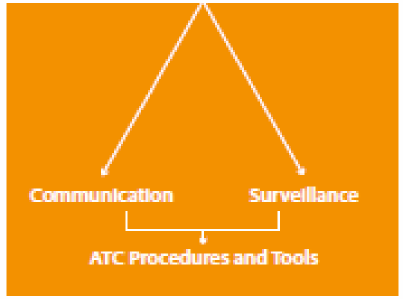
Route Spacing



Generic model used to determine separation and ATS Route spacing

Route Spacing





PBN	NAVIGATION Performance Based Concept	EXPOSURE TO RISK	INTERVENTION
Determination of **separation minima** *(1)* for tactical use *without* ATC Surveillance	✔	✔ (2)	✘
Determination of **separation minima** *(1)* for tactical use *with* ATC Surveillance	✘	✘ (2) & (3)	✔
Determination of **Route Spacing** *without* ATC Surveillance	✔	✔	✘
Determination of **Route Spacing** *with* ATC Surveillance	✔	✔	✔

✔ *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.*

Route Spacing Summary for ECAC 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.

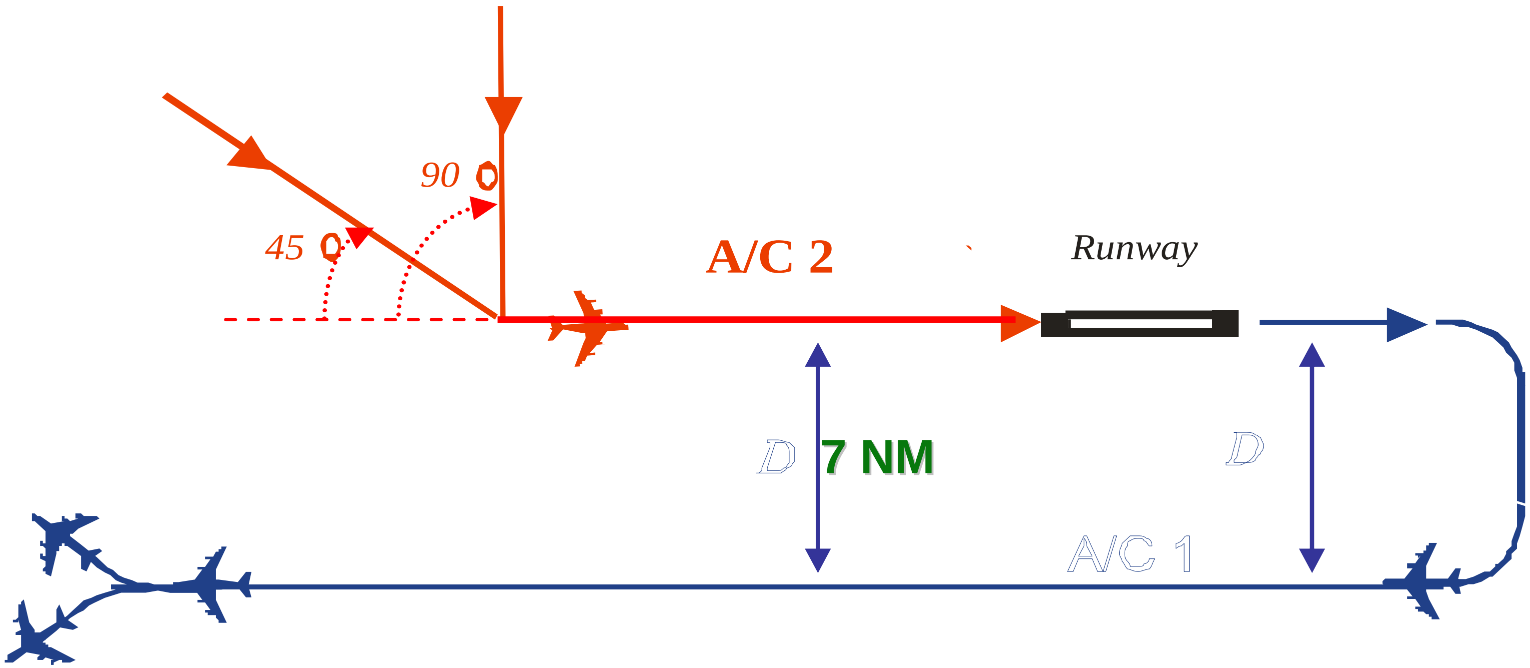
↓Parallel Routes / based on →	Advanced RNP		P-RNAV*		BRNAV
	En Route	Terminal	*En Route*	*Terminal*	*En Route*
Same Direction	7 NM	7 NM	9 NM	8 NM	16.5 NM
Opposite Direction					18 NM
Other					10 -15 NM with increased ATC intervention rates
Spacing on turning segments	As above using FRT en-route and RF for SIDs/STARs		Larger than above because no FRT		Much larger than above because of no automatic leg change

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 traffic characteristics, etc.*

PANS-ATM Route Spacing Procedural Terminal for PBN

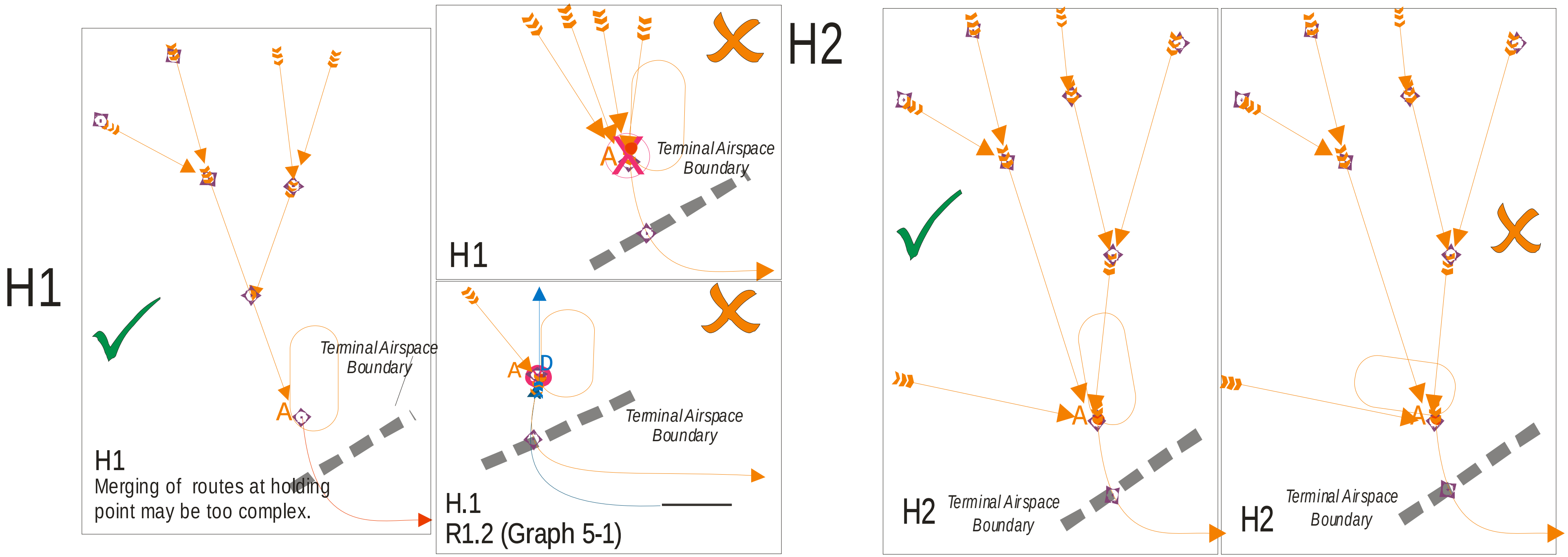
Up to 400 Movements Per day



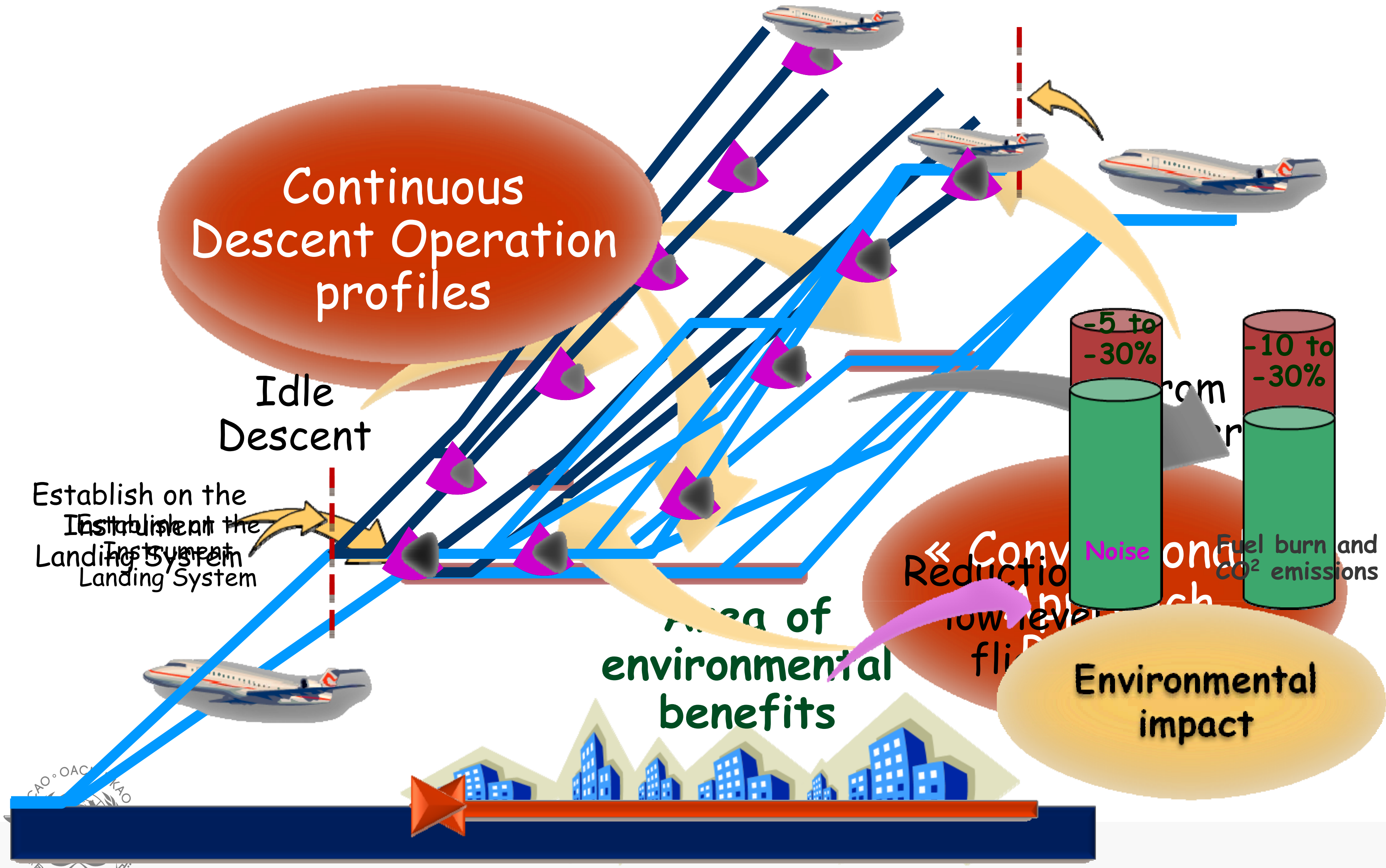
- Good for:
  - RNAV1
  - B-RNP1
  - RNP APCH
  - RNP (AR) APCH

Good Design Practice

Holds



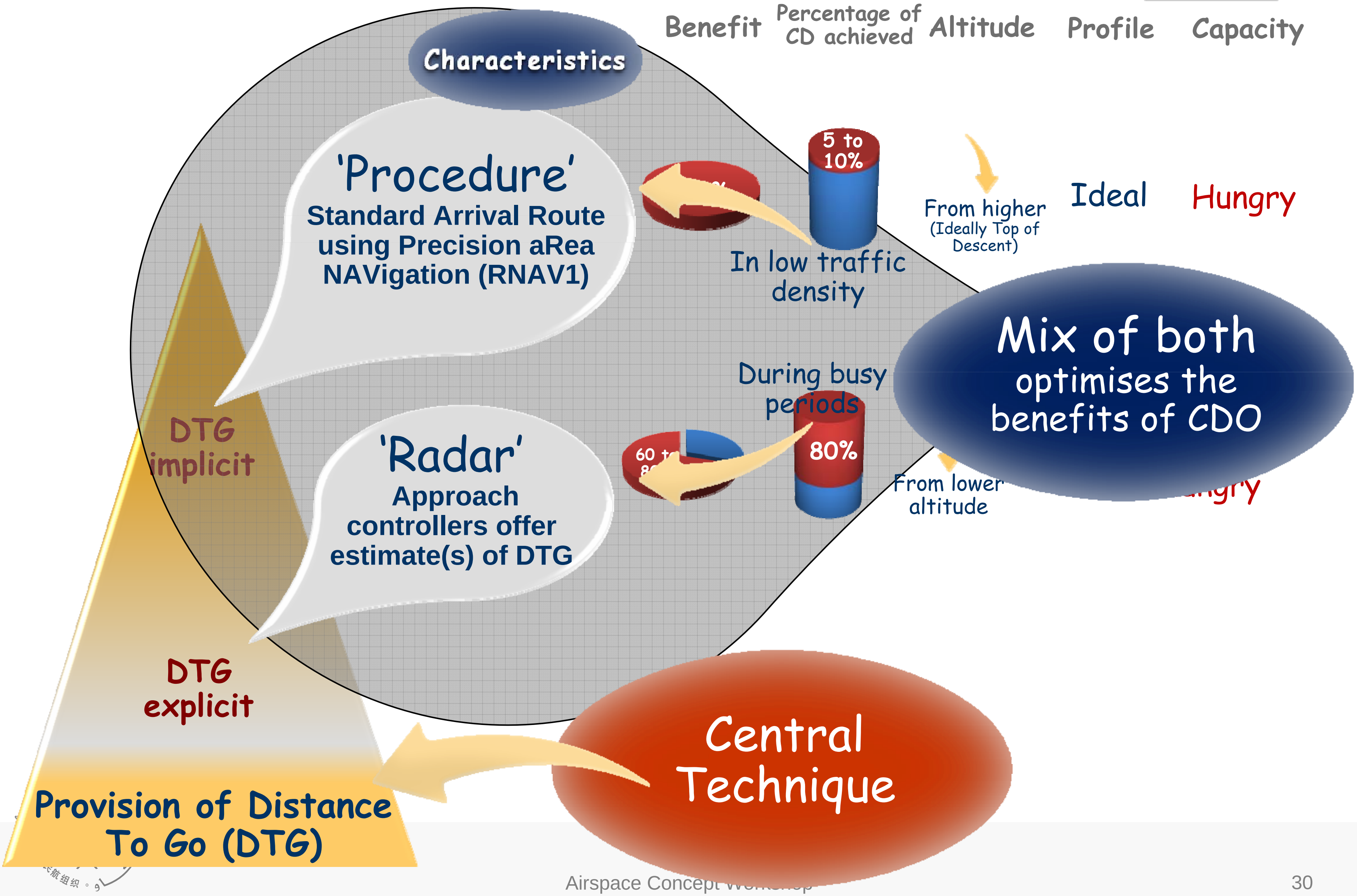
Continuous Descent Operations



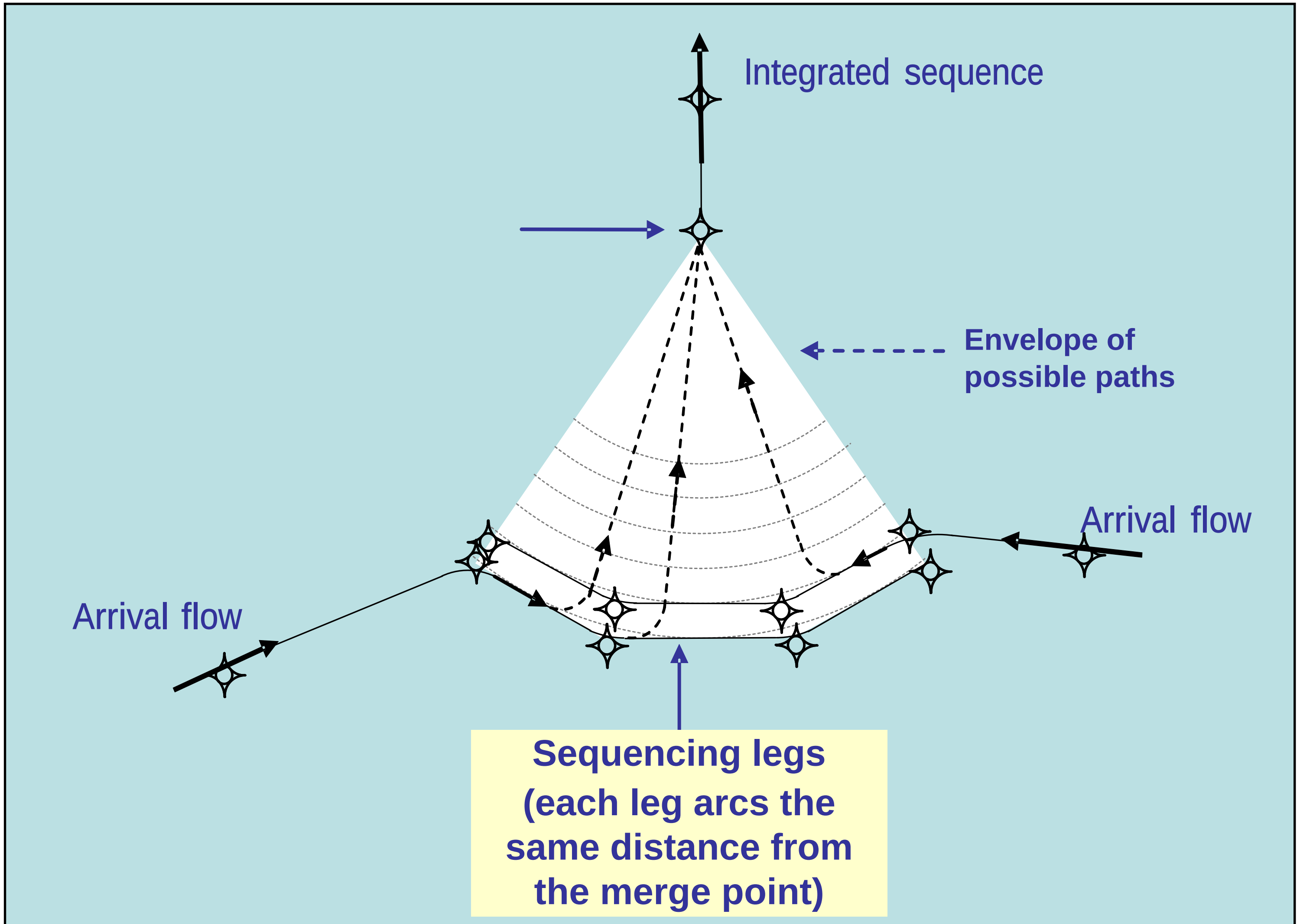
CDO Definition

"Continuous Descent Operations"
is an aircraft operating technique in which an arriving aircraft descends from an optimal position with minimum thrust and avoids level flight to the extent permitted by the safe operation of the aircraft and compliance with published procedures and ATC instructions."

A flying (pilot) technique facilitated by Air Traffic – It is not an ATC procedure

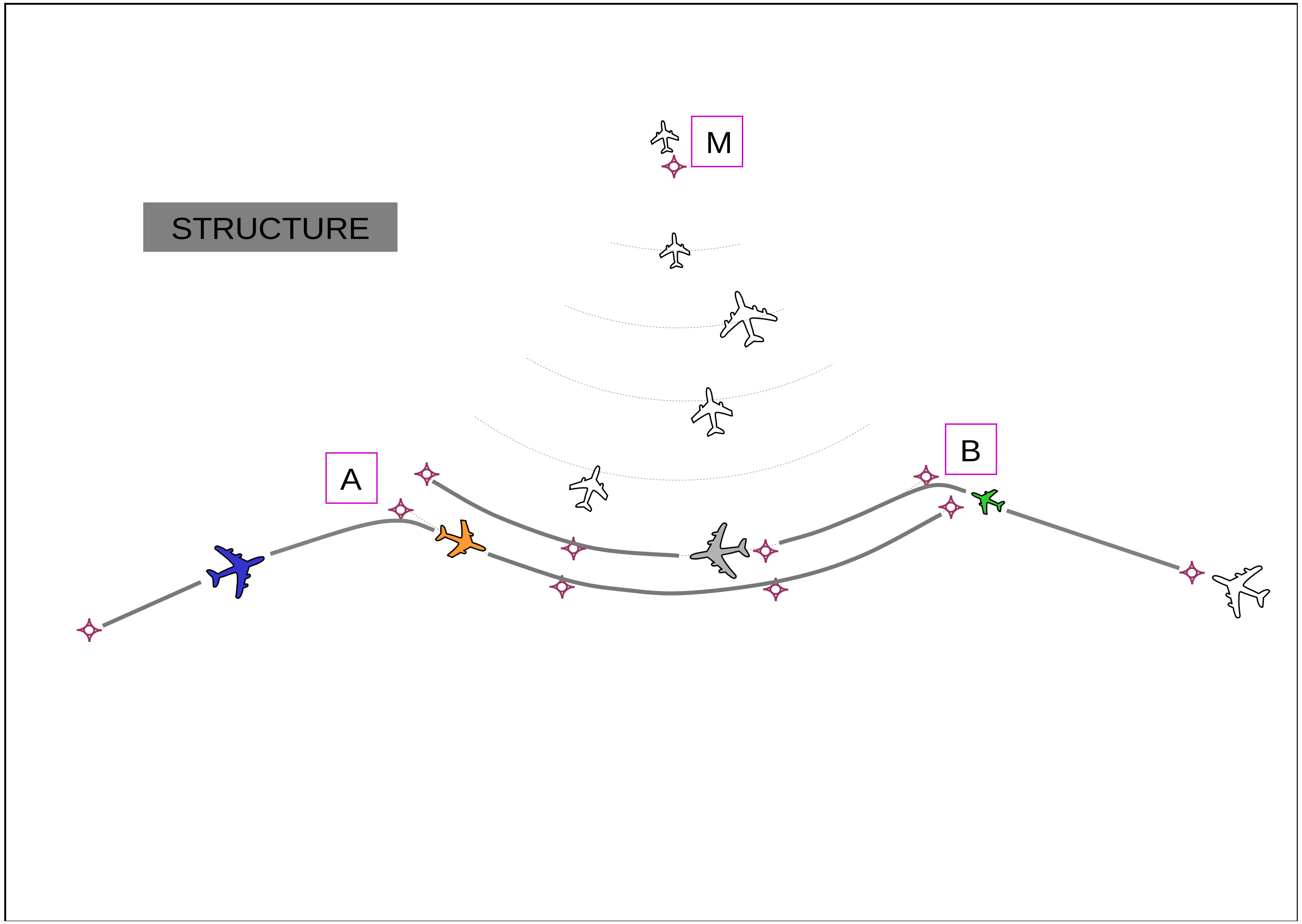

Benefit
Percentage of CD achieved
Altitude
Profile
Capacity
Characteristics
'Procedure'
Standard Arrival Route using Precision aRea NAVigation (RNAV1)
5 to 10%
In low traffic density
From higher
(Ideally Top of Descent)
Ideal
Hungry
'Radar'
Approach controllers offer estimate(s) of DTG
During busy periods
80%
From lower altitude
Mix of both optimises the benefits of CDO
DTG implicit
DTG explicit
Central Technique
Provision of Distance To Go (DTG)

Point Merge System (PMS)



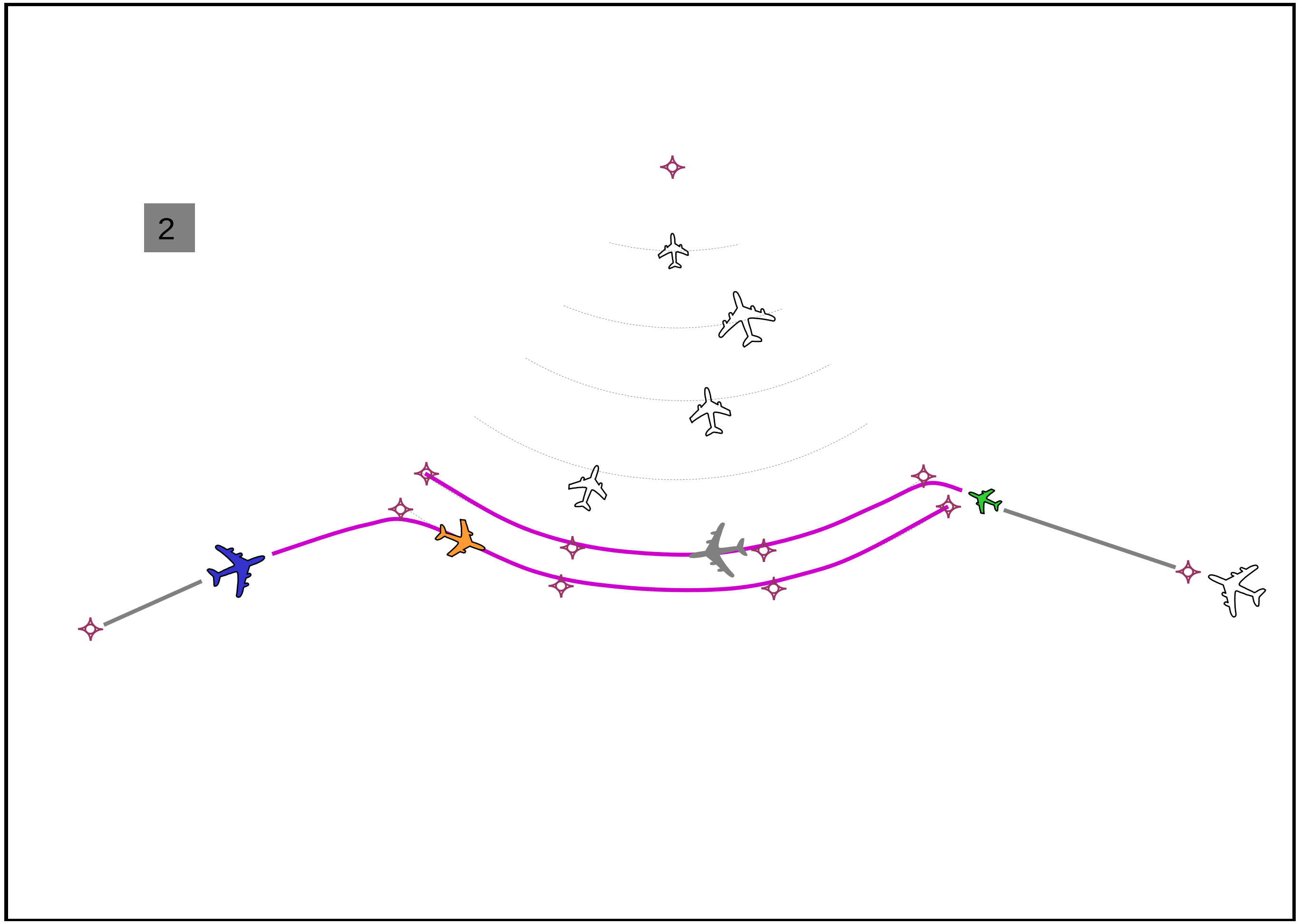
Point Merge System - example with two inbound flows

Scenario “Talk-Through” (1/5)



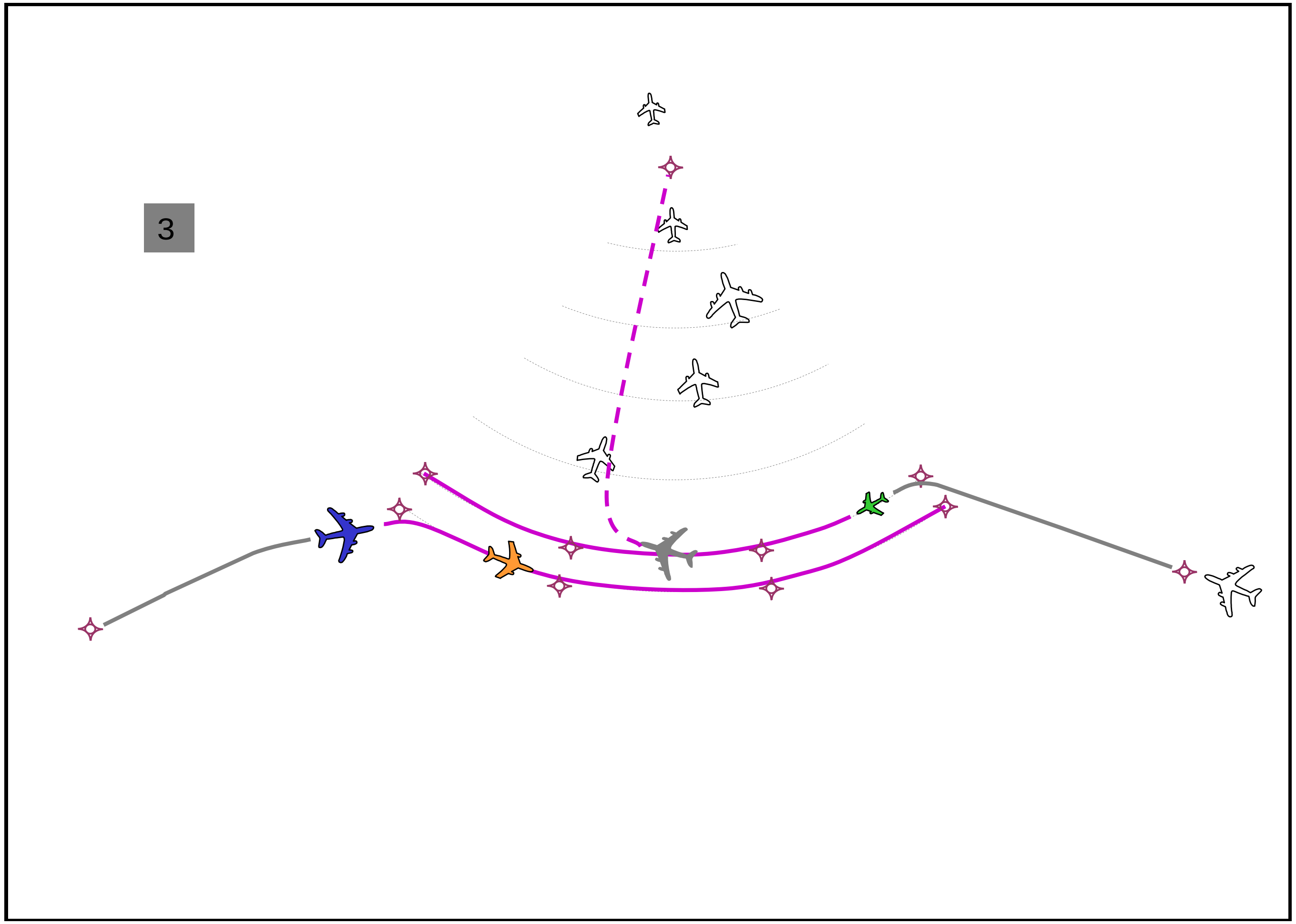
Scenario “talk-through” for Grey, Green, Gold and Blue aircraft

Scenario "Talk-Through" (2/5)



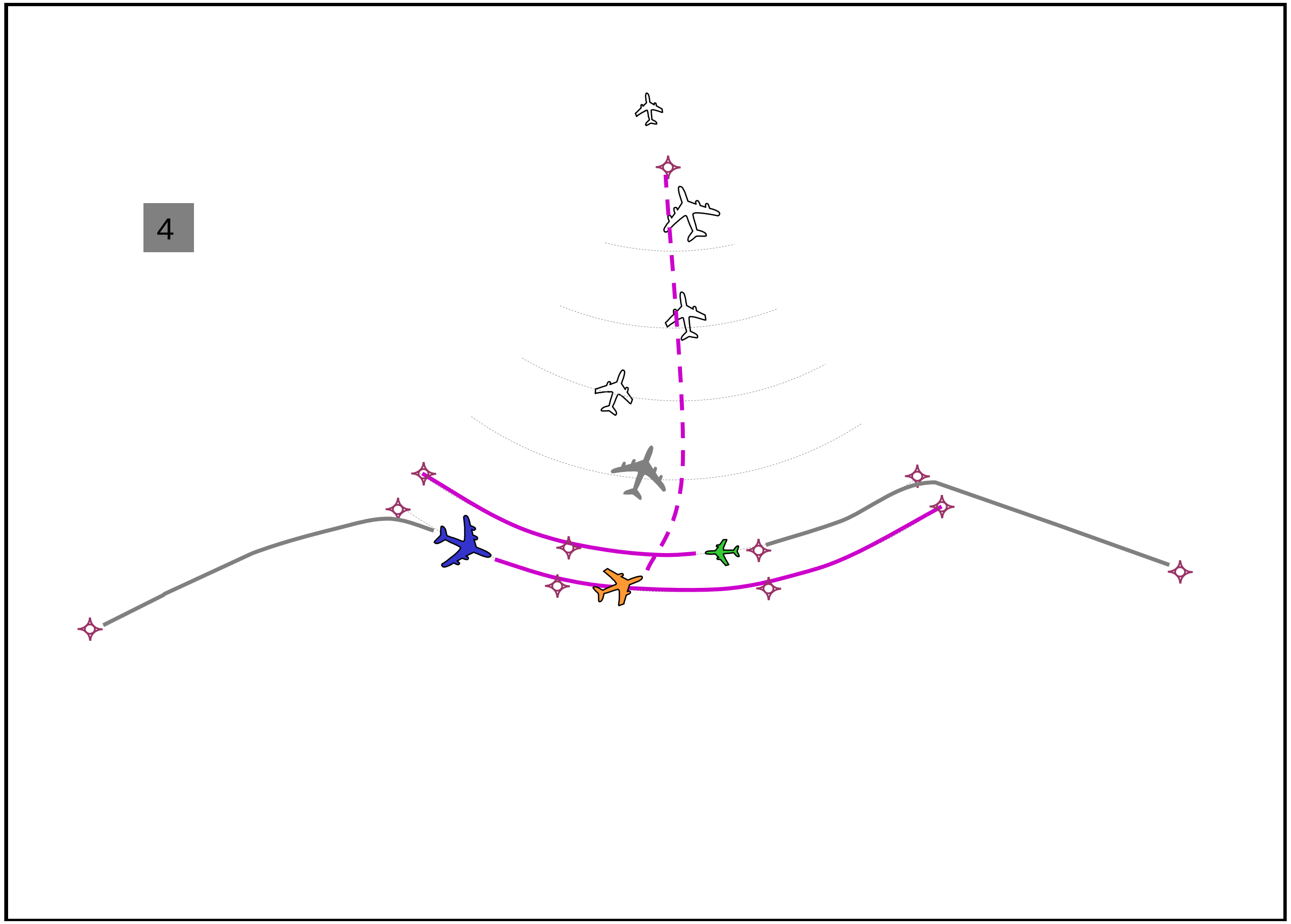
Initial situation with a busy flow of traffic to the merge point

Scenario “Talk-Through” (3/5)



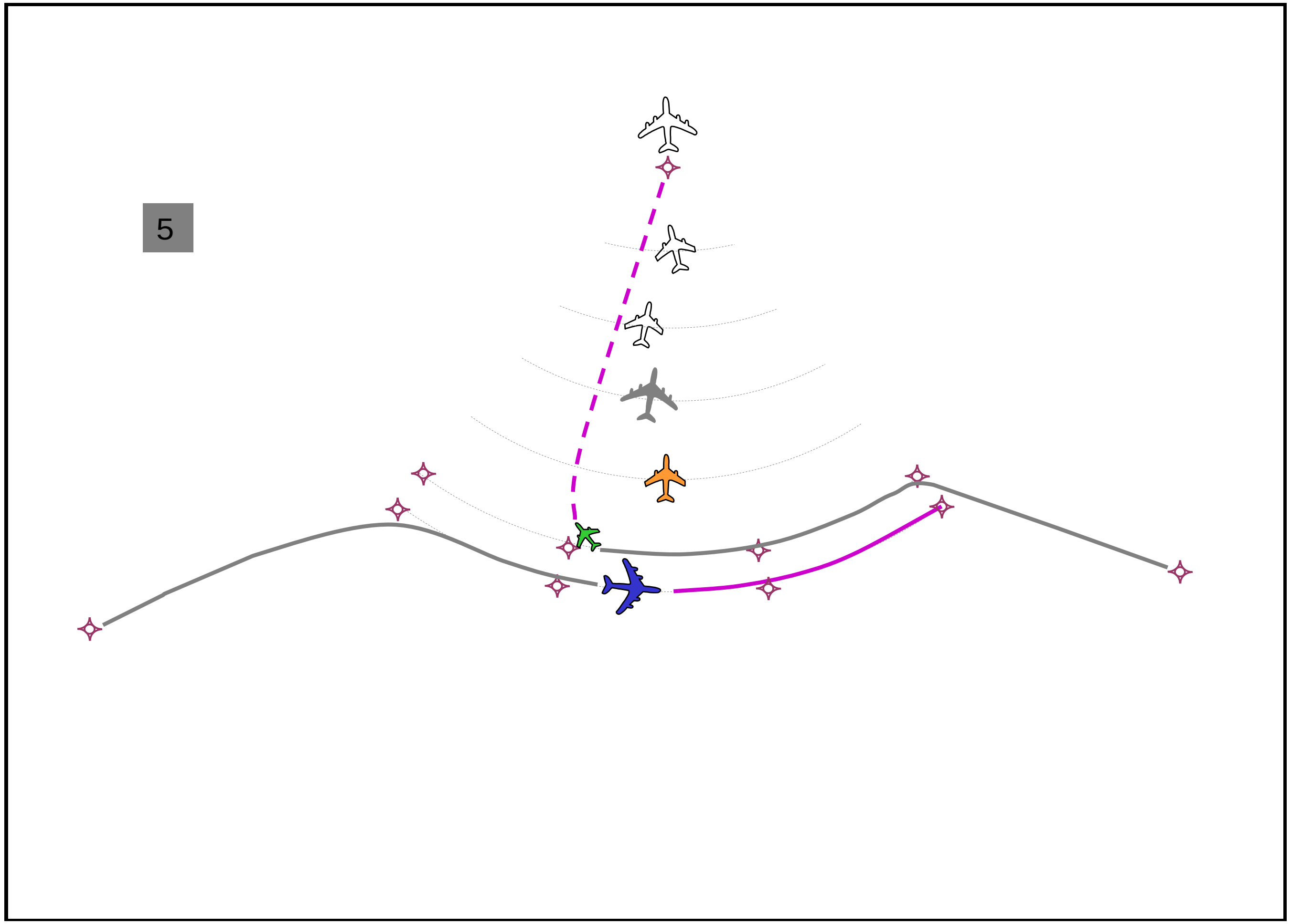
Grey heavy jet cleared direct to the merge point.
Controller determines when to issue the “Direct to merge point” instruction to the Gold aircraft to ensure that the required WTC spacing behind the preceding aircraft will be achieved.

Scenario “Talk-Through” (4/5)



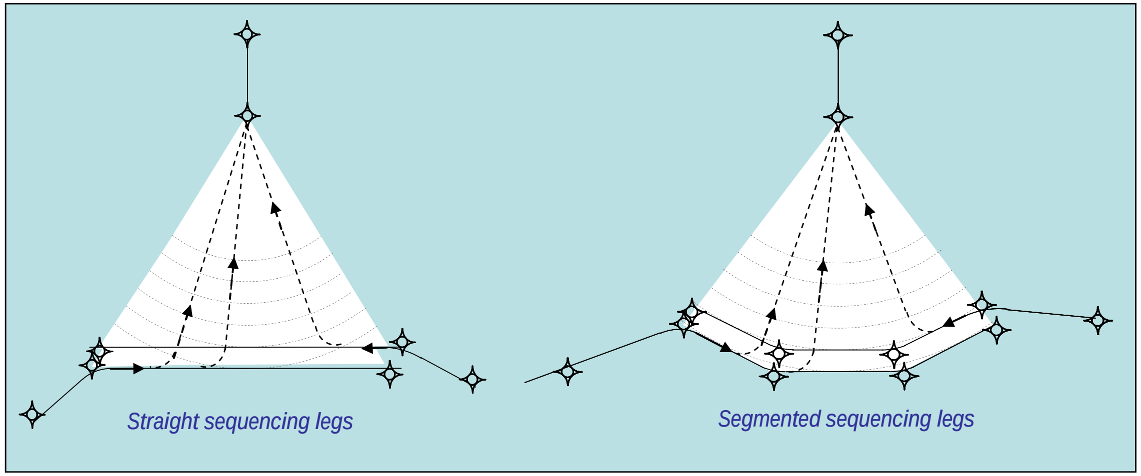
Controller issues the “Turn left direct to merge point” instruction to the Gold aircraft using the range ring arcs to assess the appropriate WTC spacing from the Grey aircraft.

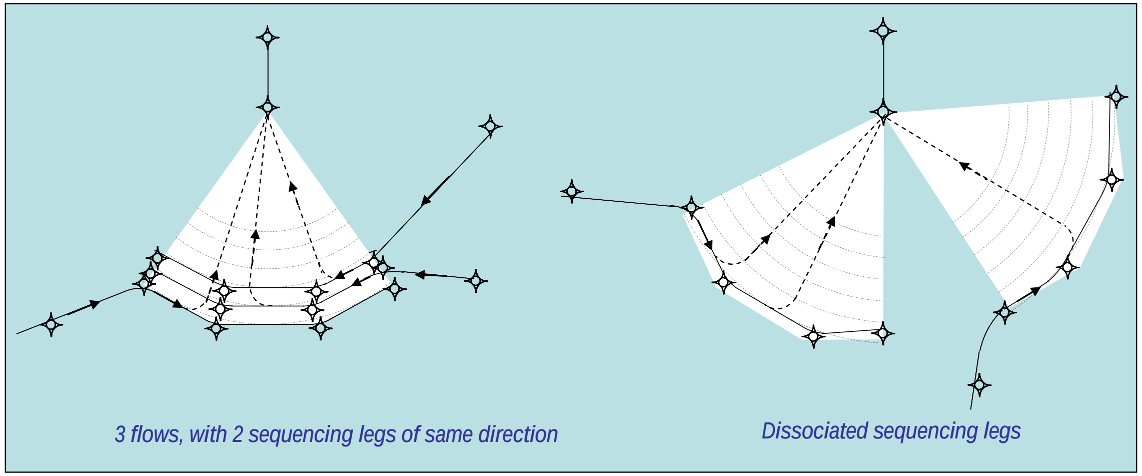
Scenario "Talk-Through" (5/5)

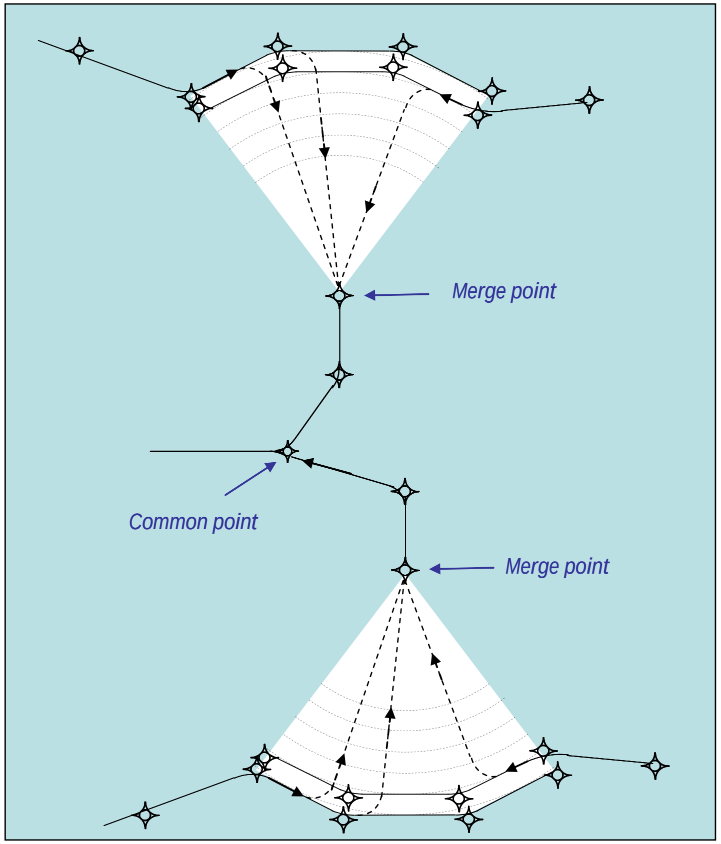


The same technique is repeated for the Green aircraft and subsequently for the Blue aircraft once the Green aircraft passes the next 'Range Ring'

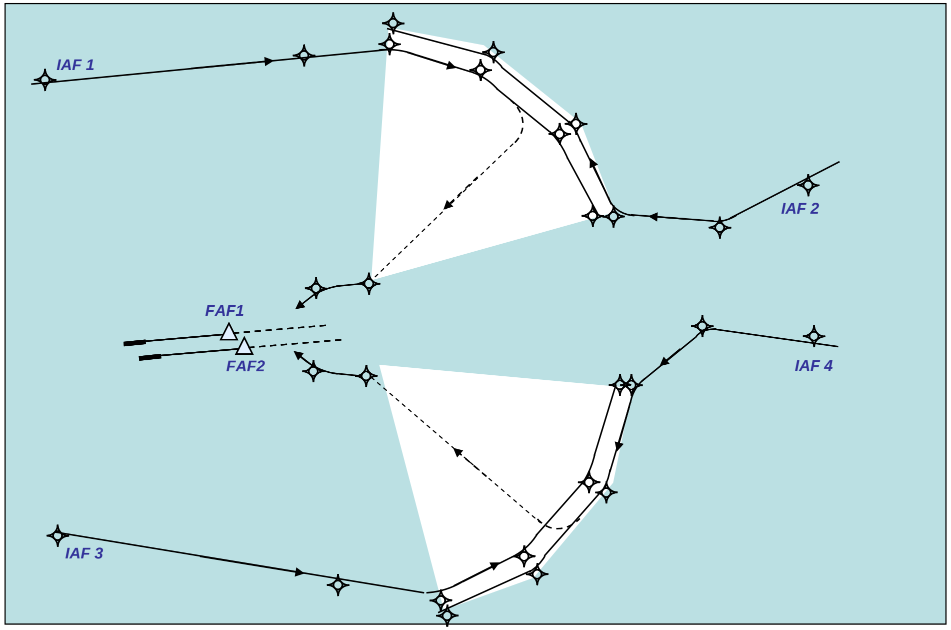
Configurations Tested (1/2)

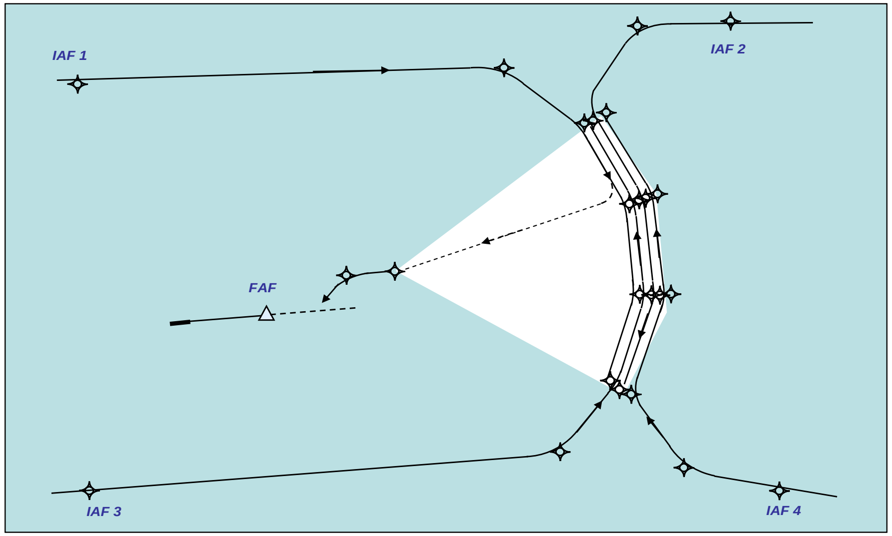


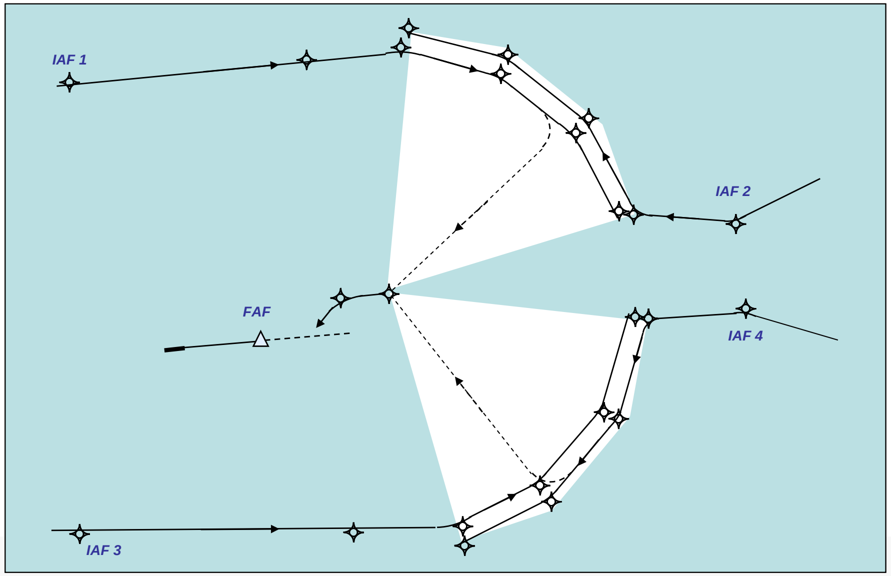




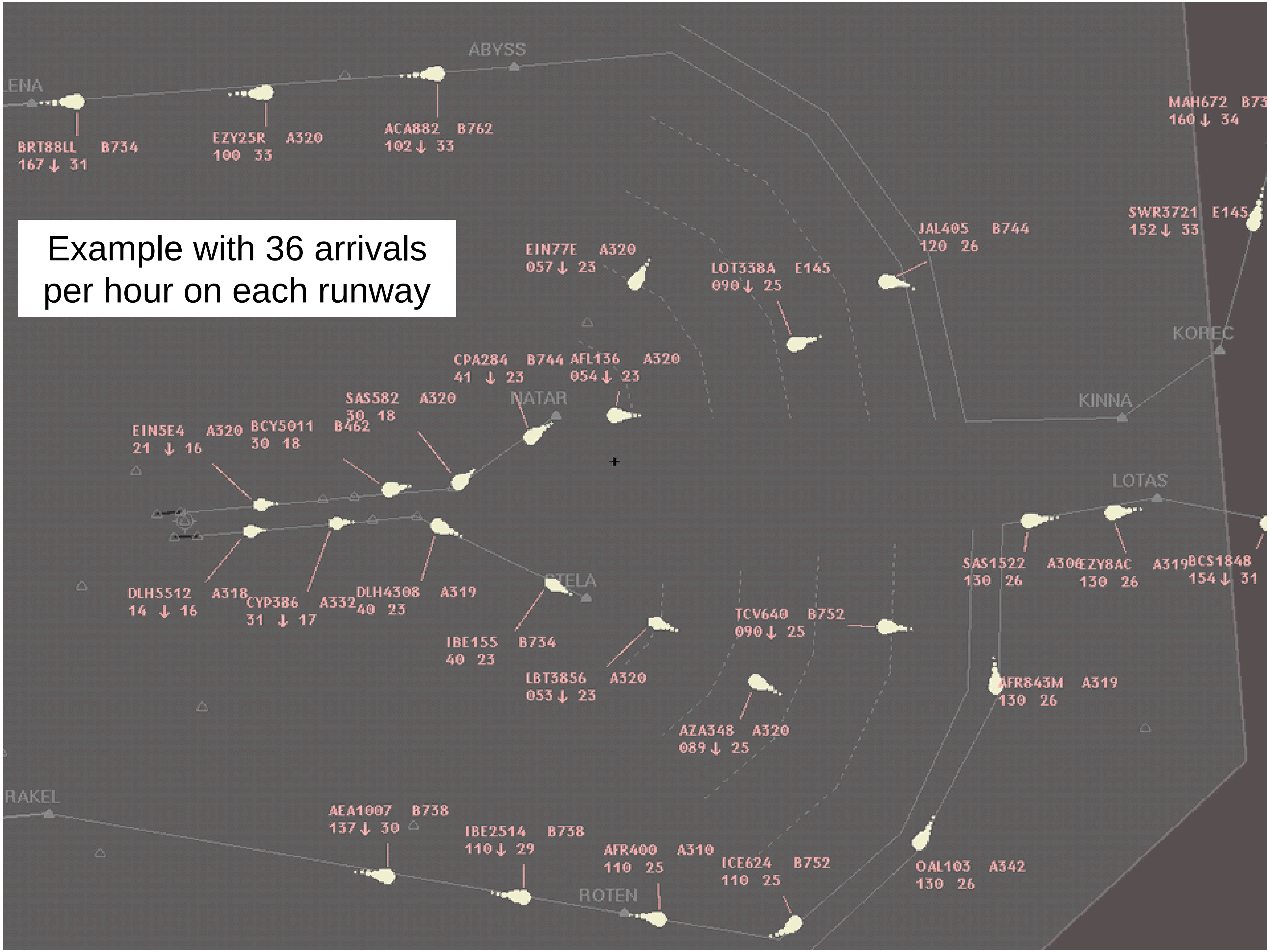
Configurations Tested (2/2)



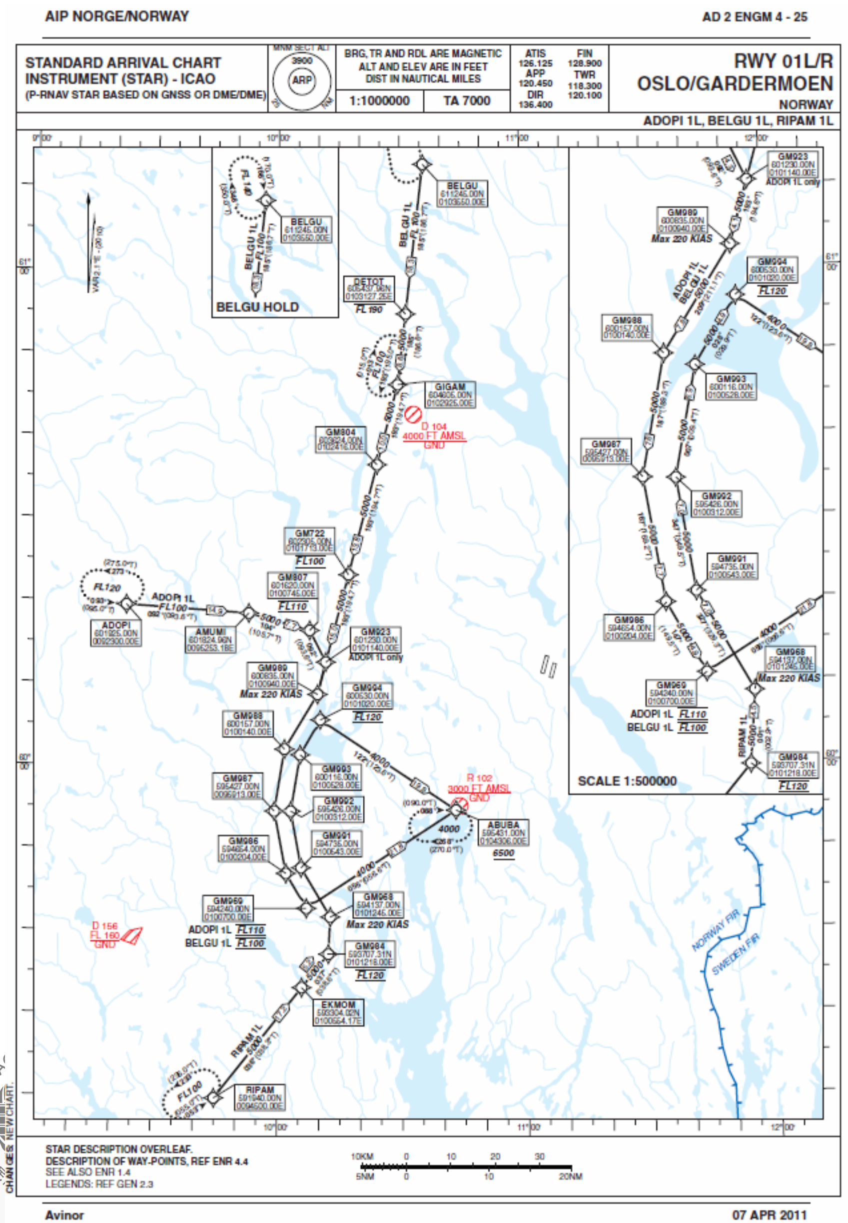


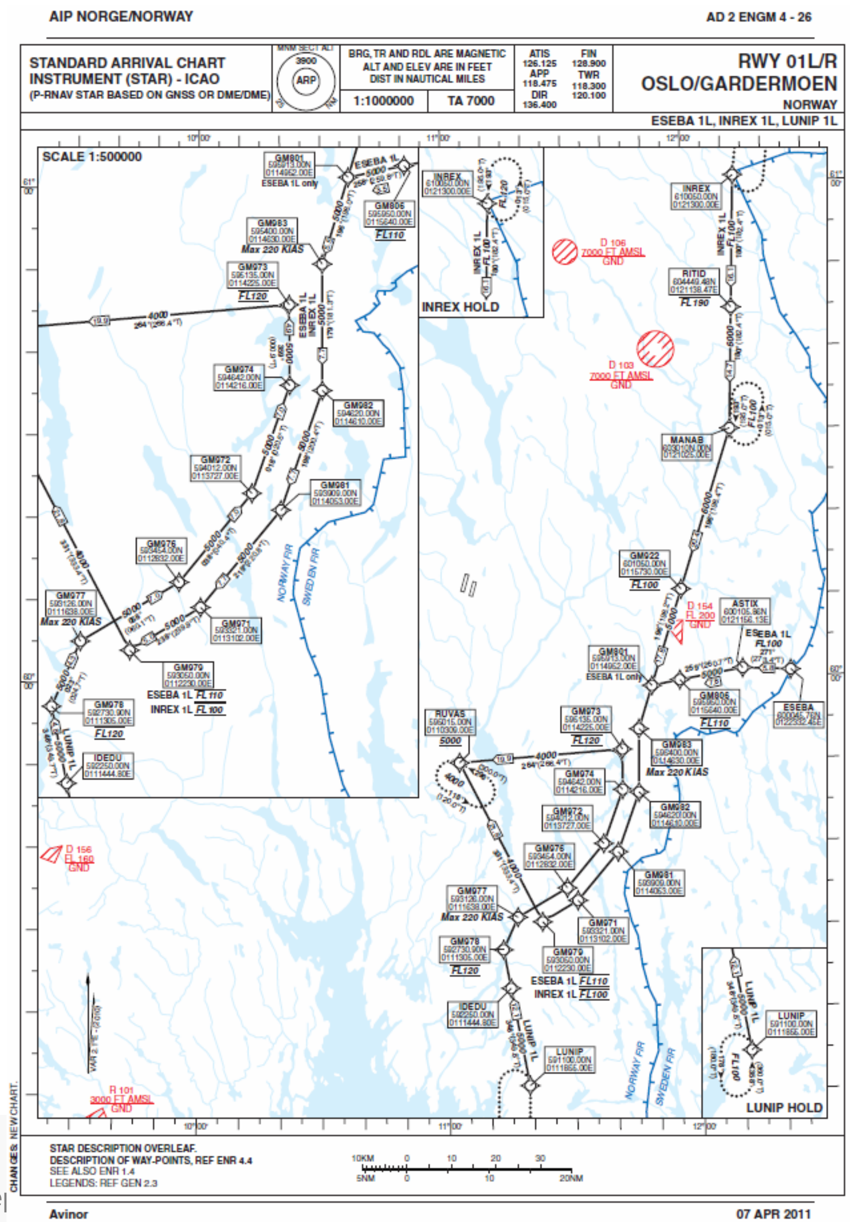


Example with 36 arrivals per hour on each runway



Point Merge - Norway

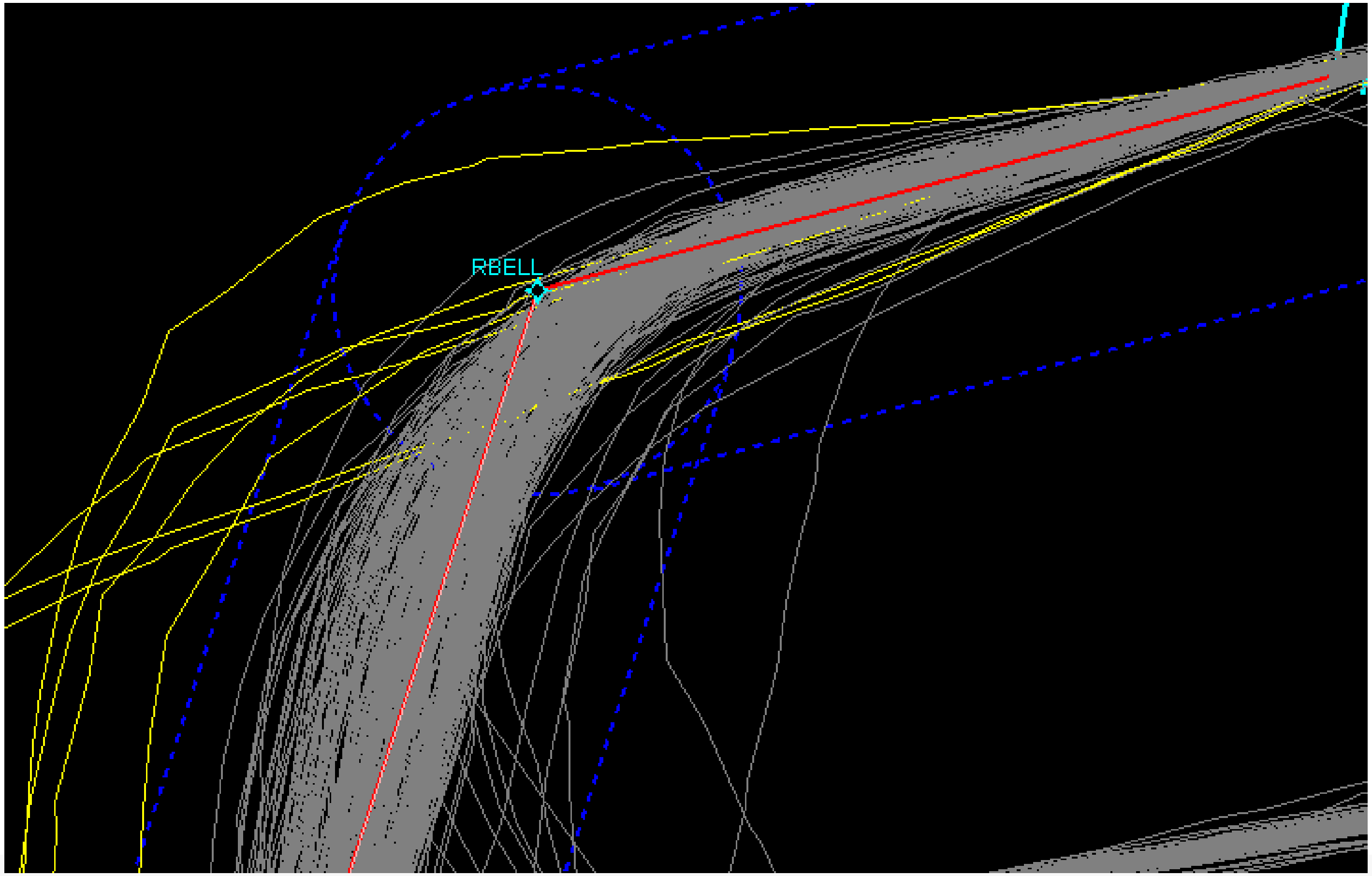




Lessons Learned

Turn Anticipation:

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

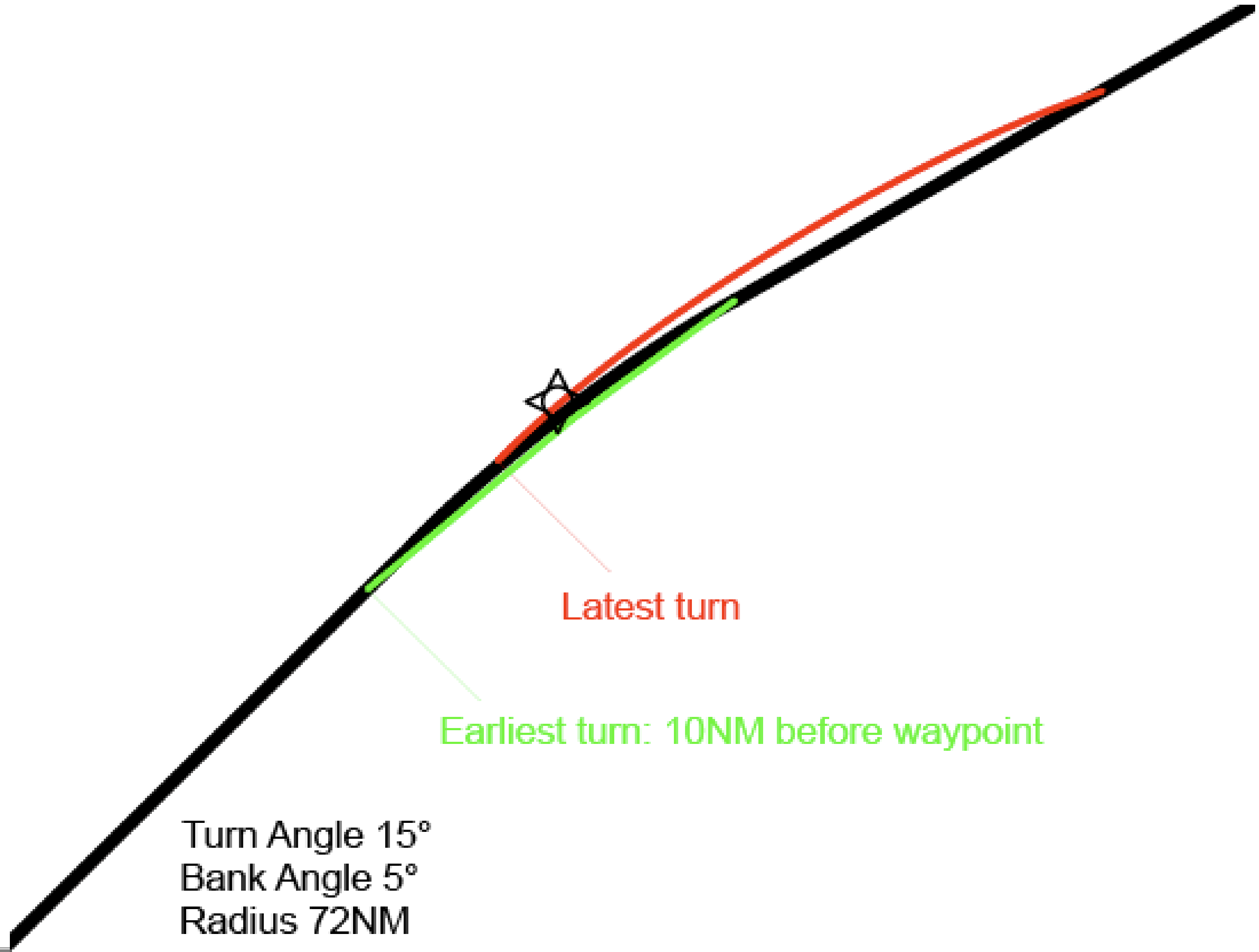


Impact of Turn Performance

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 ±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.

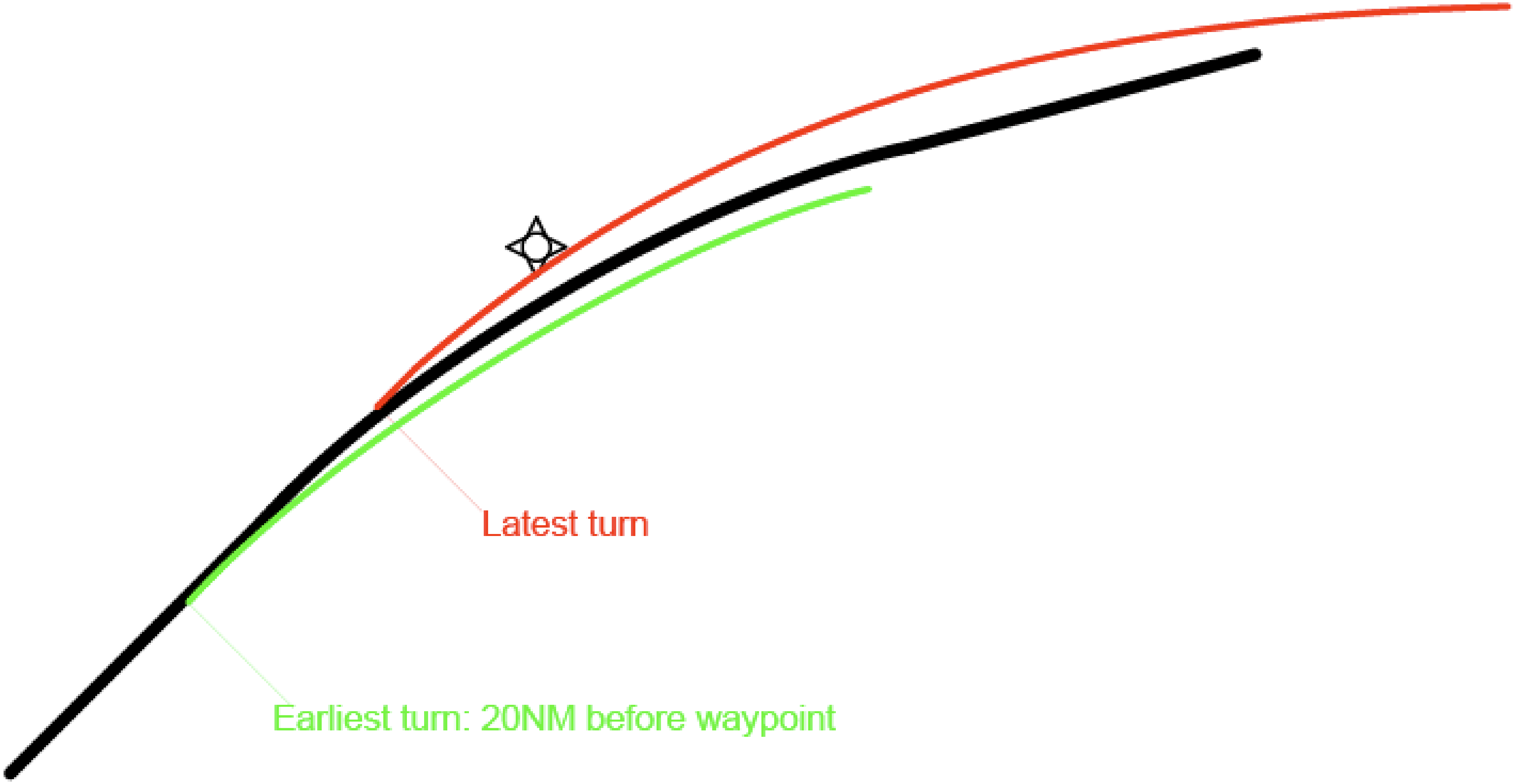
RNAV 5



Turn Angle 15°
Bank Angle 5°
Radius 72NM
Nominal track displacement < 2NM

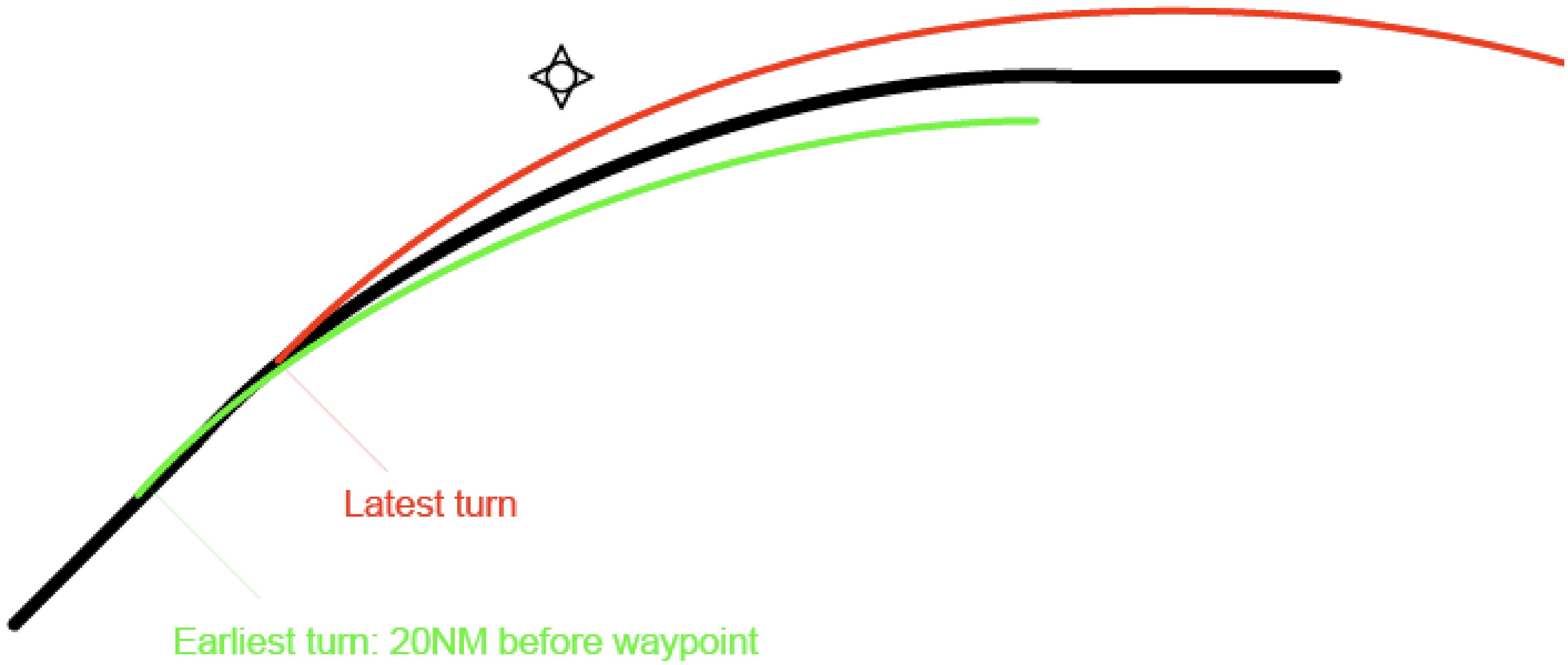
 43

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?

- Now its your turn:
- 3 Hours to:
  - Develop STARs/SIDs/HOLDs
- Both teams present results and provide rationale tomorrow