Design Airspace
(Routes, Approaches and Holds)
Module 11 – Activity 7

European Airspace Concept Workshops
for PBN Implementation
Design in Context

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

Designated IFR Arrival/Departure Routes e.g. SIDs & STARs

VFR Routes/ VFR Corridors

Key:
- Terminal (Arrival/Departure) Routes discussed in Ch.5
- Other Routes mentioned in Chapter 5.
- Note: Tactical Routeing relevant to Chapter 5.

'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.

'Terminal Routes'
Terminal Routes

Routes in Terminal Airspace link…

- Raw demand
- Runway in use
- ATS Routes of the ARN
Different Kinds of IFP

**Open Path**
- (En-Route) ATS Route
- Procedure
- - - → Tactical Vectors provided by ATC

**Closed Path**
- (En-Route) ATS Route
- Procedure
- - - → 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

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

All SIDs climb to 6200 ft.

Transition altitude 6000 feet.

Airspace Concept Workshop

26x651 to 108x722
RNAV Departures at Atlanta USA
Good Design Practice

Minimise Crossing Complexity

High Complexity

Managed Complexity
Safety Assessment for Route Spacing

GLOBAL ASSESSMENT (ICAO)

REGIONAL ASSESSMENT

STATE ASSESSMENT

LOCAL IMPLEMENTATION ASSESSMENT

Key

Assessment Scope

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

Collision Risk

- ATC Actions
- Pilot Actions
- Communication/Surveillance Issues
- Navigation Performance
Route Spacing

Generic model used to determine separation and ATS Route spacing
## Route Spacing

<table>
<thead>
<tr>
<th>PBN</th>
<th>NAVIGATION (Performance Based Concept)</th>
<th>EXPOSURE TO RISK</th>
<th>INTERVENTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<td></td>
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</tr>
<tr>
<td>Determination of <strong>separation minima</strong> (1) for tactical use <em>without ATC Surveillance</em></td>
<td>✔</td>
<td>✔ (2)</td>
<td></td>
</tr>
<tr>
<td>Determination of <strong>separation minima</strong> (1) for tactical use <em>with ATC Surveillance</em></td>
<td>✗</td>
<td>✗ (2) &amp; (3)</td>
<td>✔</td>
</tr>
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<td>✔</td>
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</tr>
</tbody>
</table>

✔ 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.

<table>
<thead>
<tr>
<th>Parallel Routes / based on</th>
<th>Advanced RNP</th>
<th>P-RNAV*</th>
<th>BRNAV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>En Route</td>
<td>Terminal</td>
<td>En Route</td>
</tr>
<tr>
<td>Same Direction</td>
<td>7 NM</td>
<td>7 NM</td>
<td>9 NM</td>
</tr>
<tr>
<td>Opposite Direction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spacing on turning segments</td>
<td>As above</td>
<td>Larger than above</td>
<td>Much larger than above</td>
</tr>
<tr>
<td></td>
<td>using FRT en-route and RF for SIDs/STARs</td>
<td>because no FRT</td>
<td>because of no automatic leg change</td>
</tr>
</tbody>
</table>

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

Runway

A/C 2

7 NM
**Good Design Practice**

**Holds**

- **H1**
  - Merging of routes at holding point may be too complex.

- **H2**
  - Terminal Airspace Boundary

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**Terms: Terminal Airspace Boundary**

**Graph 5-1**

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Airspace Concept Workshop
Continuous Descent Operations

- Continuous Descent Operation profiles
- Idle Descent
- Establish on the Instrument Landing System
- Noise Reduction - 5 to -30%
- Fuel burn and CO2 emissions - 10 to -30%

Area of environmental benefits

« Conventional Approach » Profiles

Profiles Established on the Instrument Landing System

Airspace Concept Workshop
“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
Provision of Distance To Go (DTG)

'Procedure'
Standard Arrival Route using Precision aRea NAVigation (RNAV1)

'Radars'
Approach controllers offer estimate(s) of DTG

Central Technique

Mix of both optimises the benefits of CDO

Benefits

Percentage of CD achieved
Altitude
Profile
Capacity

 Characteristics

DTG explicit

DTG implicit

5 to 10%

From higher (Ideally Top of Descent)

5 to 10%

In low traffic density

During busy periods

60 to 80%

From lower altitude

80%

Ideal

Hungry

Percentage of CD achieved

60 to 80%

5 to 10%

60 to 80%

From lower altitude

80%

Mix of both optimises the benefits of CDO

In low traffic density

During busy periods

From higher (Ideally Top of Descent)

5 to 10%

80%

Ideal

Hungry

Percentage of CD achieved

Altitude
Profile
Capacity
Point Merge System (PMS)

Point Merge System - example with two inbound flows

Integrated sequence

Envelope of possible paths

Arrival flow

Sequencing legs (each leg arcs the same distance from the merge point)
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
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.
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.
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)

- Straight sequencing legs
- Segmented sequencing legs
- 3 flows, with 2 sequencing legs of same direction
- Dissociated sequencing legs
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

Latest turn

Earliest turn: 10NM before waypoint

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

Latest turn

Earliest turn: 20NM before waypoint

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

Latest turn

Earliest turn: 20NM before waypoint

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