Designing Routes
Learning Objectives

✈ By the end of this presentation you should understand:

✈ Benefits of RNAV
✈ Considerations when designing airspace routes
✈ The basic principles behind route spacing
✈ The current nav specs and their phase of flight
✈ Matching fleet capabilities to operational requirements
Benefits of RNAV
Conventional SID

Limitations:
- Inflexible SID/STAR design: a constraint to airspace optimisation.
- Inconsistent track-keeping performance
- Requires use of VOR/DME and/or NDB

Advantages:
- All aircraft operating under IFR are suitably equipped
The Benefits of RNAV

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

Transition altitude 6000 feet.

All SIDS climb to 6000 ft.

STANDARD INSTRUMENT DEPARTURES

MSA ARP 25 NM

VOR/DME | Latitude | Longitude |
--- | --- | --- |
AIRIEZ | N54° 01’ | E003° 03.1’ |
ALMERUS | N53° 46.9’ | 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

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 left 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

KATL Before RNAV Departures

Significant track dispersion

Four departure fixes
RNAV Departures at Atlanta USA

KATL After RNAV Departures

Eight departure fixes
Design in context

Methodology

**STEPS**

1. **Traffic Analysis**
   - Traffic Distribution
   - Time/Geography
   - Check EUR ABN & Adjacent TMA Traffic
   - IFB/VFR Mix
   - MIL/Civil Mix
   - ACFT, Perform, Mix
     - (Jets/Props/Helicopters)

2. **RUNWAY**
   - Runway Length
   - Statistics
   - Landing Aids - ILS CAT?
   - Available Runways
   - Greenfield Sites
     - (Runway Orientation Choice)

3. **Surveillance**
   - Means/Coverage

4. **Navigation**
   - ACFT Navigation Equipage
   - NAV Infrastructure & Coverage
   - Conventional or RNAV?
   - FDP: RDP Link
     - Multiple Level Filters

**ATM/CNS ASSUMPTIONS**
- **Traffic Assumptions**
- **MET. Assumptions**
- **Communications Assumptions**
- **Surveillance Assumptions**
- **Navigation Assumptions**
- **ATC System Assumptions**

**Where does the traffic come from? And when?**

**Which Runway(s)?**

**Is there Radar?**

**Which equipage? How many aircraft?**
Design in context

Methodology

**STEPS**

- **Traffic Analysis**
  - Traffic Distribution
  - Time/Geography
  - Check EUR, ARN & Adjacent TMA Traffic
  - IFR/VFR Mix
  - MIL/Civil Mix
  - ACFT, Perform. Mix (Jets/Props/Helicopters)

- **Runway Length**
  - Statistics
  - Landing Aids - ILS CAT?
  - Available Runways
  - Greenfield Sites (Runway Orientation Choice)

- **Communication**
  - Means/Coverage

- **Surveillance**
  - Means/Coverage

- **ACFT Navigation Equipment**
  - NAV Infrastructure & Coverage
  - Conventional or RNAV?

- **FDP/RDP Link**
  - Multiple Level Filters

**ATM/CNS ASSUMPTIONS**
- **TRAFFIC ASSUMPTIONS**
- **RUNWAY IN USE**
  - Primary/Secondary

**MET. ASSUMPTIONS**

**COMMUNICATIONS ASSUMPTIONS**

**SURVEILLANCE ASSUMPTIONS**

**NAVIGATION ASSUMPTIONS**

**ATC SYSTEM ASSUMPTIONS**

**Activity 6**
Agree CNS/ATM Assumptions

**Activity 7**
Airspace Design Route & Holds

**Activity 8**
Initial Procedure Design

**Activity 9**
Airspace Design Volumes & Sectors

**Activity 12**
Finalisation of Procedure Design
Competing Interests
Routes

ATS Routes

Airway
Advisory Route
Un/Controlled Route
Arrival Route
Departure Route

VFR Routes/VFR Corridors

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

‘Terminal Routes’

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

‘Tactical’ Routeing
- ‘Direct-to’ way-point
- Radar Vectoring (which may replace IAP/DP or SID/STAR)

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...

- Changing demand
- Runway in use
- ATS Routes
Dependence on RWY (1)

- RWY orientation is given
- Direction of RWY in use depends on wind
Different set of SIDs and STARs for different runway in use
Demand and route placement can vary for different seasons.
Different set of SIDs and STARs per season
Selecting a Navigation Specification
What NAV SPEC is needed?

- Which phase of flight?
- How much confidence is needed in track keeping?
- Various requirements identified by Airspace Concept
  - Vertical
  - Lateral
  - Longitudinal
- Is there a need for on-board performance monitoring and alerting?
On Board Performance Monitoring and Alerting

✈ The PBN concept uses the term “on-board performance monitoring and alerting (OPMA)”

✈ The associated ICAO terms were previously containment area, contained airspace, containment value, containment distance, obstacle clearance containment

✈ ‘Navigation accuracy’ now used instead of ‘containment’
Role of OPMA

- Allows flight crew to determine whether the airborne system meets the navigation performance required.
- Relates to lateral and longitudinal performance but not vertical.
- Provides greater assurance of lateral track keeping.
# Navigation Specification by Flight Phase

<table>
<thead>
<tr>
<th>NAVIGATION SPECIFICATION</th>
<th>En Route Oceanic / Remote</th>
<th>En Route Continental</th>
<th>ARR</th>
<th>Initial</th>
<th>Intermed</th>
<th>Final</th>
<th>Missed</th>
<th>DEP</th>
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<tbody>
<tr>
<td>RNAV 10 (RNP 10)</td>
<td></td>
<td></td>
<td>10</td>
<td></td>
<td></td>
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<tr>
<td>RNAV 5</td>
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<td>5</td>
<td>5</td>
<td></td>
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<td>RNAV 2</td>
<td></td>
<td></td>
<td>2</td>
<td>2</td>
<td></td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1b</td>
<td>1</td>
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<tr>
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<td>4</td>
<td></td>
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<tr>
<td>Basic-RNP 1</td>
<td></td>
<td></td>
<td>1a</td>
<td>1a</td>
<td>1a</td>
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<td>RNP APCH</td>
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<td></td>
<td>1</td>
<td>1</td>
<td></td>
<td>0.3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>RNP AR APCH</td>
<td></td>
<td></td>
<td>1 - 0.1</td>
<td>1 - 0.1</td>
<td>0.3 - 0.1</td>
<td>1 - 0.1</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- a. The navigation application is limited to use on STARs and SIDs only.
- b. The area of application can only be used after the initial climb of a missed approach phase.
Navigation Specification by Flight Phase

- **RNAV 1/2 & RNP1 SIDs**
- **Enroute (SUR)**
- **RNAV 5/2/1**
- **RNAV 1/2 & RNP1 STARs**
- **RNP Approach**
- **RNP-AR Approach**

**OCEANIC / Enroute Remote (nonSUR)**

RNAV 10 & RNP 4
Use and Scope of Navigation Specifications

- Navigation specifications do not address all airspace requirements (e.g., comm, surv) necessary for operation in a particular airspace, route or area.

- These will be listed in AIP and ICAO Regional Supplementary Procedures.

- States must undertake a safety assessment in accordance with Annex 11 and PANS-ATM, Chapter 2.

- PBN Manual provides a standardized set of criteria, but is not a stand-alone certification document.

- Examples: RNP 4, RNAV 1, RNP AR APCH.
What kind of Nav spec?

✈ For Approach/Terminal/En-route/Oceanic?
✈ RNAV or RNP
✈ Influencing factors
   ✈ Airspace available
   ✈ Navigation infrastructure available
   ✈ Aircraft available
   ✈ Airspace requirements
Aircraft Types you cater for

- Local fast regionals
- Occasional older visitors – lack of functionality
- Heavy slow long-hauls
NAVAID Coverage

✈ Geographical Distribution of Navaids
✈ Accuracy
✈ Continuity of Service
✈ Availability
✈ Redundancy
Geographical Distribution of Navaids

**VOR/DME**

- VOR/DME1
- Nominal Track

**DME/DME**

- Designated Operational Coverage DME A
- Designated Operational Coverage DME B

**Nominal Track**

- 150°
- 30°
For DME/DME systems using DME facility pairs, geometry solutions require two DMEs to be $\geq 30^\circ$ and $\leq 150^\circ$. 

- Acceptable Angle 70°
- Acceptable Angle 60°
- Acceptable Angle 90°
- Unacceptable Angle 160°
- Unacceptable Angle 180°
Coverage - Demeter
Performance - Demeter
Redundancy - Demeter
Obstacle Constraints
The Procedure

SPECIAL AUTHORIZATION REQUIRED

This procedure is permissible for special performance aircraft ONLY and requires authorization by the Austro Control GmbH for detailed information see AD 2.24-7-2

Gnd speed-KTs
100 120 140 160 180 200
Descent angle 3.5° 619 743 867 991 1115 1239

All Set: MPs
1. GPS and IRS required (OMSECMLZ LLZ and VOR/DME updating not authorized)
2. Phraseology: Request "RNAV RNP approach RWY 26"
3. Procedure N/A below AD temp. -7°C

MISSED APPROACH:
CLIMB TO 9500 FT VIA RNAV MISSED APPROACH-TRACK TO W001 AND HOLD.
RNAV Performance

RNAV System

- RNAV 5
- RNAV 1
- RNP

RNAV Sensor

- VOR/DME
- DME/DME/IRU
- GPS
- SBAS
Obstacle Constraints - 2

Example: The Linzhi airport
Elevation 9,670 feet
Extreme mountainous terrain

Mt. Everest
Elevation: 29,035 ft.

Lhasa
Airport elevation: 11,700 ft.

Linzhi

Bay of Bengal

TIBET

CHINA

NEPAL

BHUTAN

BANGLADESH

INDIA
The Procedure
✈ Approach path 95 miles long, with 108 way points.
✈ Whole procedure 800NM long
RNAV Waypoint: GNSS

Navigation accuracy depends upon:

- Satellites in View
- Geometry
- Satellite serviceability
- Accuracy
Route Spacing

- ATC Actions
- Pilot Actions
- Collision Risk
- Navigation Performance
- Comm/Sur Issues
Route Spacing

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

<table>
<thead>
<tr>
<th>PBN</th>
<th>NAVIGATION</th>
<th>EXPOSURE TO RISK</th>
<th>INTERVENTION</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Performance Based Concept</td>
<td>Operational Error</td>
<td>Communication Surveillance</td>
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<tr>
<td></td>
<td>Navigation Application</td>
<td>Traffic Density</td>
<td>ATC Procedures and Tools</td>
</tr>
<tr>
<td></td>
<td>Navigation Specification</td>
<td>Route Configuration</td>
<td></td>
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<tr>
<td></td>
<td>NAVAID Infrastructure</td>
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</tr>
</tbody>
</table>

| Determination of separation minima (1) for tactical use | ✓ | ✓ | × |
| Determination of separation minima (1) for tactical use with ATC Surveillance | × | × | ✓ |
| 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.
PANS-ATM Route Spacing
Procedural Terminal for PBN

Up to 400 Movements Per day

RNP APCH, B-RNP 1, RNP AR APCH, RNAV 1
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.

<table>
<thead>
<tr>
<th>Parallel Routes / based on</th>
<th>Advanced RNP</th>
<th>P-RNAV*</th>
<th>B-RNAV</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>En Route</td>
<td>Terminal</td>
<td>En Route</td>
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<tr>
<td>Same Direction</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Opposite Direction</td>
<td>7 NM</td>
<td>7 NM</td>
<td>9 NM</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 because no FRT</td>
<td>Larger than above because no FRT</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 time and the traffic characteristics, etc.
ICAO route spacing

From ICAO Doc4444

5.4.1.2.1.4 Lateral separation of aircraft on published adjacent instrument flight procedures for arrivals and departures

5.4.1.2.1.4.1 Lateral separation of departing and/or arriving aircraft, using instrument flight procedures, will exist:

a) where the distance between RNAV 1, Basic RNP 1, RNP APCH and/or RNP AR APCH tracks is not less than 13 km (7 NM); or

b) where the protected areas of tracks designed using obstacle clearance criteria do not overlap and provided operational error is considered.
ICAO Spacing

✈ RNAV1/2: Radar Separation
✈ RNP4: 30NM
✈ RNAV5: 30NM, 18NM, 16.5NM
✈ RNAV10: 50NM
Thank You