What is Area Navigation?

Module 1

European Airspace Concept Workshops for PBN Implementation

Objectives

By the end of this presentation you will be:

- Aware of the evolution of navigation systems
- Understand the concept of area navigation
- Identify the main components required to perform area navigation
Navigation - The Beginning

IFR
- I Follow Roads!
- And Rivers
- And Railroads
- And Buildings
- And Telephone Lines
- And Whatever Else I Can See

The Early Days

Night and Weather!
- 1910s
  - First Bonfires and Beacons
- Early 1920s
  - Lighted airport boundaries
  - Spot-lit windsocks
  - Rotating lighted beacons on towers
  - Lighted Airways
    - 1923 Dayton to Columbus, Ohio (USA) – 72 km
Late 1920s - 1930s

Radio!

- Radio for Two-Way Communications
  - Weather Updates
  - Request Help With Navigation
- Radio for Navigation
  - Radio Marker Beacons
  - 4-Course Radio Range System
- Pilots Listen for Navigation Signals

1930s - 1940s

VOR!

- Static-Free VHF Omni-directional Radio Range
  - Pilots Navigate by Instrument
- VOR (with improvements) becomes a primary NAVAID for decades
  - Defines Routes
  - Supports Approach Procedures

VOR Has Done a Great Job For Decades
**1940s - 1950s**

**ILS!**
- 1929: First system tested
- 1946: (Provisional) ICAO selects ILS as primary landing air for international “trunk” airports
- Today ILS:
  - CAT I,
  - CAT II,
  - CAT III

**From 1950s**

**DME!**
- 1961: first regular civil use (pilot tuned)
- In PBN, DME use is based on automatic tuning
The 1970's Cockpit

Conventional Navigation

Conventional Routeing
Assume a ground infrastructure consisting of 4 VORs

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Conventional Navigation

- Ground-based navigation aids (NAVAIDs)
  - Aircraft Overfly NAVAID or Intersection
- Display Accuracy is a Function of Distance
  - Protected Area Grows ("Splayed")
  - Limited Design Flexibility

First Generation Digital Avionics

- Appeared in early 1970s
  - Basic ‘cruise control’
  - Capable of storing 4 manually inserted ‘waypoints’
  - Provided guidance on Course Deviation Indicator (CDI)
  - Flew to waypoint before switching to next leg
- Conventional ATS Routes:
  - Defined by NAVAIDs
  - NAVAID coordinates loaded into computer
  - Automatic route guidance provided from computer
Evolution to Area Navigation

- Long Range Navigation (LORAN)**
- Omega Radio Navigation System*
- Inertial Navigation
- VOR/VOR and VOR/DME
- Multi-sensor Flight Management System (FMS)
- GPS, GLONASS, and Augmentations

* Terminated in 1997
** US system terminated in 2010

What is Area Navigation?

RNAV Routeing

This section will describe how different navigation aids are used in a RNAV environment to provide a more flexible routing.
Definition of Area Navigation

- **Area navigation** is a method of navigation which permits aircraft operation on any desired flight path:
  - within the coverage of station-referenced NAVAIDS, or
  - within the limits of the capability of self-contained systems, or
  - a combination of these capabilities

Blue line shows RNAV route without constraints of ground-based NAVAIDs

Area navigation is the key enabler for Performance Based Navigation

What Can Area Navigation Provide?

- Ground or Space Based NAVAIDs
  - Aircraft Fly Waypoints
- Protected Area Constant ("Linear")

= Increased Design Flexibility
**How is Area Navigation Enabled?**

- Through the use of a navigation computer
- Waypoints (co-ordinates) are input into computer
  - Manual entry possible:
    - Not always permitted
  - Automatically with an integrated database
- Pilot creates route (series of waypoints) i.a.w. flight plan
- Computer estimates position using navigation sensors fitted and compares estimation to defined route
  - Deviation between the position and defined path will create guidance information

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**ATS Routes**

- **RNAV Routes**
  - Fixed ATS Routes (designed)
  - DCT (planned)
  - DCT (tactical)
  - Free Routes

- Airways
- Advisory Airways
- Un/Controlled Routes
- Arrival Routes
- Departure Routes
- Designated SIDs/STARs
- Airways Advisory Airways

- Designated i.a.w. Annex 11 and published in the AIP
- Published in the RAD and possibly AIP
- WPTs published
- User defined

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**Airspace Concept Workshop**
**Airspace Concept Workshop**

- Operator defines data required
- Data collated by 'Datahouses'
- Data 'packed' by OEMs

### Region
- Cities
- Routes
- Aerodromes
- UQAA
- STAR
- RW 23
- RISAD 3C

### Aircraft Functionality
- **Database**
  - Route
  - Navaids
  - Airspace
  - Constraints

- **Range and/or Bearing Information**

- **AC Management**
  - Performance:
    - Climb & Descent
    - Turns

- **Position Estimation**
- **Path Comparison**
- **Path Corrections**

### Navigation Databases
- Most navigation applications require a database
- Contains pre-stored information as requested by the AO such as:
  - NAVAIDs
  - Waypoints
  - ATS Routes
  - Terminal Procedures
  - Related information

- The navigation computer will use this information for flight planning and cross-checking of sensor information
- Databases are compiled by a specialist ‘datahouse’ and updated i.a.w. Annex 15 AIRAC cycle
  - Data integrity is the biggest challenge: ADQ1 IR in place
- Today, the size of the database is also cause for concern
Navigation Computer Functionality

- Computers built by different OEMs
  - Operating system differences - just like Microsoft, Apple, Linux
  - Industry standard ARINC 424
- Functionality defines what the computer is capable of:
  - Turn performance
  - Path terminators
  - Automatic leg sequencing
  - Offset
  - Database
  - Alerting
  - Outputs (Display)

Flight Segments

- For the navigation computer, the flight consists of different elements known as ‘segments’
- Each segment is held in a different part of the database
- The segments must be connected together by the pilot
- ‘Route Discontinuity’ occurs when segments are not linked
Turn Performance – En-Route

- Aircraft fly from waypoint to waypoint
- Track between waypoints known as ‘legs’
- Aircraft flies ‘legs’ as ‘To-To-To’
- At, or abeam, the waypoint the computer steps to the next one in the flight plan
- Computer will initiate turn approaching waypoint to be turn complete on next leg
- Turn anticipation is not always the same
  - Creates track dispersion

Instrument Flight Procedures

- IFPs define the departure and arrival paths of the aircraft
- Links terminal airspace to the ATS
  - Responsibility of Procedure Designers
- Computer limitation:
  - Only one STAR allowed per route
- So ‘Transition’ connects STAR to Approach segment
- Additional functionality enabled for IFPs, such as:
  - Waypoint Transitions
  - Path Terminators
**Waypoint Transition - IFP**

- **Fly-by**
- **Fly-over**
- **Radius to Fix**

**Path Termination - IFP**

- How does the aircraft know what to do between waypoints?
- Industry has defined a set of actions which:
  - Tells the aircraft what to fly:
    - Track
    - Course
    - Heading
    - Direct
  - What success factor must be met to complete the action:
    - Altitude
    - Distance
    - Next fix
    - etc
Path Terminators - IFP

- ARINC 424 industry standards define Path Terminators
- Not all Path Terminators are used in PBN
- Path Terminators may be different or not enabled in some aircraft

<table>
<thead>
<tr>
<th>Path</th>
<th>Terminator</th>
</tr>
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<tbody>
<tr>
<td>Constant DME arc</td>
<td>A</td>
</tr>
<tr>
<td>Course to</td>
<td>C</td>
</tr>
<tr>
<td>Direct Track</td>
<td>D</td>
</tr>
<tr>
<td>Course from a fix to</td>
<td>F</td>
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<tr>
<td>Holding pattern</td>
<td>H</td>
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<tr>
<td>Initial</td>
<td>I</td>
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<tr>
<td>Constant radius</td>
<td>R</td>
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<tr>
<td>Track between heading to</td>
<td>T</td>
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</tbody>
</table>

- A: Altitude
- C: Distance
- D: DME distance
- F: Fix
- H: Next leg
- I: Manual termination
- M: Radial termination
FMS and Navigation

Navigation Computer
(Positioning, Flight Planning, Trajectory Prediction)

AND

Aircraft Performance Management

Flight Management System

Pilot’s EFIS

Controls and Displays (3)

Radio Altimeter

Air Data Computer

VOR/ILS DME (2)

Digital Clock

IRS (3)

Compass (2)

Fuel System

Autopilot/Flight Control Computer

Thrust Management Computer

Selectors and Annunciators

ADS

GNSS (2)

TCAS

EGPWS
FMS Integrated Navigation Computer

Path Steering

- Navigation Sensors
  - GNSS
  - DME
  - VOR
  - IRU

- NAV Computer
  - Database Identification, Fixes, Navaid Idents, etc
  - Path Definition
    - Selected FP & Nav Mode
  - Path Steering
    - Path Deviation
    - Steering Command
    - Display & Sys Alerting
      - Position Data & Sensors in Use
  - Position Estimation
    - Estimated Position
  - User Interface
Navigational Accuracy

- In PBN the lateral track accuracy required for a navigation application is dependent on:
  - Navigation Sensors
  - Geometry of the NAVAIDs
  - Quality of navigation data
  - How the aircraft is flown
    - Automatic (AFCS)
    - Manually (following CDI)
  - Display of information
  - Human error (manual input to computer)

Uncoupled Steering
**Coupled Steering**


**Flight Profile with FMS**

Before T/O, the Flight Plan Route is loaded into the FMS. After T/O, the FMS captures the assigned Flight Plan Route. The FMS commands speed and thrust for optimum economy calculating optimum altitude for the weight as the flight progresses. The FMS provides continual guidance along Flight Plan route including great circle routing.
Summary

Conventional: 1950s+

Automatic: Early 1970s

Area Navigation: Europe 1998