Evolution of PBN

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Overview

– Navigation in Context
– Evolution to Performance Based Navigation
– Performance Based Navigation
  • What Is It?
  • What is Area Navigation (RNAV)?
  • What is Required Navigation Performance?
  • What is the Key Difference?
Navigation in Context

Airspace System

Communications

Navigation

Surveillance

CNS/ATM
Navigation: The Beginning

I Fly 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
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
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

**ILS Still Does a Great Job!**
From 1950s

**DME**

- 1961: first regular civil use (pilot tuned)
- In PBN, DME use is based on automatic tuning

DME (on top of VOR)
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

- From early 1970s
- 4 manually inserted waypoints
- Guidance on CDI
- Flew from to waypoint before switching to next
- Conventional defined by waypoints
- Navaids coordinates loaded into nav computer
- Automatic route guidance provided by nav computer
Evolution of RNAV

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

*terminated in 1997
** terminated in 2010
Definition: Area Navigation

• ICAO: Area Navigation is a method of navigation enabling aircraft to fly on any desired flight path:
  – within the coverage of referenced NAVAIDS, or
  – within the limits of the capability of self-contained systems, or
  – a combination of these capabilities

• The concept of PBN relies on the use of an area navigation system
Enablers

- Nav computer
- Waypoints manually or automatically inserted
- Pilot creates a route
- Computer estimates position and compares to defined routes
- Deviation between the position and defined path creates guidance
- Ground or Space Based NAVAIDs
- Aircraft Fly Waypoints
- Protected Area Constant ("Linear")

= Increased Design Flexibility
Adds to RNAV

- On Board Monitoring & Alerting
- May Incorporate Radius to Fix Turns

= Optimized Use of Airspace
Modern FMS

• FMS is a Nav computer +aircraft performance management
• Provides path steering to flight control systems
• Provides path deviation to display and alerting
• Position estimation through multi sensors
• Path definition through nav database
RNAV Application

RNAV 1

1 Nautical Mile 95% of flight time

Track Centerline

1 Nautical Mile 95% of flight time
RNP Application

RNP 1

Alert to Pilot

Track Centerline

1 Nautical Mile 95% of flight time

1 Nautical Mile 95% of flight time

The Key Difference:
On-Board Performance Monitoring and Alerting
Accuracy

• Nav sensors
• Geometry of nav aids
• Quality of navigation data
• Automatic (uncoupled vs coupled)/Manual
• Display of information
• Human error
Flight profile with FMS

- Flight plan route is loaded in FMS
- After take off, the FMS captures the flight plan
- FMS commands speed and thrust for optimum altitude for the weight as the flight progresses
- FMS provides continuous guidance along the route
- Calculates TOD for fuel efficient descent
- Fuel saving idle thrust descent
- Automatically complies with speed and altitude restrictions
- Transition to landing system
- Advises to correct landing speed (excursion avoidance)