GNSS instrument flight procedures: the designer perspective

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ENAV

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Contents

• The ENAV Airspace Design Department
• ENAV activities on PBN-related matters
• PBN Vs Conventional Instrument Flight Procedures (IFP)
• Practical applications
The Airspace Design Department

ATS Operational Directorate

Airspace Design Department

- Enroute
- Obstacle Management
- TMA, CTR & Aerodromes
- Standardization & Services
- Flexible Use of Airspace
ENAV - PBN Achievements
PBN Tasks achieved

• National PBN Task Force (ENAV – CAA) in place (2010) to tackle and handle PBN deployment inside National Airspace;

• Consultation with AUs in progress by means of periodical ENAV Customer Care meeting;

• Spring 2011:
  ➢ Introduction of P-RNAV inside Italian airspace (AIC A1/2011)

• Summer 2012:
  ➢ Publication of National PBN implementation plan
  ➢ Regulator approval of National Safety Case for the introduction of RNP-APCH inside Italian Airspace

• Winter 2012: Publication of the first RNP APCH IFPs for Milan Malpensa and Milan Linate airports (AIC A17/2012)
PBN implementation – RNAV1

• RNAV1 instrument flight procedures already published on several Italian airports;
• RNAV1 overlays provided for SID & STARs on almost all airports + several RNAV1 standalone procedures for major Italian airports;
• 2013 Implementation:
  ➢ Venice and Olbia
• 2014 Planning:
  ➢ Florence, Bologna
  ➢ Milan Terminal Area
  ➢ Torino, Verona
PBN implementation – RNP APCH

• RNP APCH procedures published initially down to LNAV and LPV minima

• First main airports interested: Milan Linate (12/2012), Milan Malpensa (12/2012), Rome Fiumicino (01/2013). At present, 8 Instrument RWY ends are served also by RNP APCH flight procedures

• APV/BARO VNAV upgrade on course and expected to be effective by summer 2014

• RNP APCH deployment for all airports served by Milan ACC Radar Service (Milan Linate, Milan Malpensa and Bergamo) and Rome ACC Radar Service (Rome Ciampino, Rome Fiumicino) is expected to be completed by summer 2014

• During 2014 other airports will follow taking into account ATCOs recurrent training needs

• RNP APCH procedures (CAT H) down to LPV minima developed for Milan Linate and Bergamo in the framework of ACCEPTA Project and already flight validated (AW 139) on 2013
PBN implementation – Training

**Air Traffic Controllers training completed**

• Training modules on PBN familiarization, RNAV 1 procedures and GNSS approaches, including operational aspects, started from autumn 2012 for **radar CTR**
  ➢ Venezia, Olbia, Firenze and Bologna approach controllers training already completed

• Training module on PBN, RNAV 1 and GNSS approach procedure already **performed** in **Milan and Rome TMA**

• Training modules for Procedure Designers in the framework of continuous training programme

• Training modules for ATCOs operating in radar CTR
  ➢ PBN familiarization and RNAV 1 procedures, including operational aspects: next to be planned **Torino** and **Verona**, according to the implementation schedule
  ➢ GNSS approach procedures: planned according to the implementation schedule

• Operational training modules on PBN and related procedure management for ATCOs instructors operating at the ENAV Academy

• Training modules on PBN familiarization for all people involved in operational activities

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**PBN training plan**

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ENAV
PBN IFPs vs Conventional IFPs: Design issues
The PBN Concept

Sensor Based Navigation
Based only on navigation accuracy

Performance Based Navigation
made up of 4 elements + functionality required
RNAV and RNP Navigation Specifications (1)

What is a Nav Spec?

A set of **aircraft** and **aircrew requirements** needed to support PBN operations within a defined airspace

RNAV ≠ RNP

RNP = RNAV + Monitoring and Alerting functions
### RNAV and RNP Navigation Specifications (2)

#### Table II-A-1. Application of navigation specification by flight phase

<table>
<thead>
<tr>
<th>Part Chapter</th>
<th>Navigation Specification</th>
<th>En-route oceanic/remote</th>
<th>En-route continental</th>
<th>Arrival</th>
<th>Approach</th>
<th>DEP</th>
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<tbody>
<tr>
<td>B Ch.1</td>
<td>RNAV 10</td>
<td>10</td>
<td></td>
<td></td>
<td>Initial</td>
<td></td>
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<td>B Ch.2</td>
<td>RNAV 5</td>
<td>5</td>
<td>5</td>
<td>1</td>
<td>Intermediate</td>
<td>Final</td>
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<td>B Ch.3</td>
<td>RNAV 2</td>
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<td>2</td>
<td>2</td>
<td>Missed</td>
<td></td>
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<td>B Ch.4</td>
<td>RNAV 1</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
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<tr>
<td>C Ch.1</td>
<td>RNP 4</td>
<td>4</td>
<td></td>
<td></td>
<td>Initial</td>
<td></td>
</tr>
<tr>
<td>C Ch.2</td>
<td>RNP 2</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C Ch.4</td>
<td>RNP 1&lt;sup&gt;1&lt;/sup&gt;</td>
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<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>C Ch.5</td>
<td>Advanced RNP&lt;sup&gt;4&lt;/sup&gt;</td>
<td>2&lt;sup&gt;4&lt;/sup&gt;</td>
<td>2 or 1</td>
<td>1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>C Ch.6</td>
<td>RNP APCH&lt;sup&gt;6&lt;/sup&gt;</td>
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<td>1&lt;sup&gt;6&lt;/sup&gt;</td>
<td>1&lt;sup&gt;6&lt;/sup&gt;</td>
<td>0.3&lt;sup&gt;7&lt;/sup&gt;</td>
<td>1&lt;sup&gt;6&lt;/sup&gt;</td>
</tr>
<tr>
<td>C Ch.7</td>
<td>RNP 0.3&lt;sup&gt;8&lt;/sup&gt;</td>
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<td>0.3&lt;sup&gt;8&lt;/sup&gt;</td>
<td>0.3&lt;sup&gt;8&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

#### Notes:
1. Only applies once 50m (40m Cat H) obstacle clearance has been achieved after the start of climb.
2. RNAV 5 is an en-route navigation specification which may be used for the initial part of a STAR outside 30 NM and above MSA.
3. The RNP 1 specification is limited to use on STARs, SIDs, the initial and intermediate segments of instrument approach procedures and the missed approach after the initial climb phase; beyond 30 NM from the airport reference point (ARP), the accuracy value for alerting becomes 2 NM.
4. Advanced RNP also permits a range of scalable RNP lateral navigation accuracies – see Part C, Chapter 4, para 4.3.3.3.4.
5. Optional – requires higher continuity.
6. There are two sections to the RNP APCH specification, Part A is enabled by GNSS and Baro VNAV, Part B is enabled by SBAS.
7. RNP 0.3 is applicable to RNP APCH Part A. Different angular performance requirements are applicable to RNP APCH Part B only.
8. The RNP 0.3 specification is primarily intended for helicopter operations.
RNAV and RNP Navigation Specifications (3)
RNAV Approach – Definition*

RNAV Approach – is a generic name for any kind of approach that is designed to be flown using the onboard area navigation system. It uses waypoints to describe the path to be flown instead of headings and radials to/from ground-based navigation aids. RNP APCH navigation specification is synonym of RNAV approach.

* [Ref. ICAO EUR Doc 025, RNP APCH Guidance Material]
The Background to RNP APCH Implementation

• ICAO Assembly Resolutions A37-11 (APV+LNAV or LNAV standalone where APV not implementable by the end of 2016)

• Strategic Objectives (e.g. Safety, Accessibility)

• Aircraft Operators request
RNAV Procedures – Expected Operational Benefits

**RNAV 1 (SIDs/STARs)**
- Improve traffic flows management
- Design nominal trajectories as much conflict-free as possible

  + Flight Efficiency
    – Workload for ATCOs and Pilots

**RNP APCH**
- Assure suitable back-up to ILS (e.g. maintenance/failure)
- Provide Vertical Guidance to RWY ends not ILS – equipped (DA<MDA)
- Design Instrument Approach Procedures where only Visual Manoeuvring is possible today

  + Pilot Situational Awareness  >  + Safety
    + Airport Accessibility
GNSS systems supporting PBN Operations

- Geostationary Satellite Based Augmentation System (SBAS)
- Aircraft Based Augmentation System (ABAS)
- Ground Based Augmentation System (GBAS)
- GPS
- GLONASS
- GALILEO (TBD)
- RAIM
- AAIM

RAIM: Receiver Autonomous Integrity Monitoring
AAIM: Aircraft Autonomous Integrity Monitoring
# RNAV Approach Classification

<table>
<thead>
<tr>
<th>RNP APCH</th>
<th>Requirements</th>
<th>Vertical Guidance</th>
<th>Chart Minima</th>
</tr>
</thead>
<tbody>
<tr>
<td>NPA</td>
<td>BASIC GNSS (core constellation + ABAS)</td>
<td></td>
<td>Down to LNAV (MDA)</td>
</tr>
<tr>
<td>APV Baro-VNAV</td>
<td>BASIC GNSS + BARO VNAV (Vertical Guidance information provided by Barometric Altimeter and referenced to a nominal VPA)</td>
<td>✓</td>
<td>Down to LNAV/VNAV (DA)</td>
</tr>
<tr>
<td>APV SBAS</td>
<td>core constellation + SBAS</td>
<td>✓</td>
<td>Down to LPV (DA)</td>
</tr>
</tbody>
</table>
Construction Criteria
Conventional

• Protection Areas based on the system in use accuracies (e.g. VOR 7.8° /2NM)
• Area Width and Track Alignment reliance on facility position (for a given segment)
• Secondary Areas applied not everywhere
• Pilot interpreted flight procedures
Construction Criteria (1)

RNAV/RNP

- Procedure construction based on navigation system tolerances (XTT, ATT) and ½ AW
- Area Width and Track Alignment independent of the navigation source position (Final Approach always aligned with ERCL).
- Secondary areas generally applied on all RNAV legs
- FMS based procedures (needs for procedure coding)
Construction Criteria (2)
RNAV/RNP (BASIC GNSS)

- $XTT = TSE = PDE + NSE + FTE$
- $ATT = 0.8 \times TSE$ and
- $\frac{1}{2} AW = 1.5 \times XTT + BV$ \hspace{1cm} (BV to mitigate the not truly Gaussian distribution for FTE)

![Figure II-A-2-1. Lateral navigation errors (95 per cent)](image)

Table III-1-2-8. XTT and ATT, area semi-width for RNP APCH (CAT A to E) in initial/intermediate/final approach and missed approach phases of flight (NM)

<table>
<thead>
<tr>
<th>IF/LAF/missed approach (&lt;30 NM ARP)</th>
<th>FAF</th>
<th>MAPt</th>
<th>Missed approach (&lt;15 NM ARP)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$XTT$</td>
<td>$ATT$</td>
<td>$\frac{1}{2} A/W$</td>
<td>$XTT$</td>
</tr>
<tr>
<td>1.00</td>
<td>0.80</td>
<td>2.50</td>
<td>0.30</td>
</tr>
</tbody>
</table>
Obstacle Clearance Areas Comparison (VOR Vs LNAV)
Key elements for LNAV

• NPA Approach (no vertical guidance to pilots)

• MAPt defined

• SDF allowed in the final segment and not coded

• Obstacle Clearance Areas for Final and Missed Approach segments

• MOC concept applied to obstacle calculating OCA/H
Key elements for APV BARO - VNAV (1)

• Approach Procedures with computer-resolved **Vertical Guidance based on Barometric Altitude** and referenced to a specified Vertical Path Angle

• Temperature corrections and QNH crucial to calculate the reference VPA

• OAS based on the specific lateral guidance system (LNAV Areas) and MOC concept applied to assess obstacles in the Final and Missed Approach segments

• Baro-VNAV procedures are used in association with LNAV- only procedures

• The LNAV-only FAF and MAPt are used to define the areas but are not part of the VNAV procedure (DA instead of MDA)
Key elements for APV BARO - VNAV(2)
Key elements for APV – SBAS (1)

• Approach Procedures with Vertical Guidance based on SBAS provided information

• OAS similar to those for ILS and HL concept to assess obstacles in the Final and Missed Approach segments (Init. and Interm.), but with $\frac{1}{2}$ AW limited to a 0.95NM in the MA

• DA/H not lower than 300FT for NPA RWY ends and not lower than 250FT for PA RWY ends

• The Coding Process is a main step (FAS DB production). Guidance information referenced to the FAS coded and storaged in the on-board database

• An SBAS Channel (univocal) has to be assigned and provided on the Chart
Key elements for APV – SBAS (2)

Plan View

Profile View

FAS DB
Safety Issues (Nowadays Mitigations)

• MA procedures currently designed to be flown also in conventional navigation mode as back-up for RNAV
  ➢ DME/DME coverage evaluation at low altitudes in progress to reduce such mitigation

• RNAV Approach currently implemented on CTRs where Radar Service is provided (Radar Monitoring required)
  ➢ Performance Monitoring Reports will be provided on 2014 to eliminate such a Safety Requirement
Coding Issues

• MAPT located on THR (optimum position)
  
  ➢ A single approach chart can be published with the three OCA/H inside the minimum box (LNAV, LNAV/VNAV and LPV)
  
  ➢ Naming as RNAV \(_\text{(GNSS)}\) RWY XY

• MAPT not located on THR

  ➢ Separate charts has to be provided for LNAV and APV-BARO/SBAS
  
  ➢ Naming procedure convention as reported in PANS-OPS 8168 has to be used
Implementation aspects

- RNAV approach similar to ILS procedures, where published, (taking into account RNAV stabilization distances between waypoints) not to increase ATCOs workload
- RNAV1 specification until FAF (excluded)
- Intermediate Fix located not earlier than $4 \div 5$ NM from FAF to ease traffic management, sequencing and the need to perform a Stabilized Approach
A practical Example:
Bologna Airport
LIPE RNAV\(_{(GNSS)}\) RWY12
RNAV (GNSS) LIPE RWY12
RNAV (GNSS) LIPE RWY12 – Design Elements (1)

Initial and Intermediate Segments
RNAV (GNSS) LIPE RWY12 – Design Elements (2)

Final Approach Segment
Missed Approach Segment
Missed Approach Holding Patterns construction
RNAV (GNSS) LIPE RWY12 – Design Elements (5)

LPV OAS and Protection Areas
Required input to start the design activity for Beirut Apt

• 3 RWY Ends selection
• ATS Geography Data
  ➢ RWYs (THR, Declared distances etc.)
  ➢ Available Navaids and their nominal coverage
  ➢ Aeronautical Fixes
  ➢ Airspace (Lat and Vert limits, P-D-R zones)
  ➢ SIDs and STARs
  ➢ IFPs

• Terrain Information (Scale factor e.g.1:25.000 and sampling step)
• Obstacles (Coordinates in WGS84 and AMSL elevation)
• Temperature Data (low temperature of the coldest month of the year for the last five years of data, at the aerodrome elevation [Ref. ICAO 8168 Vol II, Note1 at the bottom of pag. III-3-4-3])
• SBAS channel number (request to be submitted to the ICAO Regional Office)
Thank You for Your Attention!