PBN Implementation from Industry perspective
RNAV, RNP & RNP AR
Hafid El Boukfaoui
Airbus ProSky
Objectives

- What is PBN? What’s the difference between RNAV, RNP and RNP AR?

- Why customers(airlines/ANSPs) need it?

- Why they need support for the deployment of PBN?
What is PBN?
Conventional Navigation Means

- Visual flight
- Position computation based on Ground Navigation Aids
  - NDB
  - VOR
  - DME
  - ILS
- Radar Guidance
Conventional Routes

- Defined based on old aircraft capabilities and use of conventional navigation means
  - Large protection areas and separation criteria to cope with limited accuracy of position estimation

- Based on Ground Navigation Aids
  - Overfly
  - Relative position

- Limited design flexibility
  - Leading to traffic saturation

Widely used but no more suitable due to traffic increase and high fuel cost
Global Navigation Satellite System

Providing highly accurate and reliable positioning
RNAV stands for Area Navigation

**RNAV** : Capability to fly any desired flight path, defined by waypoints such as geographic fixes (LAT/LONG) and not necessarily by ground navaids

“RNAV X” capability represents the linear lateral Accuracy of the Navigation system expected to be achieved 95% of the flight time

“RNAV X” capability directly affects the FMS navigation mode, thus the sensors required, without any Monitoring or Alerting function
RNP Concept: Navigation Performance by reference to MASPS DO-236/ED-75

- Desired Path
- Defined Path
- Estimated Position
- True Position

- Path Steering Error (PSE)
- Flight Technical Error (FTE)
- Path Definition Error (PDE)
- Position Estimation Error (PEE) or Navigation System Error (NSE)

Total System Error (TSE)
DO-236 / ED-75 RNP requirements

> ACCURACY
- Aircraft must remain within accuracy limit 95% of flight time
  - The maximum TSE with 95% probability $\leq 1 \times \text{RNP}$

> INTEGRITY
- Probability to transgress the containment limit set at $2 \times \text{RNP}$ without alert must be $< 10^{-5}/\text{FH}$

> CONTINUITY
- Probability of RNP capability loss with alert must be $< 10^{-4}/\text{FH}$
RNP Concept

\[
RNP = \begin{cases} 
\text{Navigation accuracy} \\
\text{On board containment integrity} \\
\text{Continuity of RNP capability} \\
\end{cases}
\]

+ On Board Performance Monitoring and Alerting (OBPMA)

RNP \( X = \) +/- X NM corridor for the accuracy limit,

+/- 2\( X \) NM corridor for the containment limit
• All PBN is based on area navigation (RNAV)
• To meet the required airspace operational requirements, PBN defines:
  • RNAV specifications
  • RNP specifications
PBN Manual

VOLUME I
Concept and Implementation Guidance

VOLUME II
Implementing RNAV and RNP

A NAVIGATION SPECIFICATION defines:

- What **PERFORMANCE** of RNAV system is required for aircraft operating on air traffic routes or instrument approach procedures, in a designated airspace
- Defined in term of accuracy, integrity, continuity and availability

- What **FUNCTIONALITIES** RNAV system must have to achieve performance
  - e.g. Display type, leg types….

- What **NAVIGATION SENSORS** must be integrated in RNAV system to achieve performance

- What **REQUIREMENTS** are placed on AIR CREW to achieve the required performance from the RNAV system
<table>
<thead>
<tr>
<th>PBN APPLICATION</th>
<th>RNAV2</th>
<th>RNAV1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Navaid</strong></td>
<td></td>
<td></td>
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<tr>
<td>Spec</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Navaid <strong>infrastructure</strong></td>
<td><strong>on board</strong></td>
<td><strong>DME</strong>&lt;br&gt;<strong>GNSS</strong>&lt;br&gt;<strong>INS</strong></td>
</tr>
<tr>
<td></td>
<td><strong>TSE</strong></td>
<td><strong>&lt;2 NM</strong></td>
</tr>
<tr>
<td><strong>Leg type</strong></td>
<td><strong>IF CF TF DF VA VM VI CA FA FM</strong></td>
<td><strong>IF CF TF DF VA VM VI CA FA FM</strong></td>
</tr>
<tr>
<td><strong>Function</strong></td>
<td><strong>Data base ( LOA)</strong>&lt;br&gt;<strong>FB turn</strong></td>
<td><strong>Data base ( LOA)</strong>&lt;br&gt;<strong>FB turn</strong></td>
</tr>
<tr>
<td><strong>Surveillance</strong></td>
<td><strong>Radar</strong></td>
<td><strong>Radar separation</strong>&lt;br&gt;<strong>Specific Safety Assessment</strong></td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td><strong>voice</strong></td>
<td><strong>voice</strong></td>
</tr>
<tr>
<td><strong>ATM</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Publication</strong></td>
<td><strong>RNAV 2</strong>&lt;br&gt;<strong>Critical DME if any</strong></td>
<td><strong>RNAV 1</strong>&lt;br&gt;<strong>Critical DME if any</strong></td>
</tr>
</tbody>
</table>
# PBN Nav Spec: RNP APCH & RNP AR

<table>
<thead>
<tr>
<th>PBN APPLICATION</th>
<th>RNP APCH</th>
<th>RNP AR</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nav Spec</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On board</td>
<td>OPMA</td>
<td>OPMA</td>
</tr>
<tr>
<td>TSE</td>
<td>Final 0.3 NM</td>
<td>From 0.3 to 0.1</td>
</tr>
<tr>
<td>Leg type</td>
<td>IF TF DF (VA CA FA)*</td>
<td>IF CF TF DF VA VM VI CA FA FM RF</td>
</tr>
<tr>
<td>Function</td>
<td>Data base ( LOA) FB turn</td>
<td>Data base ( LOA) FB turn VNAV</td>
</tr>
<tr>
<td><strong>Surveillance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>ATS or procedural</td>
<td>ATS or procedural</td>
</tr>
<tr>
<td><strong>Communication</strong></td>
<td></td>
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</tr>
<tr>
<td></td>
<td>voice</td>
<td>voice</td>
</tr>
<tr>
<td><strong>ATM</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Separation minima</td>
<td>Doc 4444</td>
<td>Doc 4444</td>
</tr>
<tr>
<td>Publication</td>
<td>RNP APCH RNAV (GNSS)</td>
<td>RNP AR RNAV (RNP)</td>
</tr>
</tbody>
</table>
Conventional Navigation

Limited use of airspace due to Waypoints ground based navaids defined.

Current Ground NAVAIDs
Eg: VOR/ADF

RNAV Navigation

Improved use of airspace due to Waypoints geographically defined.

Waypoints

RNP Navigation

Optimum use of airspace due to navigation system capability to contain aircraft position within a “tunnel”.

On board Performance Monitoring & Alerting

“curved” paths
<table>
<thead>
<tr>
<th>Condition</th>
<th>RNP Operation</th>
<th>RNP AR Operation</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNP Value 0.3</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>RNP Value &lt; 0.3 (down to 0.1)</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Straight segment between FAP and RWY</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Curve between FAP and RWY</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Minima DA / DH could be as low as 250ft</td>
<td>✓</td>
<td>*</td>
</tr>
<tr>
<td>Departure and/or missed approach RNP Value &lt; 1</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>
A word on A-RNP

RNAV
On Board Perf. Monitoring and Alerting system not mandatory
- RNAV 10
- RNAV 5
- RNAV 1
- RNAV 2

ADVANCED RNP (Advanced features: RF, FRT, …)

RNP
On Board Perf. Monitoring and Alerting system mandatory
- EN-ROUTE
- TERMINAL
- APPROACH
- RNP 4
- RNP 2
- RNP 1
- RNP AR
- RNP AR APCH
- RNP 0.3
for helicopter

New operations
A word on A-RNP

**NOTE:**
RF are optional for RNP APCH
RF are required for A-RNP and RNP AR (RF in Final segment only possible for RNP AR)
<table>
<thead>
<tr>
<th></th>
<th>FAA regulations</th>
<th>EASA regulations</th>
<th>Airbus A/C compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNP 1</td>
<td>AC90-105</td>
<td>No regulation</td>
<td>With GPS</td>
</tr>
<tr>
<td>RNP APCH</td>
<td>AC90-107</td>
<td>AMC20-27</td>
<td>LNAV: with GPS</td>
</tr>
<tr>
<td></td>
<td>(not yet released)</td>
<td></td>
<td><strong>LNAV/VNAV</strong>: with FMS2+GPS</td>
</tr>
<tr>
<td>Advanced RNP</td>
<td>AC90-105</td>
<td>No regulation</td>
<td>With FMS2+GPS</td>
</tr>
<tr>
<td>RNP AR</td>
<td>AC90-101A</td>
<td>AMC20-26</td>
<td>With specific MOD</td>
</tr>
</tbody>
</table>
Each application has its strengths and weaknesses

<table>
<thead>
<tr>
<th>TMA Application</th>
<th>A/c equipage requirements &amp; training</th>
<th>Flexibility of trajectories</th>
<th>Minima</th>
<th>Ops approval</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNP AR</td>
<td>High (a/c upgrade required, crews to be trained)</td>
<td>High (use of RF legs)</td>
<td>Medium</td>
<td>Heavy</td>
</tr>
<tr>
<td>Advanced RNP (RNP APCH with RF legs)</td>
<td>Low</td>
<td>Medium (use of RF legs)</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>RNP APCH</td>
<td>Low</td>
<td>Low</td>
<td>Medium/High</td>
<td>Light*</td>
</tr>
</tbody>
</table>

The selection of Nav Spec is always a compromise between the benefits expected, cost of operation (a/c upgrade, ops approval, crew training), ATM infrastructure readiness

* Europe is planning to remove requirements for ops approval for RNP APCH
Approaches: different augmentations

GLS (GBAS)
- Precision Approach
- Lateral and vertical guidance
- Decision Altitude vs. MDA
- CAT I only (for now)

LPV (SBAS)
- Localizer Performance with Vertical Guidance
- Only available in the U.S. and in Europe
- Charted as RNAV (GNSS)
- Not supported by Boeing and Airbus today except on A350

RNP (ABAS)
- Non Precision Approach with lateral guidance
- Based on GNSS (lateral) & Baro VNAV (Vertical Guidance)
- RNP APCH & RNP AR
- Charted as RNAV (GNSS) or RNAV (RNP)
Why Our Customers need it?
What PBN can bring to our customers?

3D trajectories

- Laterally, accurate and flexible trajectories
- Vertically, managed descent with CDO

Benefits in
- Airspace Capacity
- Safety
- Airport Access
- Efficiency (Track miles savings)
- Environment (noise, CO2)
PBN Benefits for ATC

Higher Predictability
Trajectory and time: better sequencing
Less Dispersion of Traffic
Easier to manage crossing of SIDs and Stars
Less Communication
Allowing ATCos to concentrate on their Tasks
PBN Benefits for Airlines

Optimized use of airspace
Improved capacity
Traffic de-confliction
Improved predictability of arrival time

RNP AR at OMAA

- De-confliction of OMAA arrivals and a corporate jet airport nearby
- Improved sequencing of traffic
PBN Benefits for Airlines

Lower Fuel Burn
Less distance to Fly
Better Vertical Profile
Fully Managed Descent

FACT RNP AR
for SAA

15nm saved

Conventional Arrival

Level flight segments

Continuous Descent Operation

Level flight segment

Optimized Segment(s)

About 200kg saved per CDO
PBN Benefits for Airlines

Safety
Can potentially Remove Circle to Land
Better Energy Management
Fully Managed Approach

Conventional approach: 5.5° then changed to 3°
RNP AR 0.3 at VNKT: 2.8° CDO

RNP AR 0.1 at EKVG: stabilized approach avoiding terrain and turbulence area
RNP AR 0.1 to ILS: lower minima
Why they need Support?
What it takes to implement PBN?

In high density airspace or terrain challenging environment, the deployment of PBN requires knowledge in

- procedure design
- air traffic management
- a/c performance and systems
- a/c operation services

Difficult for ANSP or airlines to do it alone given the wide range of expertise required, esp. when it comes to deployment in complex environment (high density airspace or challenging terrain)
And there come the regulations

<table>
<thead>
<tr>
<th>Legacy RNP</th>
<th>Airworthiness</th>
<th>OPS</th>
<th>Procedure</th>
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<tbody>
<tr>
<td>FAA RNP AR** Formerly SAAAR*</td>
<td>DO 236</td>
<td>JAR OPS AC 120.29A</td>
<td>PANS OPS TERPS</td>
</tr>
<tr>
<td>FAA RNP APCH LNAV and LNAV/VNAV</td>
<td></td>
<td>AC 90.105</td>
<td>Order 8260.52</td>
</tr>
<tr>
<td>ICAO RNP (AR)**</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EASA RNP APCH LNAV and LNAV/VNAV</td>
<td></td>
<td>AMC 20-27</td>
<td></td>
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<td></td>
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<td></td>
</tr>
</tbody>
</table>

* Special Aircraft and Aircrew Authorization Required
** Authorization Required
What it takes to implement PBN

There’s A LOT to do to materialize the operational benefits and be compliant with all applicable regulations.

- Airspace & procedure design
- Ops approval package
- FOSA
- Flight crew and ATC controller training
- Operational services

Need of a project and collaboration management
A full range of PBN services by Airbus ProSky

Airbus ProSky Services Offering

- Project Setup & New Procedure Design
- Cost/Benefit Analysis
- Data Survey
- FOSA
- Procedure Design
- Procedure Test & Validation
- OPS Application Package

PBN Operations

- Training
- GPS Prediction
- RNP Monitoring
- NDB Services

Project Setup & New Procedure Design

I. Cost/Benefit Analysis
II. Data Survey
III. FOSA
IV. Procedure Design
V. Procedure Testing & Validation
VI. OPS application Package & Support
VII. Upgrade Coordination
VIII. Procedure Update

PBN Operations

IX. Training
X. GPS Prediction
XI. RNP Monitoring
XII. Nav database validation
We are a link of the ATM collaboration chain