ICAO SARPs and Documentation on Navigation Infrastructure to Support PBN

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Workshop for the Implementation of Navigation Infrastructure to Support PBN and GNSS Precision Approach Operations in NAM/CAR/SAM regions,
15 -17 August 2016, Lima, Peru
Outline

• Assembly Resolution 37-11
• Global Air Navigation Plan (GANP)
• PBN Documentation Framework
• NAV Infrastructure Specification Documentation to Support PBN
Why PBN? A37-11

Approach procedures with vertical guidance (APV (Baro-VNAV)) including LNAV-only minima for all instrument runway ends by 2016

Time is running out to meet the Performance-based Navigation (PBN) objectives of A37-11
Global Air Navigation Plan (GANP)

- ICAO focus is on development and implementation of:
  - PBN
  - CCO and CDO
  - ATFM (including runway sequencing capabilities (AMAN/DMAN))
Our Priorities

PBN: Our Highest Priority

Prior to the development of the ASBU Modules, ICAO focused its efforts on the development and implementation of Performance-based Navigation (PBN), Continuous Descent Operations (CDO), Continuous Climb Operations (CCO) and runway sequencing capabilities (AMAN/DMAN).

The introduction of PBN has met the expectations of the entire aviation community. Current implementation plans should help deliver additional benefits but remain contingent upon adequate training, expert support to States, continued maintenance and development of international Standards and Recommended Practices (SARPs), and closer coordination between States and aviation stakeholders.
## Navigation Roadmap

### Enablers (Conventional)

<table>
<thead>
<tr>
<th>Navigation</th>
<th>Block 0</th>
<th>2018</th>
<th>Block 1</th>
<th>2024</th>
<th>Block 2</th>
<th>2030</th>
<th>Block 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>ILS/MLS</td>
<td>Retain to support precision approach and mitigate GNSS outage</td>
<td></td>
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<tr>
<td>DME</td>
<td>Optimize existing network to support PBN operations</td>
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<tr>
<td>VOR/NDB</td>
<td>Rationalize based on need and equipage</td>
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</tbody>
</table>

### Enablers (Satellite-Based)

<table>
<thead>
<tr>
<th>Core GNSS Constellations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single frequency (GPS/GLONASS)</td>
</tr>
<tr>
<td>Multi-Frequency/Multi-Constellation (GPS/GLONASS/BeiDou/Galileo)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>GNSS Augmentations</th>
</tr>
</thead>
<tbody>
<tr>
<td>SBAS</td>
</tr>
<tr>
<td>GBAS Cat I</td>
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<tr>
<td>GBAS Cat II/III</td>
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<tr>
<td>Multi-Freq GBAS/STAS</td>
</tr>
</tbody>
</table>

### Enablers

- APNT

### Capabilities (PBN - see roadmap)

- **PBN Operations**
  - B0-APTA, B0-CDO, B0-FRTO
  - B1-FRTO
  - B1-CDO
  - B3-TBO, B3-NOPS

### Capabilities (Precision Approach)

- **CAT I/II/III Landing**
  - ILS/MLS
  - GBAS Cat I
  - CAT I/II/III
  - GBAS LPV 200
  - B0-APTA
  - B1-APTA
<table>
<thead>
<tr>
<th>PBN Roadmap</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>NAVIGATION</th>
<th>BLOCK 0</th>
<th>2018</th>
<th>BLOCK 1</th>
<th>2024</th>
<th>BLOCK 2</th>
<th>2030</th>
<th>BLOCK 3</th>
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<tbody>
<tr>
<td>PBN</td>
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<tr>
<td>En-route Oceanic and Remote Continental</td>
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<td>RNAV 10 (RNP 10)</td>
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<td>RNP 4</td>
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<td>Advanced RNP</td>
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<td>RNP 0.3 (Helicopter only)</td>
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<td>En-route Continental</td>
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<td>RNAV 5</td>
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<td>Advanced RNP</td>
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<td>RNP 2</td>
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<td>FRT</td>
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<td>Terminal Airspace: Arrival &amp; Departure</td>
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<td>B1-RSEQ</td>
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<td>B1-FRTO</td>
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<td>B2-CDD</td>
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<td>Approach</td>
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<tr>
<td>RNP APCH (LPV, LNAV/VNAV, LNAV)</td>
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<td>RNP AR APCH (where beneficial)</td>
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<td>B1-APTA</td>
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<td>B0-APTA</td>
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Global Air Safety Plan (GASP)

- Identifies **PBN Products and Services** as one of the main implementation activities available to States (*No Country Left Behind*)

- “Many safety benefits can be gained from PBN implementation”
  - PBN instrument approaches with vertical guidance (APV) can help reduce probability of runway excursions and CFIT
PBN Documentation Framework

- PBN Ops Approval Manual (Doc 9997)
- Manual on PBN Use in Airspace Design (Doc 9992)
- RNP AR Procedure Design Manual (Doc 9905)
- PANS Ops Volume I & II
- CDO Manual (Doc 9931)
- CCO Manual (Doc 9993)
- Procedure QA Manual (Vol 1 to Vol 6) (Doc 9906)
NAV specifications

RNP Specifications
- RNP 4
- RNP 2
  - Oceanic and Remote
- RNP 1
- A-RNP
- RNP APCH
- RNP AR APCH
- RNP 0.3
  - En-route and terminal

RNAV Specifications
- Designation
  - RNP
    - with additional requirements to be determined (ex. 3D, 4D)
- Designation
  - RNAV 10
    - oceanic and Remote
- Designation
  - RNAV 5
  - RNAV 2
  - RNAV 1
    - En-route and terminal
Airspace concept and PBN

**AIR SPACE CONCEPT**

- COM
- NAV
- SUR
- ATM

**NAVIGATION PBN**

- Navigation Application
  - Navigation Specification
  - NAVAID Infrastructure

Doc 9992
Airspace concept constituents

Assumption: CNS/ATM/RWY/Traffic/MET

Airspace design:
- routes
- volumes
- sectors

Inter-facility
Letters of agreement
Sector interaction
Traffic assignment
(including regulation)

Special techniques
(CCO, CDO, etc.)

Flexible use of airspace
Airspace classification

Doc 9992
Airspace Concept Development and Implementation Process

**PLAN**
- Activity 1: Agree on operational requirements
- Activity 2: Create an airspace design team
- Activity 3: Agree on objectives, scope and timeline
- Activity 4: Analyse reference scenario
- Activity 5: Select safety criteria, safety policy and performance criteria
- Activity 6: Agree on CNS/ATM assumptions, enablers and constraints

**DESIGN**
- Activity 7: Design airspace routes and holds
- Activity 8: Design initial procedure
- Activity 9: Design airspace volumes and sectors
- Activity 10: Confirm ICAO navigation specification

**VALIDATE**
- Activity 11: Validate airspace concept
- Activity 12: Finalize procedure design
- Activity 13: Validate procedure

**IMPLEMENT**
- Activity 14: Integrate ATC system
- Activity 15: Develop awareness and training material
- Activity 16: Implement
- Activity 17: Conduct post-implementation review
PBN IMPLEMENTATION PROCESS

PROCESS 1: IDENTIFYING AN ICAO NAVIGATION SPECIFICATION FOR IMPLEMENTATION

Activity 6: Agree on CNS/ATM assumptions (allowing for identification of potential navigation specification)

• The airspace concept to be developed is based upon certain CNS/ATM assumptions.
• These assumptions must take account of the environment that is expected to exist at the time when the new airspace operation is intended to be implemented (e.g. in 20XX).
## CNS/ATM assumptions

### Traffic analysis
- Representative traffic sample
- Distribution — time/geography
- Cross-check adjacent facility traffic
- Instrument flight rules (IFR) visual flight rules (VFR) mix
- Civil/military mix
- Aircraft performance mix (jet/turboprop/helicopter)

### Runway in use (primary/secondary)
- Available runways/length
- Meteorological conditions
- Landing aids
- Greenfield site? Orientation choice?
- Runway usage statistics

### ATC system
- Sectors/personnel/equipment
- Traffic sequencing and management

### Navigation
- Aircraft navigation equipage
- NAV infrastructure and coverage
- PBN conventional mix

### Surveillance means/coverage
- Radar/ADS-B/MLAT/none

### Communications means/coverage
- Voice/datalink

*Doc 9992*
### Example of an application of RNAV and RNP specifications to ATS routes and instrument procedures

<table>
<thead>
<tr>
<th>NAVIGATION SPECIFICATION</th>
<th>FLIGHT PHASE</th>
<th>DEP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>En-route Oceanic/Remote</td>
<td>Arrival</td>
</tr>
<tr>
<td>RNAV 10</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>RNAV 5</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>RNAV 2</td>
<td>2</td>
<td>5</td>
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<tr>
<td>RNAV 1</td>
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<td>2</td>
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<tr>
<td>RNP 4</td>
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<tr>
<td>RNP 2</td>
<td>2</td>
<td>2</td>
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<tr>
<td>RNP 1</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Advanced RNP</td>
<td>2</td>
<td>2 or 1</td>
</tr>
<tr>
<td>RNP APCH</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>RNP AR APCH</td>
<td>1-0.1</td>
<td>1-0.1</td>
</tr>
<tr>
<td>RNP 0.3</td>
<td>0.3</td>
<td>0.3</td>
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<tr>
<td>----------------------------------------</td>
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<td>--------------------------</td>
</tr>
<tr>
<td>Oceanic/Remote</td>
<td>10</td>
<td>RNAV 10 / (RNP 10)</td>
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<tr>
<td></td>
<td>4</td>
<td>RNP 4</td>
</tr>
<tr>
<td>En route – Continental</td>
<td>5</td>
<td>RNAV 5</td>
</tr>
<tr>
<td>En route – Continental and Terminal</td>
<td>2</td>
<td>RNAV 2</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>RNP 2 (TBD)</td>
</tr>
<tr>
<td>Terminal</td>
<td>1</td>
<td>RNAV 1</td>
</tr>
<tr>
<td></td>
<td>1</td>
<td>Basic RNP 1</td>
</tr>
<tr>
<td>Approach</td>
<td>0.3</td>
<td>RNP APCH</td>
</tr>
<tr>
<td></td>
<td>0.3-0.1</td>
<td>RNP AR</td>
</tr>
</tbody>
</table>
NAV Infrastructure Specification Documentation to Support PBN (especially related to GNSS)

- Annex 10 Aeronautical Telecommunications Volume I, Radio Navigation Aids,
  CHAPTER 3. Specifications for radio navigation aids
  Appendix B Technical specifications for the Global Navigation Satellite System (GNSS)
  And other attachments includes:
  Attachment B, Strategy for Introduction and Application of Non-visual Aids to Approach and Landing and Attachment D Information and material for guidance in the application of the GNSS Standards and Recommended Practices


<table>
<thead>
<tr>
<th>NAV specification</th>
<th>Communication and Surveillance</th>
<th>Navigation</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNAV 10 (RNP 10)</td>
<td>Determined in the implementation process in accordance to local and regional characteristics</td>
<td>No ground-based Navaids required</td>
</tr>
</tbody>
</table>
| RNAV 5 (B RNAV)   | • Direct pilot to ATC Communications  
                     • Radar monitoring by ATS | • VOR/DME  
                     • DME/DME  
                     • INS/IRS  
                     • GNSS |
| RNAV 2/ RNAV 1    | • Direct pilot to ATC Communications  
                     • Radar surveillance by ATS | • GNSS  
                     • DME/DME  
                     • DME/DME/IRU  
                     • DME/VOR |
| RNP 4             | Determined in the implementation process in accordance to local and regional characteristics (CPDLC, ADS-C, …) | GNSS |
| RNP 2             | Determined based on operational considerations (route spacing, traffic density, etc.) | GNSS |
| RNP 1 (Basic)     | • Direct pilot to ATC Communications | GNSS |
| RNP APCH          | No specific requirements. Obstacle clearance required | • GNSS down to LNAV or LNAV/VNAV minima (SBAS, etc.)  
                     • Missed approach segment (conventional navaids) |
| RNP AR APCH       | No specific requirements. | GNSS  
                     DME/DME as alternative |
| RNP 0.3           | No specific requirements. | GNSS |
PBN Validation

Guidance

- PBN Manual (DOC 9613)
- Quality Assurance Manual for Flight Procedure Design (Doc 9906),
  - Volume 5 - Validation of Instrument Flight Procedures.
  - Volume 6 - Flight Validation Pilot Training and Evaluation
PBN Validation

PBN Manual (DOC 9613)
Implementation Guidance

PROCESS 2 PHASE 3: VALIDATION

Step 13a — Instrument Flight Procedure (IFP) validation

PBN Validation

THE VALIDATION PROCESS
### Requirements for the Global Navigation Satellite System (GNSS)  
**Signal-in-space performance requirements**

<table>
<thead>
<tr>
<th>Typical operation</th>
<th>Accuracy horizontal 95% (Notes 1 and 3)</th>
<th>Accuracy vertical 95% (Notes 1 and 3)</th>
<th>Integrity (Note 2)</th>
<th>Time-to-alert (Note 3)</th>
<th>Continuity (Note 4)</th>
<th>Availability (Note 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>En-route</td>
<td>3.7 km (2.0 NM)</td>
<td>N/A</td>
<td>$1 - 1 \times 10^{-7}$/h</td>
<td>5 min</td>
<td>$1 - 1 \times 10^{-6}$/h to $1 - 1 \times 10^{-8}$/h</td>
<td>0.99 to 0.999999</td>
</tr>
<tr>
<td>En-route, Terminal</td>
<td>0.74 km (0.4 NM)</td>
<td>N/A</td>
<td>$1 - 1 \times 10^{-7}$/h</td>
<td>15 s</td>
<td>$1 - 1 \times 10^{-6}$/h to $1 - 1 \times 10^{-8}$/h</td>
<td>0.99 to 0.999999</td>
</tr>
<tr>
<td>Initial approach, Intermediate approach, Non-precision approach (NPA), Departure</td>
<td>220 m (720 ft)</td>
<td>N/A</td>
<td>$1 - 1 \times 10^{-7}$/h</td>
<td>10 s</td>
<td>$1 - 1 \times 10^{-6}$/h to $1 - 1 \times 10^{-8}$/h</td>
<td>0.99 to 0.999999</td>
</tr>
<tr>
<td>Approach operations with vertical guidance (APV-I)</td>
<td>16.0 m (52 ft)</td>
<td>20 m (66 ft)</td>
<td>$1 - 2 \times 10^{-7}$ in any approach</td>
<td>10 s</td>
<td>$1 - 8 \times 10^{-6}$ per 15 s</td>
<td>0.99 to 0.999999</td>
</tr>
<tr>
<td>Approach operations with vertical guidance (APV-II)</td>
<td>16.0 m (52 ft)</td>
<td>8.0 m (26 ft)</td>
<td>$1 - 2 \times 10^{-7}$ in any approach</td>
<td>6 s</td>
<td>$1 - 8 \times 10^{-6}$ per 15 s</td>
<td>0.99 to 0.999999</td>
</tr>
<tr>
<td>Category I precision approach (Note 7)</td>
<td>16.0 m (52 ft)</td>
<td>6.0 m to 4.0 m (20 ft to 13 ft) (Note 6)</td>
<td>$1 - 2 \times 10^{-7}$ in any approach</td>
<td>6 s</td>
<td>$1 - 8 \times 10^{-6}$ per 15 s</td>
<td>0.99 to 0.999999</td>
</tr>
</tbody>
</table>
Other Standards and Guidance Material to support PBN

- ATM Operational Concept, Doc 9735, RPB/ANIP
- ATM system requirements
- PANS-ATM for ATS use based on radar, ADS-B, GNSS for lateral & longitudinal separation
- Safety assessment
- PBN airspace concept: Regional performance framework and training (pilots, ATCOs) for En-route (Oceanic/Domestic), TMA and RNP approach procedures Doc 7030 & Doc 8733; develop a PFA, as required (ANI/WG/3, WP xx)
- Update LOAs
- Development of transition strategies (pre-tactical)