Performance Based Navigation
Navigating in the 21st Century

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Performance Based Navigation (PBN)

Benefits:
- Increased safety
- Improved flight efficiency
  - Lower emissions
  - Less total noise exposure
- Increased capacity
  - More route options
- Improved airport access in IMC
- Improved predictability
  - Trajectory Based Operations

Challenges:
- Community concerns
  - Noise concentration
  - Noise transfer
- Aircraft equipage
PBN Procedures by Phase of Flight

<table>
<thead>
<tr>
<th>DEPARTURE/ASCENT</th>
<th>EN ROUTE/CRUISE</th>
<th>ARRIVAL/DESCENT</th>
<th>APPROACH/LANDING</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNAV-1 DP</td>
<td>Q Routes</td>
<td>RNAV-1 STAR</td>
<td>RNAV (GPS)</td>
</tr>
<tr>
<td></td>
<td>T Routes</td>
<td></td>
<td>LNAV</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>LNAV/VNAV</td>
</tr>
<tr>
<td></td>
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<td></td>
<td>LP</td>
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<td></td>
<td></td>
<td></td>
<td>LPV</td>
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<td></td>
<td></td>
<td></td>
<td>RNP AR</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>RNP 0.3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>RNP 0.15</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>RNP 0.1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>GLS</td>
</tr>
</tbody>
</table>

Up to 250 nm

Up to 250 nm

Up to 20 nm

DP – Departure Procedures
GBAS – Ground-Based Augmentation System
GLS – GBAS Landing System
LNAV – Lateral Navigation
LP – Localizer Precision

LPV – Localizer Precision with Vertical Guidance
RNAV – Area Navigation
RNP – Required Navigation Performance
STAR – Standard Terminal Arrival Route
VNAV – Vertical Navigation
Performance Based Navigation (PBN)
As of: Nov. 2018

Key
- Airport with STAR
- Airport with SID
- Airport with RNP

<table>
<thead>
<tr>
<th>Type</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNAV SIDS</td>
<td>630</td>
</tr>
<tr>
<td>RNAV STARs</td>
<td>440</td>
</tr>
<tr>
<td>RNP ARs</td>
<td>413</td>
</tr>
<tr>
<td>Airports</td>
<td>523</td>
</tr>
</tbody>
</table>
Metroplex Performance Based Navigation (PBN)
As of: Nov. 2018
## Airports with RNAV (GPS) Approaches

As of: Jan. 2019

<table>
<thead>
<tr>
<th>Approach Type</th>
<th>Non-Part 139 Airports</th>
<th>Part 139 Airports</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>LPV</td>
<td>1,450</td>
<td>481</td>
<td>1,931</td>
</tr>
<tr>
<td>LPV w/200’ DH</td>
<td>318</td>
<td>719</td>
<td>1,037</td>
</tr>
<tr>
<td>LNAV/VNAV</td>
<td>1,385</td>
<td>478</td>
<td>1,863</td>
</tr>
<tr>
<td>LNAV</td>
<td>2,329</td>
<td>535</td>
<td>2,864</td>
</tr>
<tr>
<td>LP</td>
<td>447</td>
<td>75</td>
<td>522</td>
</tr>
</tbody>
</table>
Required Navigational Performance (RNP)

- RNP extends an aircraft’s RNAV capability with on-board performance monitoring and alerting functions.
- RNP provides high confidence that an aircraft will precisely follow a desired path (i.e., procedure).
- Airspace planners can design RNP procedures with tight segments and complex curved paths.
- FAA is allowing reduced separation minima on approach, in certain specific circumstances, for aircraft using RNP Authorization Required (AR) approach procedures.

Total System Error = Path Definition + Flight Technical + Navigation System Errors

For **RNP 0.3**,
- TSE must remain ≤ 0.3 nmi for 95% of the flight time
- \( P(TSE > 2 \cdot 0.3 \text{ nmi w/o annunciation}) < 10^{-5} \)

**RNP AR** procedures require a TSE lower than for standard RNP procedures.
- For RNP AR an aircraft typically requires:
  - Dual GNSS sensors
  - Dual FMS
  - Dual air data systems
  - Dual autopilots
  - Inertial Reference Unit (IRU)
RNP Approach Example
DCA 19 – Ronald Reagan Washington National Airport

- Safety enhancement, with 3-D path to runway
- Provides a corridor which avoids restricted airspace
- RNP AR approach significantly improves availability of Runway 19 during low visibility conditions
  - There is no ILS for Runway 19
## RNP Approach Benefits

<table>
<thead>
<tr>
<th>Converging Approaches</th>
<th>Lower Minima</th>
<th>Noise Abatement</th>
<th>Airport De-Confliction</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Diagram" /> Early, guided turns on missed approach.</td>
<td><img src="image2.png" alt="Diagram" /> Lower Decision Height (DH)</td>
<td><img src="image3.png" alt="Diagram" /> Avoids noise-sensitive area</td>
<td><img src="image4.png" alt="Diagram" /> Allows proximate airports to maintain capacity</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Geographic Mitigation</th>
<th>Improved Vertical Guidance</th>
<th>Improved Parallel Approaches</th>
<th>Defined Turn to Final</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image5.png" alt="Diagram" /> Avoids Special Activity Airspace or high terrain</td>
<td><img src="image6.png" alt="Diagram" /> Alt. restrictions removed, vert. guidance further from runway</td>
<td><img src="image7.png" alt="Diagram" /> Simultaneous approaches to parallel runways</td>
<td><img src="image8.png" alt="Diagram" /> Defined turn to final yields a shorter flight path</td>
</tr>
</tbody>
</table>
Established on RNP (EoR)

- Allows ATC to clear an aircraft on an RNP approach incorporating a turn to final without ensuring 1,000 ft. vertical / 3 mile horizontal separation from aircraft on parallel approaches
- Provides a shorter, repeatable, stabilized path to runway for RNP aircraft
EoR at IAH
Multiple Airport Route Separation (MARS)

- Uses RNP and EoR concept to de-conflict traffic flows to separate airports
- Currently being explored for application in New York

Notional Example: JFK ILS 13L

*Before*

- Vertical Separation
- Missed approach
- ILS Rw 13L
- Parkway Visual
- RNP Special

*After*

- Vertical Separation
- Missed approach
- ILS Rw 13L
- Parkway Visual
- RNP Special

MITRE
PBN NAS Navigation Strategy

Key Elements

- Clear vision of PBN as the basis for daily operations at all locations in the NAS
- Identification of key navigation capabilities that will be available in the NAS over the next 15 years
- Defined Navigation Service Groups (NSG) for navigation capabilities
- Expectations for evolution of operator capabilities
- Emphasizes stakeholder/community engagement and collaboration
Navigation Services across Airport Groups
Summary of Availability in the Far-Term (2026-2030)
Trajectory Based Operations (TBO)

‘TBO is an ATM method for strategically planning, managing, and optimizing flights throughout the operation by using time-based management, information exchange between air and ground systems, and the aircraft’s ability to fly precise paths in time and space.’
TBO = TBM + PBN

TBO manages aircraft based on where they will be at “critical points in time” during the flight. Two key elements of TBO are (1) Performance Based Navigation and (2) Time-Based Management.

Trajectory Based Operations Objectives

- Efficient use of available airspace and airports
- Improved schedule predictability - fewer delays

- Increased operational flexibility
- Improved flight efficiency – shorter flight distance and flight time between cities
IF YOU STOP EVOLVING YOU STOP FLYING.