Operators may need to retrofit their airplanes to ensure existing fleets are properly equipped for RNP operations.
Equipping a Fleet for Required Navigation Performance

Required navigation performance (RNP) is the global benchmark for all future aviation navigation. Operators need a properly equipped fleet to receive RNP operational approval and take advantage of the benefits offered by RNP operations.

By Dan Ellis, Avionics Design Engineer, Flight Management Systems; Gary Limesand, Model Focal, Flight Deck/Crew Operations; and Bill Syblon, Flight Operations Specialist, Modification Services

RNP operations can improve the safety, capacity, efficiency, access, and environmental impact of the greater airspace system, providing real economic benefits for RNP operators. RNP also is the foundation to evolving ATM operations and establishes a basis for global interoperability. Operators must understand the airplane equipage requirements for RNP operations in order to determine what level of capability and operational approval will offer them the greatest benefit.

This article provides a standardized equipage configuration for each model, suitable for all RNP applications. It also explains concepts surrounding RNP and explores existing RNP standards.

REQUiRED NaviG atioN PERfoR maNc E DEfiNED

RNP is a statement of the navigation performance necessary for operation within a defined airspace. Specifically, RNP can be visualized as the requirement to keep the actual airplane position within a specified radius for a given percentage of the time. RNP is formally defined by four main terms:

Accuracy: The requirement to keep the actual airplane position within a radius that is $1\times\text{RNP}$ for 95 percent of the time.

Integrity: The requirement to keep the actual airplane position within a radius that is $2\times\text{RNP}$ for 99.999 percent of the time.

Availability: The probability, using general risk, that the navigation service (e.g., global positioning system [GPS], distance measuring equipment [DME] infrastructure) providing the required accuracy and integrity will be present during the intended operation.

Continuity: The probability, using specific risk, that the navigation system (e.g., flight management system [FMS] and other equipment) will provide the required accuracy and integrity during the intended operation.

The required level of availability and continuity for a given route or procedure is established by the regulator and optionally improved upon by the operator. Figure 1 provides an example of a Boeing analysis for generalized availability while GPS
The availability of an RNP operation varies depending on the number of satellites operating in the global positioning system (GPS) constellation. For example, this table shows that general availability for an RNP 0.3-nmi operation is 99.98 percent when there are 24 satellites operating. This means the required accuracy and integrity will be unavailable one out of every 5,000 attempts. Operators can use estimates like this to evaluate whether the benefits of performing the intended operation outweigh the challenges posed by the given availability. Operators should refer to the applicable RNP capabilities document for the specific availability values for their fleet.

<table>
<thead>
<tr>
<th>Number of Satellites in GPS Constellation</th>
<th>Availability RNP 10 nmi</th>
<th>Availability RNP 4 nmi</th>
<th>Availability RNP 2 nmi</th>
<th>Availability RNP 1 nmi</th>
<th>Availability RNP 0.5 nmi</th>
<th>Availability RNP 0.3 nmi</th>
<th>Availability RNP 0.15 nmi</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>&gt;99.999%</td>
<td>&gt;99.999%</td>
<td>&gt;99.999%</td>
<td>&gt;99.999%</td>
<td>99.99%</td>
<td>99.98%</td>
<td>99.62%</td>
</tr>
<tr>
<td>23</td>
<td>&gt;99.999%</td>
<td>&gt;99.999%</td>
<td>&gt;99.999%</td>
<td>99.98%</td>
<td>99.87%</td>
<td>99.67%</td>
<td>97.76%</td>
</tr>
<tr>
<td>22</td>
<td>&gt;99.999%</td>
<td>99.90%</td>
<td>99.99%</td>
<td>99.82%</td>
<td>99.30%</td>
<td>98.61%</td>
<td>94.29%</td>
</tr>
<tr>
<td>21</td>
<td>&gt;99.999%</td>
<td>99.96%</td>
<td>99.89%</td>
<td>99.33%</td>
<td>98.10%</td>
<td>96.60%</td>
<td>89.34%</td>
</tr>
</tbody>
</table>

Figure 2: Performance-based navigation standards
Required navigation performance (RNP) and area navigation (rNav) are both part of performance-based navigation, a framework for defining navigation performance requirements that can be applied to an air traffic route, instrument procedure, or defined airspace.
--- | --- | --- | --- | ---
RNP Authorization Required | Terminal and Approach | ≤0.3 | AC 90-101A | AMC 20-26
RNP Approach | Approach | 0.3 | AC 90-105 | AMC 20-27
RNP 1 | Terminal and En Route | 1 | AC 90-100A | TGL-10/AMC 20-16
RNP 2 | Terminal and En Route | 2 | AC 90-100A | N/A
RNP 5 | Terminal and En Route | 5 | N/A | AMC 20-4
RNP 4 | Oceanic and Remote | 4 | Order 8400.33 | N/A
RNP 10 | Oceanic and Remote | 10 | Order 8400.12b | AMC 20-12

* The FAA and EASA standards have not been completely harmonized.

**Figure 3: Required navigation performance (RNP) and area navigation (RNAV) standards**

RNP is a subset of performance-based navigation (PBN), which also includes area navigation (RNAV) (see fig. 2). For an explanation of RNAV, see AERO second-quarter 2008.

As air traffic management (ATM) operations in the world evolve, there is an increasing dependence on RNP operations as a foundation for improvements in airspace design and management, safety, operational efficiencies, and environmental improvements. Many states have begun to implement changes in their ATM systems, and more are expected. These changes will allow airlines with RNP-capable airplanes to derive value from their existing capabilities. As the new ATM environments grow, providing more opportunities for operational efficiencies, it is expected that such benefits will offset the cost of equipage changes for airplanes.

**RNP in air traffic control**

RNP is an enabling technology for modernizing air traffic management, improving efficiency, and reducing environmental impacts. RNP allows airlines to use safer and more efficient flight paths that will enable a variety of possible benefits, including airspace efficiency through reduced separation, reduced fuel burn/emissions from shorter flight paths, and improved runway access from lower minima. RNP can be used in conjunction with RNAV or even with an instrument landing system (ILS) or global navigation satellite system landing system (GLS). RNP allows for better transition routes to these landing systems and better accommodation of missed approach paths.

The RNP concept enables airlines to gain efficiency by optimizing the use of available airspace, enabling reductions in aircraft separation, and enabling shorter routes by not being constrained by overflight of ground navigational-aid locations. RNP also allows for better use of all other airspace, such as oceanic and remote areas.

A fixed lateral flight path also affords better energy management and quieter climbs (i.e., up and away quicker at best climb gradient via a more direct path) and descents (i.e., idle or near-idle). Finally, RNP enables airlines to precisely control what their airplanes are flying over, such as avoiding noise-sensitive areas.

In the future, use of RNP routes and procedures is likely to be the best way to efficiently and cost-effectively accommodate and coordinate the various demands of all airspace users globally, from transports and unmanned aerial vehicles, to business and sport aviation, to security and military uses of airspace.

Increased application of RNP instrument procedures will allow for better use of multiple airport runway configurations for increased airport capacity.

**Qualifying for RNP operations**

To perform RNP operations, operators must apply for and receive operational approval from the applicable regulator. It is not enough for an operator to simply purchase and enable the RNP options in their fleet and confirm the airplane flight manual–demonstrated RNP supports the intended operation. Instead, operators must equip their fleets and establish appropriate procedures, documentation, and training as specified in the regulator’s published
RNP standard as part of the application process (see fig. 3).

Boeing provides full services around the world to completely equip and train operators for RNP operations. Additionally, Boeing completes applications for operational approval to qualify operators to become RNP certified through their regulators.

**RNP STANDARDS**

Existing and upcoming RNP standards will increasingly leverage RNP-capable systems in order to derive additional airspace system benefits (e.g., any one or all of capacity, efficiency, safety, or access). The current set of possible RNAV and RNP operations has differing equipage requirements. Before determining which type of RNP operations to equip for, airlines must understand their operational needs — including the primary level of operations and what level is acceptable for contingency operations at destinations served and planned.

The standards for each level of RNP are defined by various regulators, including the U.S. Federal Aviation Administration (FAA) and the European Aviation Safety Agency (EASA) (see fig. 3). The FAA and EASA have slightly different definitions of what constitutes an RNP-capable system.

---

**U.S. Federal Aviation Administration and European Aviation Safety Agency Requirements**

<table>
<thead>
<tr>
<th>RNP Capability — Required Hardware/Features</th>
<th>Boeing Recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-mode receivers (included in basic airplane configuration)</td>
<td>Speed and altitude intervention activation (Boeing recommendation).</td>
</tr>
<tr>
<td>Two flight management computers (FMCs) (dual).</td>
<td>Navigation performance scales (airplane flight manual RNP 0.10).</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>RNP AR 0.30 nmi Final and 1.0 nmi Missed Approach</th>
<th>Boeing recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Captain’s FMC, multipurpose control and display unit (MCDU), and inboard display unit on standby power.</td>
<td>Default distance measuring equipment (DME) update to off (if required by procedure).</td>
</tr>
<tr>
<td>Navigation performance scales (airplane flight manual RNP 0.10).</td>
<td>Takeoff/go-around (TOGA) to lateral navigation (LNAV) go-around.</td>
</tr>
<tr>
<td>737-3C data frame software update to digital flight data acquisition unit.</td>
<td>Flight control computer 710 or P3.0 software or later.</td>
</tr>
<tr>
<td>Common display system (CDS) operational software (OPS) 2004A software or later.</td>
<td>CDS OPS 2004A software or later.</td>
</tr>
<tr>
<td>Takeoff/go-around (TOGA) to lateral navigation (LNAV) go-around.</td>
<td>FMC U10.6 software or later.</td>
</tr>
</tbody>
</table>

---

**EQUIPPING AN EXISTING FLEET FOR RNP OPERATIONS**

Boeing has defined the specific equipment requirements for each of its commercial airplane models that are available for RNP equipage retrofit: 737-300/-400/-500, Next-Generation 737, 757, 767, 747-400, 777, MD-10, MD-11, 717, MD-80, and MD-90. Figure 4 provides one example, listing the RNP AR equipage requirements for a Next-Generation 737.

While specific airplane equipment requirements must be met for each level of operational approval, Boeing has defined a minimum demonstrated RNP for each airplane model.

**RNP EQUIPAGE RETROFITTING AND OPERATIONAL APPROVAL SERVICES FROM BOEING**

Boeing provides an integrated RNP retrofitting and operational approval program. Boeing works with operators to identify the markets and airplanes in their fleets that will offer the greatest return on their RNP capability investment and then manages all phases of the implementation process. This includes:

- Designing and validating RNP procedures.
- Establishing operational specifications and operations manual revisions, as required by the airline.
- Identifying and managing suppliers and contractor services.
- Instituting the rigorous navigation data services necessary for RNP operations and regulatory approval.
- Developing avionics configuration recommendations to support fleet RNP capabilities and providing a modification kit, if required.
- Providing flight crew and dispatcher training, if required.
- Supporting airlines in gaining regulatory approval for RNP operations.

---

**SUMMARY**

Depending on the types of intended operations and the evolving nature of air traffic operations globally, retrofitting an operator’s existing fleet for RNP operations may be required. Boeing is prepared to support RNP implementation by guiding operators through the entire retrofit and operational approval process.

For more information, please contact Boeing Modification Services at modservices@boeing.com.

---

Figure 4: 737-600/-700/-800/-900: Standardized equipment configuration

Required configurations for other Boeing models are available in the online version of this article (see www.boeing.com/commercial/aeromagazine).

---

<table>
<thead>
<tr>
<th>RNP AR &lt;0.30 nmi Final and/or &lt;1.0 nmi Missed Approach</th>
<th>Boeing recommendation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Default distance measuring equipment (DME) update to off (if required by procedure).</td>
<td>Takeoff/go-around (TOGA) to lateral navigation (LNAV) go-around.</td>
</tr>
<tr>
<td>Navigation performance scales (airplane flight manual RNP 0.10).</td>
<td>Flight control computer 710 or P3.0 software or later.</td>
</tr>
<tr>
<td>737-3C data frame software update to digital flight data acquisition unit.</td>
<td>CDS OPS 2004A software or later.</td>
</tr>
<tr>
<td>Common display system (CDS) operational software (OPS) 2004A software or later.</td>
<td>FMC U10.6 software or later.</td>
</tr>
</tbody>
</table>