



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.

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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 equipment 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 equipment configuration for each model, suitable for all RNP applications. It also explains concepts surrounding RNP and explores existing RNP standards.

REQUIRED NAVIGATION PERFORMANCE 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 1xRNP for 95 percent of the time.

Integrity: The requirement to keep the actual airplane position within a radius that is 2xRNP 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

Figure 1: Example of worldwide navigation availability for selected required navigation performance (RNP) with GPS updating

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.

Number of Satellites in GPS Constellation	Availability RNP 10 nmi	Availability RNP 4 nmi	Availability RNP 2 nmi	Availability RNP 1 nmi	Availability RNP 0.5 nmi	Availability RNP 0.3 nmi	Availability RNP 0.15 nmi
24	>99.999%	>99.999%	>99.999%	>99.999%	99.99%	99.98%	99.62%
23	>99.999%	>99.999%	>99.999%	99.98%	99.87%	99.67%	97.76%
22	>99.999%	99.99%	99.99%	99.82%	99.30%	98.61%	94.29%
21	>99.999%	99.96%	99.89%	99.33%	98.10%	96.60%	89.34%

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.

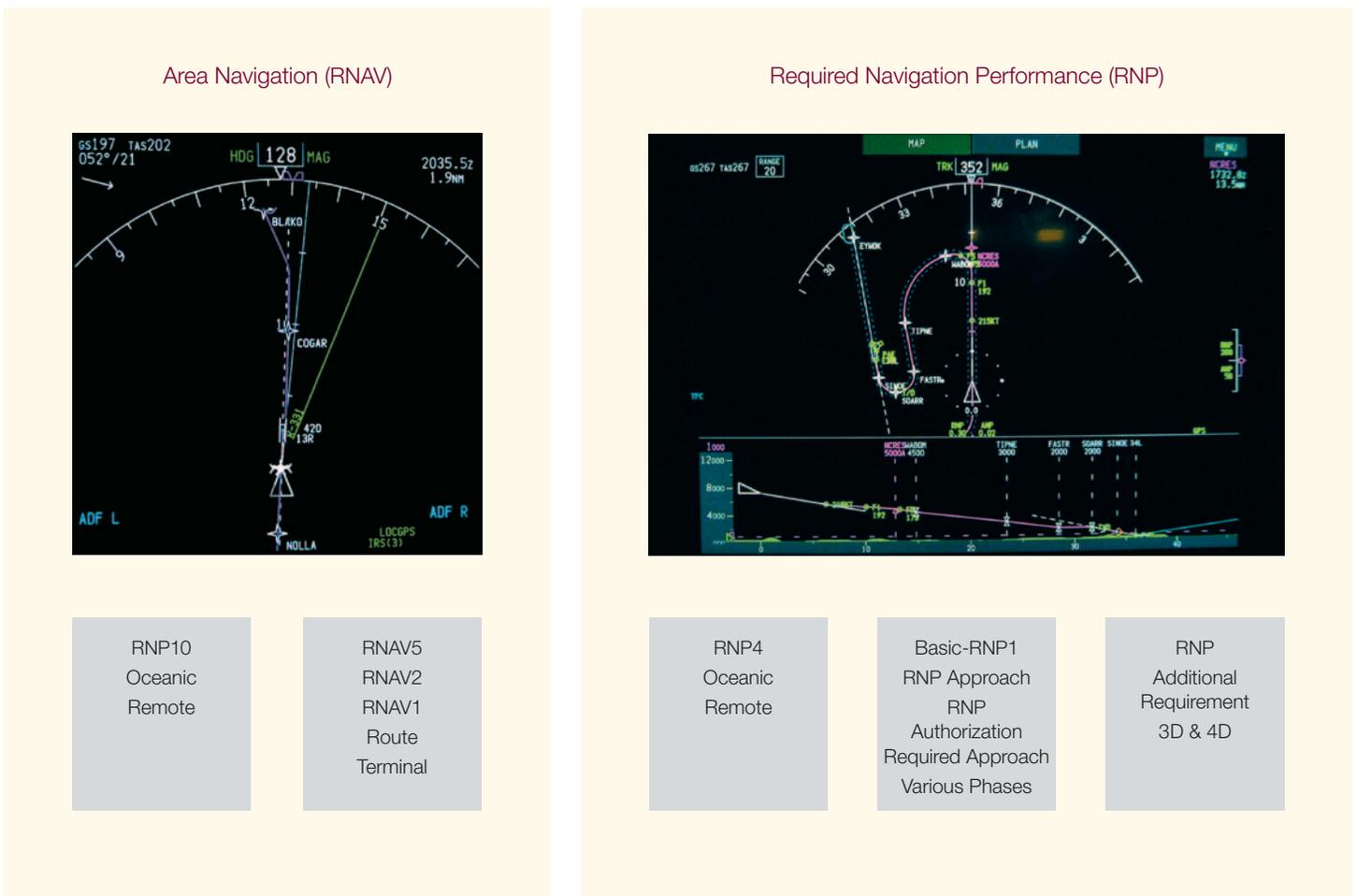


Figure 3: Required navigation performance (RNP) and area navigation (RNAV) standards*

Navigational Specification	Area of Application	Navigational Accuracy (nmi)	Applicable Regulatory Document	
			Federal Aviation Administration	European Aviation Safety Agency/Joint Aviation Authorities
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
RNAV 1	Terminal and En Route	1	AC 90-100A	TGL-10/AMC 20-16
RNAV 2	Terminal and En Route	2	AC 90-100A	N/A
RNAV 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.

updating. Route- and region-specific analysis tools are available outside Boeing and may yield different results.

Actual navigation performance (ANP) represents the current 95 percent accuracy of the Boeing FMS position. ANP and RNP are displayed in nautical miles on the navigation displays and the control and display units.

When ANP exceeds RNP, an UNABLE RNP message is displayed to the flight crew. This indicates that the FMS position does not meet the required accuracy, so the procedure (such as an approach) must be aborted.

RNP IN AIR TRAFFIC CONTROL

RNP is a key component of the basic air-traffic services triad of communication, navigation, and surveillance (or monitoring) that is required for a safe and efficient airspace system.

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 equipment changes for airplanes.

BENEFITS TO AIRLINES, AIRPORT AUTHORITIES, AND COMMUNITIES

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

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).

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

RNP Capability — Required Hardware/Features	<ul style="list-style-type: none"> ■ Multi-mode receivers (included in basic airplane configuration)
RNP AR 0.30 nmi Final and 1.0 nmi Missed Approach	<ul style="list-style-type: none"> ■ Speed and altitude intervention activation (Boeing recommendation). ■ Two flight management computers (FMCs) (dual).
RNP AR <0.30 nmi Final and/or <1.0 nmi Missed Approach	<ul style="list-style-type: none"> ■ Captain’s FMC, multipurpose control and display unit (MCDU), and inboard display unit on standby power. ■ Default distance measuring equipment (DME) update to off (if required by procedure). ■ Navigation performance scales (airplane flight manual RNP 0.10). <ul style="list-style-type: none"> □ 737-3C data frame software update to digital flight data acquisition unit. □ Common display system (CDS) operational software (OPS) 2004A software or later. ■ Takeoff/go-around (TOGA) to lateral navigation (LNAV) go-around. <ul style="list-style-type: none"> □ Flight control computer 710 or P3.0 software or later. □ CDS OPS 2004A software or later. □ FMC U10.6 software or later.

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.

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. **A**