Honeywell

UNDERSTANDING PBN, RNAV AND RNP OPERATIONS AND THEIR BENEFITS TO AIRLINE OPERATORS

Introduction

In any discussion of next-generation airspace navigation, there are three key terms to know: PBN, RNAV and RNP.

Performance-Based Navigation (PBN) is a term used to describe the broad range of technologies that are moving aviation away from a ground-based navigation system toward a system that relies more on the performance and capabilities of equipment on board the aircraft.

It involves a major shift from conventional ground-based navigation aids and procedures to satellite-based navigation aids and area navigation procedures, which are more accurate and allow for shorter, more direct routes between two given points as well as more efficient takeoffs and landings. This reduces fuel burn, airport and airspace congestion, and aircraft emissions.

Area Navigation (RNAV) refers to a method of navigation which permits aircraft operation on any desired flight path within the coverage of ground- or space-based navigation aids or within the limits of the capability of self-contained aids, or a combination of these. (Area navigation includes Performance-Based Navigation as well as other legacy RNAV operations that do not meet the definition of performance-based navigation.)

And finally **Required Navigation Performance (RNP)** which is the latest-generation area navigation (RNAV) system which supports on-board performance monitoring and alerting. RNP allows the aircraft to be flown along a precise flight path with exceptional accuracy and most importantly, the ability to determine aircraft position with both accuracy and integrity and provide alerts if that required for the route flown is not adequate.

Table of contents

In any discussion of next-generation airspace navigation, there are three key terms to know: PBN, RNAV and RNP.

The following figures compare and contrast conventional navigation using ground-based navigation aids, RNAV and RNAV RNP.

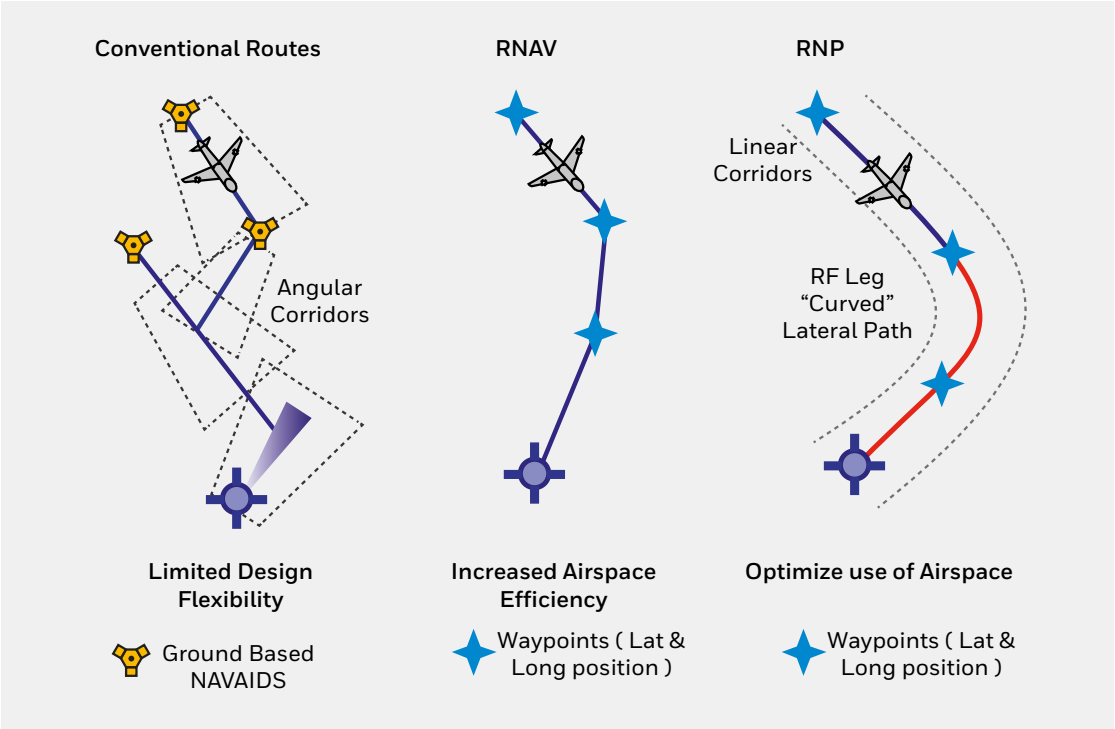


Figure 1: Conventional Navigation versus RNAV and RNP

RNP is formally defined by four main terms:

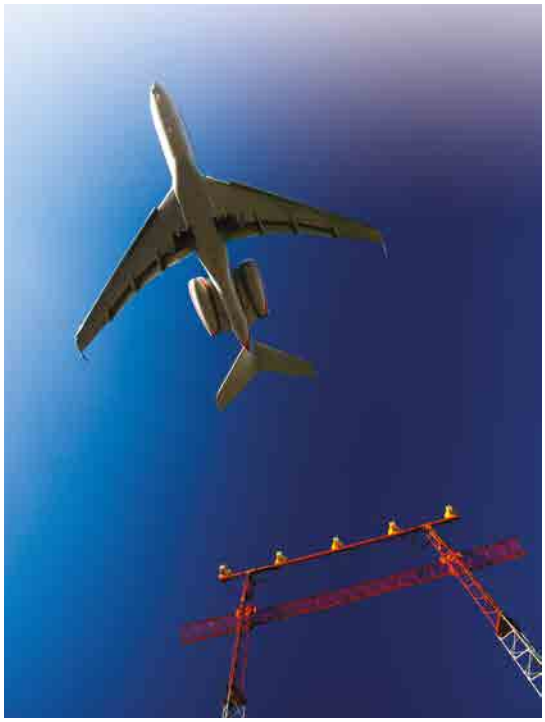
Accuracy: The requirement to keep the actual airplane position within a radius that is 1xRNP for 95 percent of the time.

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.

What are the Key Benefits of RNP to Airlines?



RNP and RNP AR Approach allow airlines to use safer and more efficient flight paths that will enable a variety of possible benefits including:

— Airspace efficiency through reduced separation.

— Better use of multiple airport runway configurations for increased airport capacity.

— Reduced fuel burn/emissions from shorter flight paths via not being constrained to overflight of navigational-aids on the ground.

— Improved runway access and lower minima for runways constrained by terrain/airspace.

— RNP can be used in conjunction 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.

— 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).

— RNP enables airlines to precisely control what their aircraft are flying over, such as avoiding noise-sensitive areas.

— RNP approaches along with RNP to xLS could eventually become the standard Instrument Approach Procedure, allowing unification and standardization of instrument approach operations and pilot training cost reductions along with the safety improvements.

In the future, use of RNP routes and terminal area procedures are 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. RNP/RNAV capability therefore is a key emerging requirement for all airline transport aircraft.

RNP AR Instrument Approach Procedures

Flexible flight paths allow aircraft to be directed around obstacles or restricted noise areas – even on final approach – while keeping the most direct routing possible.

AR, which stands for Authorization Required, refers specifically to RNP Instrument Approach Procedures that are amongst the most modern and precise instrument approach options available today. The Authorization Required qualifier refers to the RNP AR approval the operator must maintain to operate their RNP-approach-capable aircraft in the execution of RNP AR procedures. RNP AR approach procedures include unique capabilities that require special aircraft and aircrew authorization similar to Category II/III ILS operations.

RNP AR procedures can provide significant operational and safety advantages over other area navigation (RNAV) procedures by incorporating additional navigational accuracy, integrity and functional capabilities to permit operations using reduced obstacle clearance tolerances that enable approach and departure procedures to be implemented in circumstances where other types of approach and departure procedures are not operationally possible or satisfactory.

RNP AR Procedures implemented in accordance with ICAO and other regulatory authorities allow the exploitation of high-quality, managed lateral and vertical navigation (VNAV) capabilities provided by the Flight Management System and other avionics of modern aircraft that provide improvements in operational safety and reduced Controlled Flight Into Terrain (CFIT) risks.

RNP AR APCH procedures are only published where significant operational advantages can be achieved while preserving or improving safety of operation. RNP AR procedures provide improved access to select airports in terrain or traffic-challenged conditions. Understanding multiple variables that take aircraft, equipment, and aircrew performance into account supports the evaluation and deployment of previously unattainable flight paths in the terminal area.

The RNP AR Approach is particularly suited to areas where operations are limited by terrain, infrastructure availability or airspace constraints (such as parallel, converging or adjacent airport operations). Flexible flight paths allow aircraft to be directed around obstacles or restricted noise areas – even on final approach – while keeping the most direct routing possible. This process opens access to airports and runways not previously served by instrument approaches and/or the relatively low minima typically offered by RNP AR approach procedures. RNP AR approaches also serve as a reliable backup to conventional radio-based approaches that are subject to shutdowns due to maintenance and environmental conditions.

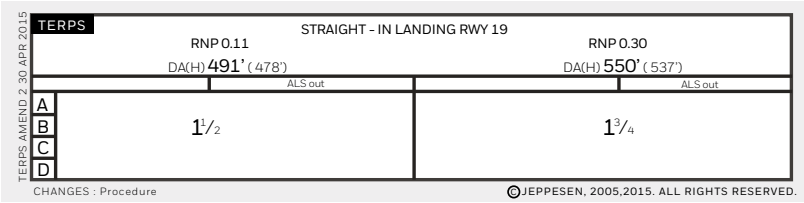


Figure 2: Approach Minima for Reagan National RNAV (RNP) Rwy 19 Approach

RNP AR Approach Procedures utilize variable RNP values that range from 1.0 as low as 0.10, and may include curved paths known as RF (Radius to Fix) legs. RF legs can be used to provide a path around high terrain in the terminal area as shown in the example approach plate from Queenstown New Zealand (figure 3), and to reduce the track miles by providing early turns to the final approach course from a base or downwind leg, so-called "short transition" approach which have been cited by airline operators as providing significant reductions in fuel burn.

RNP AR approaches, typically titled as RNAV (RNP) Rwy XX may include several lines of minima, at RNP of 0.30 down to RNP 0.10. In general, the lines of minima below 0.30 provide increasingly lower landing minima (e.g., lower Decision Altitude/Height and or visibility). For example, the RNAV (RNP) Runway 19 approach at Ronald Reagan Washington National Airport has lines of minima at RNP 0.30 and RNP 0.11 as shown in figure 2 above.

Note that for the 0.11 line of minima, the Decision Altitude is 491 feet versus 550 feet for the RNP 0.30 line and the required visibility for the 0.11 is a quarter mile lower. This provides an operator utilizing both certified equipment and attainment of operational approval for the lower RNP line significantly improved opportunities for safely landing at the field during poor weather.

Honeywell has been a leader of bringing RNP AR approach capabilities to Airline Transport Aircraft, attaining RNP AR approach capability below 0.30 RNP on the following platforms:

- Boeing 747-8, and 747-400 with the NGFMS retrofit
- Boeing 757
- Boeing 767
- Boeing 777
- Boeing 787
- Airbus A320 series
- Airbus A330
- Airbus A350
- Embraer E-Jet 170/190 with Load 27.1-NGFMS (certification in July 2016)

As illustrated in the example to the right, RNP AR approach capability down to RNP 0.10 is key for current and future airline operations. The FMS is a key component of having an RNP compliant implementation, particularly for RNP AR approach operations below 0.30 RNP.

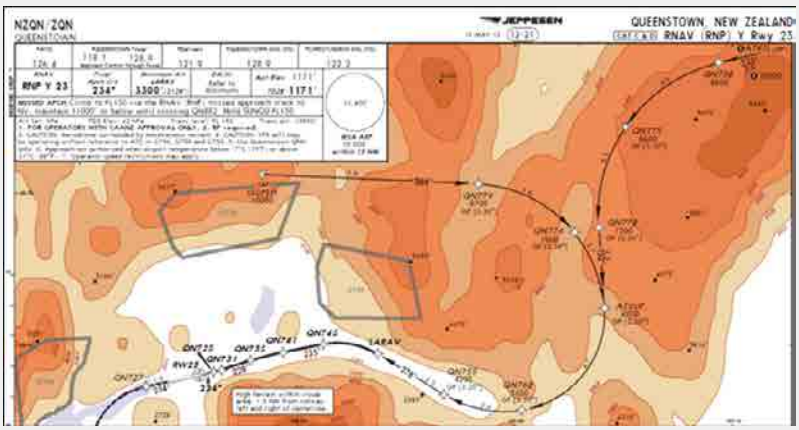


Figure 3: RNAV RNP Approach with RF Legs

Case Studies and More Information on Airline Value

Some of the early adopters of RNP AR approach have been cited in a number of articles touting the benefits of RNP AR, many of them quantified in terms of realized fuel savings. These articles are suggested as additional reading on this topic as they highlight the key advantages and benefits from the airline perspective.

WestJet, for example is quoted in a 2010 article (http://www.navcanada.ca/EN/media/Publications/In%20the%20News/Rounding-The-Corners-EN.pdf) as follows:

"WestJet Flight Operations estimates the RNP AR approaches at Kelowna and Abbotsford have saved 265,000 and 285,000 liters of fuel annually at these airports."

Similarly, a JetBlue executive was quoted about their savings from RNP AR operations in an article in 2013 (http://www.flightglobal.com/news/articles/mroam-jetblue-touts-cost-savings-from-rnp-approaches-384795/) :

"The airline's senior vice president of operations Jeff Martin estimates that the carrier saves $5,000 on each RNP approach to Long Beach airport. The carrier has conducted about 144 RNP approaches to Long Beach since 2008, when it received FAA authorization for such approaches."That is about $720,000 saved," says Martin."

RNP AR operations are not limited to North America, airlines around the world are embracing the technology. For example, South African Airways had this to say about savings they expected in this 2014 article (https://www.flysaa.com/na/en/flyingSAA/News/SAA_saves_fuel_with_innovative_navigation_approach.html):

"SAA initiated a pilot programme for RNP-AR technology at Cape Town International Airport in 2009 and, in an Africa-wide first, put it into operation by early 2013. "Research conducted by French company, Airbus Prosky, showed potential savings of over 690 tons of fuel and a reduction of some 230 hours of flight time per year, based on an average saving of 100kg of fuel per approach and a reduction of two minutes' flying time for each approach."

And lastly, to see what an RNP AR approach in mountainous terrain with a letdown through a cloud deck from the perspective of the pilots, see this video on YouTube posted by an Air New Zealand Airbus crew: https://www.youtube.com/watch?v=7mxmFCw-Dig

For more information
aerospace.honeywell.com

Honeywell Aerospace
1944 East Sky Harbor Circle
Phoenix, Arizona 85034
+1 (800) 601 3099
www.honeywell.com

C61-1630-000-000 | 08/2016

Honeywell