Flight Evaluation and Validation of RNP AR/SAAAR Instrument Flight Procedures

Donald P. Pate
Consultant
Aviation Airspace Consulting, Inc.
Edmond, OK, USA
E-mail: donppate1@yahoo.com

AUTHOR
PHOTO
HERE

ABSTRACT

With the recent publication of ICAO manuals establishing Performance Based Navigation (PBN) concepts and design standards for developing Required Navigation Performance (RNP) procedures with Authorization Required (AR), there is a need to closely examine the flight inspection requirements for validating such procedures.

There are a number of new concepts introduced by the RNP/AR procedures which need special attention during flight validation. The lateral obstruction clearance areas can be reduced to 0.2 nm each side of the center line and may not have secondary areas. In addition, the final approach vertical clearance surface, referred to as the VEB, derived from barometric system errors, is based on an aircraft flying the glide path using an approved barometric VNAV system. The flight track may have curved path (RF) segments with curved obstacle clearance areas that can be reduced to 0.2 nm each side of the circular turning track.

To maintain obstruction clearance safety for these procedures, additional responsibility is given to the flight crew to monitor the maximum vertical deviation permitted on glide path, and maximum lateral deviation (typically one RNP) throughout the approach. Flight inspection should give particular attention to obstacle validation and TAWS/GPWS alerts that might occur during flight evaluation.

Operators flying these procedures on autopilot or flight director mode can experience a strong linkage to the flyability of these procedures with aircraft configuration, speed control and Flight Management System (FMS) coding. Flight procedure validation will need to address these interactions during evaluations. Other equipment that enhances vertical transition from IMC, such as VGSI

should align with the glide path angle. This paper will note the attributes introduced by RNP AR (SAAAR), and the flight inspection standards that should be addressed to accommodate these requirements.

INTRODUCTION

World wide demand for air transportation has placed tremendous pressure on the international airspace system (IAS). In view of this demand, significant efforts have been underway by individual states, regions and the International Civil Aviation Organization (ICAO) to improve the efficiency of the global IAS. One area where airspace designers have determined that gains can be made is in the selection of an alternative navigation concept for the IAS. The navigation system for the current IAS has been structured on sensor specific ground based navigation systems, e.g. VOR, ILS, NDB, etc. These systems have served the IAS well, but inherently have design limitations when an airspace designer attempts to improve the capacity of operations in the terminal, en route and approach airspace.

From an airspace designer perspective, the limitations of these ground based navaids include the requirement that routes must be planned 'to' and 'from' the facility, the navigation system error is typically angular and the airspace requirements expand with distance from the facility and the routes between the facilities cannot be conveniently aligned along a straight path. With the introduction of area navigation (RNAV) using global navigation satellite sensors (GNSS), many of these limitations can be reduced or eliminated.

In particular, modern RNAV aircraft equipped with inertial navigation systems updated with GNSS offer significant opportunities to improve the efficiency of the IAS. Experience has shown that such aircraft perform the navigation task with incredible accuracy throughout all

phases of the flight operation. The errors tend to be linear, and the route can be designed to meet the requirements of airspace rather than based on the location of the ground navaids.

Given the proliferation of modern new RNAV equipped aircraft in the global IAS and the increasing availability of GNSS, airspace designers are beginning to change the concept for designing their National Airspace Systems (NAS). In particular the U.S. NAS is currently evolving into a new Performance Based Navigation (PBN) concept.

PERFORMANCE BASED NAVIGATION

The PBN concept outlined in ICAO documents Performance Based Navigation Manual, Volumes I & II [1] defines requirement for airspace to support en route, terminal and approach operations in terms of accuracy, integrity, availability, continuity and functionality. In a PBN NAS, the navigation requirements are expressed as operational requirements rather than in terms of a specific navigation sensor.

One airborne navigation technology that currently functions very well with the PBN concept is an inertial based RNAV system with GNSS updating. The PBN concept does not technically limit operations to a specific navigation sensor, but to the performance required to operate in the airspace. Other technologies, such as DME/DME, may support a PBN requirement along a certain route, but place additional requirements on the state to position DME ground facilities in appropriate locations along the route to meet the required performance. This reduces one of the more significant gains for enhancing the efficiency of navigable airspace since routes are constrained by the availability of appropriate DME ground facilities along the route. One advantage of organizing airspace under the PBN concept is the navigation technology operating in the airspace can evolve by simply complying with the required performance parameters.

A key point here is that aircraft operating in PBN airspace must comply with the required performance to assure containment within the protected airspace of a route. This requires that some means be provided to the crew and AT to assure them that an aircraft's navigation system is performing as required. For conventional multi-sensor RNAV systems, not equipped with GNSS, this was accomplished by providing sensors needed to navigate a route in sufficient quantity and geometry to achieve the performance required. The integrity of such an operation is maintained outside the aircraft by operating in a radar environment. A PBN airspace constructed in this manner loses much of the flexibility required to gain the efficiencies necessary to increase the capacity of a NAS.

Another navigation concept for implementing PBN airspace is to consider aircraft with inertial based RNAV and GNSS updating approved for Required Navigation Performance (RNP) operations. RNP RNAV aircraft provide onboard integrity checking by monitoring navigation system performance and alerting the crew when the system is no longer capable of verifying the accuracy set by the flight crew. The RNP RNAV concept provides a good match for a PBN NAS since it permits the crew to set the navigation monitoring to the accuracy level required by the airspace they intend to use.

The traditional flight inspection task should be carefully reexamined for application to PBN airspace. Flight inspection of conventional airspace based on ground navaids has of necessity been focused on examination of the performance of the facility. In the case of the current level of U.S. PBN NAS implementation, navigation is based on GNSS complemented, in some applications, by on board inertial systems. The flight verification requirements for PBN approaches implemented in PBN airspace are described in reference [1].

The best example of an advanced implementation of PBN in the approach phase is the Required Navigation Performance Authorization Required or Special Aircraft Aircrew Authorization Required (RNP AR or SAAAR) approach procedure. Due to their complexity and performance requirements, RNP AR/SAAAR approaches are only authorized with GNSS as the primary navigation sensor.

RNP AR/SAAAR OPERATIONS

As the title implies, an RNP AR/SAAAR operation must be approved by a state authority for a qualified operator and aircraft with specific capabilities. The concept is similar to that for obtaining Category II or III operational approval for ILS approach procedures. Approval is required for aircraft, crew procedures and the elements of procedure design.

Due to the unique requirements for RNP AR/SAAAR operations, crew procedures specific to the particular aircraft and operation are required. To support the aircraft approval process, the operator will need to obtain documentation from the aircraft manufacturer describing the navigation capability of the applicant's aircraft necessary to support RNP AR/SAAAR operations. The FAA has published guidance for obtaining U.S. NAS RNP AR/SAAAR approval in AC 90-101, Approval Guidance for RNP Procedures with Special Aircraft and Aircrew Authorization Required [2]. The European Aviation Safety Agency (EASA) is currently developing similar guidance.

Minimum Equipment Lists (MEL) may need to be revised to accommodate RNP AR/SAAAR procedures. Guidance

from the manufacturer must be carefully followed to establish these requirements. The equipment list can vary depending on a variety of factors such as the level of accuracy to be used, e.g. accuracy values less than RNP 0.3, or missed approaches with values less than RNP 1.0. For example, flight director or autopilot must be used for all operations with Radius to Fix (RF) legs and for accuracy values less than RNP 0.3. Some aircraft may require an autopilot for navigation accuracies less than RNP 0.3. Dual equipment may also be specified for operations with accuracy values less than RNP 0.3. An operable Class A Terrain Awareness Warning System (TAWS) is typically required for all RNP AR/SAAAR operations in obstacle rich environments.

The operator is expected to provide for flight crew training on RNP AR/SAAAR procedures approved for their operations. The training must include types of procedures, required equipment and regulatory requirements. The flight crew must complete all ground and flight training prior to engaging in RNP AR/SAAAR operations. The training may be conducted in aircraft or aircraft flight simulators that accurately replicate the operator's equipment and the approved RNP AR/SAAAR operations.

Operators are expected to address RNP AR/SAAAR qualifications for initial, transition, upgrade, recurrent, differences or stand-alone training. The operator must develop recurrent qualification standards to ensure that flight crews maintain an appropriate level of RNP AR/SAAAR knowledge and skills.

Flight crew procedures must be established for each approved RNP AR/SAAAR procedure and each aircraft/navigation equipment type. Crew procedures should focus on configuration management, speed control, maneuvering limits and airspace containment for each segment of the procedure.

Training and crew procedures should reflect the requirements that flight crews are expected to maintain centerline while limiting lateral deviations to values less than +/- 1/2xRNP, and executing a missed approach for deviations greater than 1xRNP, e.g. for RNP 0.1, it is expected that a missed approach would be executed if the lateral deviation should exceed 0.1 nm. For vertical tracking on the final segment, it is expected that a missed approach would be executed if the vertical deviation should exceed +/- 75 feet.

The third critical element for approving an RNP AR/SAAAR operation is the instrument flight procedure design. Procedure design standards for international applications are published in the ICAO manual Procedures Design for RNP(AR) Approach Procedures [3] and for U.S. operations in the FAA Order 8260.52 U.S. Standard for Required Navigation Performance

(RNP) Approach Procedures with SAAAR [4]. The standards for designing RNP AR/SAAAR procedures are very flexible. They permit designation of airspace segments to accuracy values as low as RNP 0.1, application of RF turns on the final approach segment, missed approaches with climb gradients and RF turns and low RNP 0.1 values. The obstacle clearance areas are based on a width of +/- 2xRNP value without buffer areas. Aircraft containment in these areas is maintained by a combination of 1xRNP alerting, pilot monitoring and the accuracy of the navigation system.

Due to the flexibility of the construction and the potential small containment areas, certain aspects of the procedure become critical to the safety of the design. The accuracy of the data base that codes the track, the correct location of obstacle data and the flyability of the procedure become elements requiring special attention for verification.

PROCEDURE VALIDATION

Reference [1] and draft U.S. guidance recommend a series of steps to validate all proposed RNP AR/SAAAR procedures. The validation process is to improve the quality and integrity of the published procedure. Areas to be checked include the track accuracy, correct position of relevant obstacle data, compliance of the design with criteria, flyability of the procedure, and correct coding of the approach path (ARINC coding).

Some of the areas to be evaluated are accomplished by the regulatory authority using a variety of methods including flight simulator or an aircraft equipped for RNP AR/SAAAR operations. Reference [1] calls for an operator to validate every RNP AR/SAAAR approach procedure before flying the procedure in instrument meteorological conditions (IMC).

This is to be done to ensure compatibility with the operator's aircraft and to ensure the coded path matches the published procedure. In this validation the operator must as a minimum compare the navigation data to be loaded into the flight management system (FMS) with the published procedure, validate the loaded navigation data for the procedure either in a flight simulator or in the actual aircraft in Visual Meteorological Conditions (VMC).

The compatibility of the operator's aircraft with the procedure is accomplished through an assessment of flyability. The flyability assessment should confirm the acceptability of bank angles on RF turns, missed approach climb gradients, RNP values, approach angles, segment lengths, missed approach procedures and descent gradients. Because of the flexibility of the design criteria, it is essential that the operator verify the acceptability of the design for their specific aircraft/equipment type.

Normally, the operator would also develop flight crew procedures for each aircraft/navigation equipment type during this process. Direction is given to the operator to document and maintain records of this validation process for comparison to subsequent data updates.

Reference [1] indicates that obstacle validation is required and can be accomplished by the regulatory authority through an aircraft flight evaluation or through ground inspection or other approved survey techniques. Draft FAA guidance indicates that obstacle data should be verified by airborne assessment which may be augmented by optional on-site verification.

The procedures that can be designed from the RNP AR/SAAAR criteria range in difficulty from straight in approaches similar to an ILS to complex procedures with RF turns on the final segment and in the missed approach, RNP values to 0.1 nm and climb gradients on the missed approach. Reference [1] and draft FAA guidance state that it is essential that complex procedures be evaluated in a flight simulator prior to publication. The objective is to assess the capability of RNP AR/SAAAR aircraft and avionics to fly the approach as designed and coded for the Flight Management System (FMS) data base.

To accomplish a simulator evaluation the flight crew must be specially trained and qualified for the task. Because of the highly interactive nature of the design with the aircraft operation, it is highly recommended that the procedure designer participate in the evaluation.

The crew will review operational issues such as wind limitations, bank angle limits (RF turns), climb gradients and TAWS alerts. The crew will also determine any equipment or operational issues requiring specific training and verify the procedure documentation against the FMS data base. Any deficiencies in the procedure design would be reported to the procedure designer for revision of the design. To improve the quality of the first design, optional desk top high speed computer simulations can be run by the designer. Such simulations can check basic flyability and compliance with criteria.

The simulator evaluation should be conducted in a level C or level D flight simulator. The simulator should represent an aircraft certifiable for RNP AR/SAAAR operations and capable of flying the procedures in normal operations. The objective here is to evaluate the aircraft against the procedure for the general case. As discussed earlier, each operator must validate each RNP AR/SAAAR procedure in their specific aircraft or simulator and with the equipment used for the operation.

FLIGHT VALIDATION

Flight Validation (FV) is the final check of a GNSS based PBN instrument flight procedure (IFP) flown in an approved PBN aircraft by a qualified FV flight crew. FV is the final step in the PBN IFP process prior to publication. The FV should confirm the correct ground track has been coded and the lateral/vertical protection boundaries have been correctly identified, the data base functions as intended, and determine any anomalies with procedure and FMS operation, validate controlling obstructions, verify communications and surveillance and confirm expected airport infrastructure. The FV crews should be familiar with any special crew procedures or training requirements that approved operators will be expected to comply with.

During FV, the crew should note operational issues such as wind limits, maximum bank angle commands, Enhanced Ground Proximity Warning System (EGPWS) alerts, and any anomalies with the IFP, FMS, or the infrastructure. Particular attention should be given to any differences between the IFP charted track and the flight track flown and recorded. Missed approaches constructed with climb gradients greater than 40:1 and incorporating RF turns should be given special attention for determination of flyability.

The aircraft used for FV must be capable of flying all public RNP AR/SAAAR procedures and contain a data collection system such as an Autonomous Global Positioning System Recording System (AGRS). Reports from any previous obstacle checks and simulator evaluations will be made available to the FV crew. One of the FV reports should contain a map that depicts the flight track versus the IFP plotted path with all fixes.

Appropriate documentation should be maintained of the obstacle verification, simulator evaluation and FV. Chart notes and other pilot information may be derived from the results of these evaluations.

CONCLUSION

The flexibility of RNP AR/SAAAR procedures provide for implementation of safe and efficient ground tracks over areas clear of terrain and other obstacles. This flexibility has the potential to provide for greater efficiency in the airspace, operations at locations where ground navaids may not support approaches and improved procedures at locations where straight in operations may not be achievable.

Due to the high interaction between aircraft/equipment performance, flight crew procedures and advanced procedure design it is necessary to verify the integrity of this interaction prior to publication. This verification is accomplished through a new set of flight simulator, obstacle validation and flight validation requirements.

REFERENCES

[1] ICAO, March 2007, <u>Performance Based Navigation</u>, Volumes I and II, Working Draft 5.1, Required Navigation Performance (RNP) Special Operational Requirements Study Group (RNPSORSG)

[2] FAA, December 2005<u>, Approval Guidance for RNP Procedures with Special Aircraft and Aircrew Authorization Required</u>, AC 90-101

[3] ICAO, <u>Procedures Design for RNP(AR) Approach Procedures</u>, Pans Ops Manual

[4] FAA, <u>U.S. Standard for Required Navigation Performance (RNP) Approach Procedures with SAAAR</u>, FAA Order 8260.52

Vitae:

Donald P. Pate

Mr. Pate, president of Aviation Airspace Consulting, Inc (AAC), retired from the FAA as Program Manager of the instrument flight procedure standards program. He had the responsibility for establishing rules, standards, criteria and policy for 14 CFR Part 97 and Part 95 public and special terminal instrument flight procedures, and the administration of the flight procedures and airspace program. In that capacity, he served as the FAA's senior representative to the ICAO Obstacle Clearance Panel (OCP), the All Weather Operations Panel (AWOP) and a number of industry/governmental instrument standards working groups. He was the chief spokesman for the FAA on instrument flight procedure standards and has made numerous presentations at technical aviation conferences including the IFIS 2007 in Toulouse, France, the 52nd Annual FSF International Air Safety Seminar, Helicopter Association International 2001 Heli-Expo, Airline Transport Association 2000 RNAV TF Conference, IATA FMS/RNAV International Workshop, 2000 Regional Airlines Association Forum, 1999 EAA Air Venture, 1999 NBAA Convention, National Association of State Aviation Officials (NASAO) Navaids 2000 Conference, 2001 Eurocontrol RNAV Conference and the RTCA Symposium 2000.   Programs included development of standards and criteria for GPS Non Precision Approaches (NPA), Helicopter GPS NPA, GPS Wide Area Augmentation System (WAAS) Approaches, Multi-sensor RNAV Terminal Route (SID, STAR) Procedures, Required Navigation Performance (RNP) SAAAR and RNAV/Barometric VNAV approach procedures. Mr. Pate has worked extensively within the aviation industry to address safety concerns regarding CFIT accidents during non stabilized NPA's. From these efforts, he developed FAA policy to chart vertical descent angles on approach charts, establish standards for new RNP SAAAR approach procedures with vertical guidance and GPS and WAAS procedures with vertical guidance. The organization he managed provided the US member to the ICAO Obstacle Clearance Panel (now the Instrument Flight Procedures Panel, IFPP), Co-Chair of the Aeronautical Charting Forum, chair of the AIS WG, chair of the Satellite Procedures Implementation Team and co chair of the Industry/FAA Charting Database Avionics Harmonization (CDAH) Working Group. Instituted after the Cali accident, the CDAH addressed lack of harmonization of paper charts and airborne databases. He has been responsible for new charting standards for RNAV procedures and database requirements to support these operations. Mr. Pate is currently provided aviation consulting services through AAC.

Mr. Pate's academic education is in aeronautical engineering and mathematics. His specialty in mathematics was probability theory, which he has applied to establish risk metrics for development of instrument flight procedure obstacle clearance protection. He held a professional position in the FAA as a Management Test Pilot and is both helicopter and airplane rated.