Approach Specifications Part 1

RNP Approach (RNP APCH) and Baro-VNAV

Learning Objectives

At the end of this presentation, you should:

- Understand the relationship between RNP APCH and Basic GNSS approaches
- Be familiar with the aircraft and operator performance requirements for RNP APCH
- Be familiar with the aircraft and operator requirements for barometric-VNAV performance

Application of Navigation Specification by Flight Phase

PBN Manual Vol II

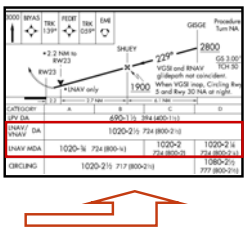
Table 1-1: Application of Navigation Specification by Flight Phase

NAVIGATION SPECIFICATION	FLIGHT PHASE							
	En Route OCEANIC /REMOTE	En Route Continental	ARR	APPROACH				DEP
				Initial	Interm.	Final	MISSED	
RNAV 10	10							
RNAV 5		5	5					
RNAV 2		2	2					2
RNAV 1		1	1	1	1		1[b]	1
RNP 4	4							
Basic-RNP 1			1[a,c]	1[a]	1[a]		1[a]	1[a,c]
RNP APCH				1	1	0.3	1	
RNP AR APCH				1-0.1	1-0.1	0.3 – 0.1	1-0.1	

Background: RNP APCH

- RNPSORSG recognized capability of Basic GNSS aircraft was consistent with PBN RNP
  - Area navigation capability with requisite performance
  - Monitoring and alerting through aircraft-based augmentation system (ABAS) and suitably-scaled deviation displays
- Objective: to accommodate RNP-certified aircraft within same PBN criteria
- Other GNSS solutions evolving
  - adopting within PBN framework will eliminate need to modify procedures for new solutions
- Incorporate barometric-VNAV (as an option)

Example of Current RNAV (GPS) Approach in USA



ICAO PBN Manual
Chapter 5 – *Implementing RNP APCH*

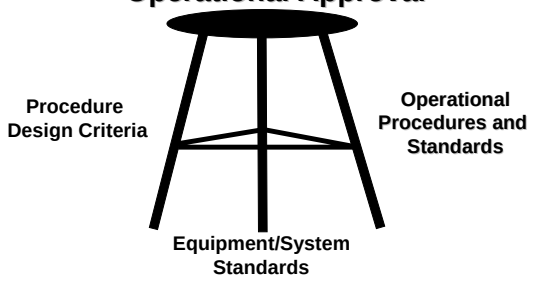
- Criteria reflects both existing stand-alone and multi-sensor RNAV systems using GNSS
  - Implementing RNP APCH does not require new airworthiness demonstrations and documentation
  - Charting standards are currently in development
    - Initial indication is that future procedures will be titled RNAV(GNSS)
- Keys on compliance to European and US performance and functional specifications
  - Ensures compliance to ICAO specification
  - Simplifies operational implementation for States

Air Navigation Service Provider (ANSP) Considerations

- Navaid infrastructure
  - GNSS is the primary navigation system to support RNP APCH procedures
  - Missed approach segment may be based upon conventional navaid (e.g., VOR, DME, NDB)
- Communication and ATS Surveillance
  - RNP APCH does not include specific requirements

PBN, Vol II, Part C, Sections 5.2.1 and 5.2.2

Key Elements of Operational Approval: RNP APCH



RNP APCH Procedure Design

- Characteristics of RNP APCH
  - Straight segments, fly-by turns
  - Allows for two-dimensional (2-D) non-precision approach (NPA)
  - Allows for three-dimensional (3-D) approaches with vertical guidance through use of barometric, vertical navigation (baro-VNAV)
- RNP APCH can be implemented with existing PANS OPS (Doc 8168, Vol II, Part III, Section 1)
  - Basic GNSS Chapter
  - Barometric VNAV Chapter
- Procedure design criteria will be aligned to the PBN concept
  - Basic GNSS procedures already implemented will not be affected

PBN, Vol II, Part C, Section 5.2.3

Key Elements of Operational Approval: RNP APCH

System Performance

PBN, Vol II, Part C, Section 5.3.3

Accuracy

- Initial & Intermediate Approach Segments →
  - *Lateral Total System Error (TSE)*: 1.0 NM, 95%
  - *Along-Track Error*: 1.0 NM, 95%
- Final Approach Segment →
  - *Lateral TSE*: 0.30 NM, 95%
  - *Along-Track Error*: 0.3 NM, 95%
- Flight Technical Error (FTE) Limits →
  - *Initial, Intermediate & Missed Approach*: FTE < 0.50 NM, 95%
  - *Final Approach Segment*: FTE < 0.25 NM, 95%
  - May drive equipment requirements for RNP APCH operations
    - Navigation data displayed on a lateral deviation display (CDI, (E)HSI, and/or navigation map display)

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System Performance

Integrity

- *Major* failure conditions can result in significant reduction in safety and significant increase in pilot workload
- RNP APCH criteria protects for *major* failure conditions
- Probability of *major* failure condition < 1×10^{-5}

Continuity

- Protects for *minor* failure condition → *if* operator can revert to an alternate navigation system
- If the procedure contains a conventional missed approach:
  - The necessary navigation equipment must be installed & operable
  - Required ground-based navigation must be available (VOR or NDB)

Signal-In-Space Monitoring & Alerting

- *During initial, intermediate and missed approach segments, navigation system shall alert:*
  - Probability of SIS error causing a lateral position error greater than 2.0 NM exceeds 1×10^{-7}, or
- *During the final approach segment:*
  - Probability of SIS error causing a lateral position error greater than 0.6 NM exceeds 1×10^{-7}

Performance Monitoring & Alerting

- *During initial, intermediate and missed approach segments, the RNP system (or RNP system and pilot in combination) shall alert:*
  - When the accuracy requirement is not met, or
  - When the probability that lateral Total System Error (TSE) exceeds 2.0 NM is greater than 1×10^{-5}
- *During the final approach segment, the RNP system (or RNP system and pilot in combination) shall alert:*
  - When the accuracy requirement is not met, or
  - When the probability that lateral Total System Error (TSE) exceeds 0.6 NM is greater than 1×10^{-5}

On-Board Performance Monitoring & Alerting Function

- On-board performance monitoring and alerting should comprise:
  - Navigation System Error monitoring and alerting, and
  - Automatic monitoring of flight technical error (FTE) or Lateral Deviation Display enabling the flight crew to monitor FTE

Systems Meeting Accuracy, Integrity and Continuity Requirements

- GNSS stand-alone systems approved IAW FAA AC 20-138A or equivalent:
  - TSO-C129a / ETSO-C129a Class A1, or
  - E/TSO-C146() Class Gamma & Operations Class 1, 2 or 3.
- Multi-sensor systems using GNSS approved IAW FAA AC 20-130A*:
  - TSO-C115b*
  - TSO-C129( ) / ETSO-C129( ) Class B1, C1, B3, C3; or
  - E/TSO-C145() class 1, 2 or 3 (with equivalent integration guidance)

*Must demonstrate RNP APCH capability
- GNSS receiver approved IAW E/TSO-C129() → capability for satellite Fault Detection and Exclusion (FDE) is recommended

Key Aircraft Functional Requirements

- Lateral deviation display should agree with alerting and annunciation limits
- Lateral deviation display must have full-scale deflection suitable to phase of flight
  - Scale set automatically or from navigation database
  - Must be known or displayed to the flight crew
  - As previously stated, navigation map display *may* meet the requirement

PBN, Vol II, Part C, Section 5.3.3.3

More Key Aircraft Functions

- Continuous display to pilot flying, on primary flight instruments for navigation, RNAV-computed desired path and aircraft's position relative to the path
- Capability to load the entire approach, by name, from the on-board navigation database
- Display of RNAV system failure, including sensor failures, in pilot's primary field of view
- Alert when Navigation System Error (NSE) exceeds limits → provided by on-board monitoring & alerting

Key Elements of Operational Approval: RNP APCH

Operational Approval

Procedure Design Criteria

Operational Procedures and Standards

Equipment/System Standards

RNP APCH Operational Approval Overview

- RNP APCH Pre-Flight Planning
- General Operating Procedures
- Contingency Procedures
- Pilot Knowledge & Training
- Navigation Database Requirements

PBN, Vol II, Part C, Section 5.3.4

RNP APCH Pre-flight Planning

- Flight plan suffixes should reflect the navigation capability of the aircraft
- Flight crew must confirm the aircraft navigation database is current and contains desired procedures
- Navigation data must be current for flight duration
  - Operator and pilot procedures must ensure data integrity and accuracy when the AIRAC cycle changes during flight

RNP APCH Pre-flight Planning

- Operators and pilots must confirm:
  - Availability of GNSS required for the intended RNP APCH operation
    - May be a prediction service offered by the State or private service
    - A prediction tool may be integrated into the aircraft's avionics
    - Pilots should follow guidance per their State operating authority
  - Availability of any conventional ground-based navigation aids for non-RNAV contingencies

General Operating Procedures (1)

- The flight crew must retrieve the RNP APCH procedure from the on-board database by procedure name
- Before the initial approach fix (IAF), the flight crew must verify the correct RNP APCH procedure is displayed
- As a minimum, the flight crew must:
  - Check the waypoint sequence loaded by the navigation database & system
  - Compare avionics display with available charts (paper or electronic)
  - Ensure the path complies with the ATC clearance (when assigned)

General Operating Procedures (2)

During the RNP APCH operation:

- If the aircraft does not meet the criteria for the RNP APCH operation → pilot must inform ATC and request an alternate clearance
- Pilots must use a lateral deviation indicator, flight director and/or autopilot in the lateral navigation (LNAV) mode
- If using barometric-VNAV → the flight crew must confirm the current, local altimeter setting
- If using multi-sensor systems → the flight crew must confirm GNSS is available and being used by the navigation system

General Operating Procedures (3)

During the RNP APCH operation:

- Lateral deviation scaling should match required navigation accuracy for each approach segment:
  - 1.0 nm for the initial & intermediate approach segments,
  - 0.3 nm for the final approach segment, and
  - 1.0 nm for the missed approach segment
- All pilots are expected to maintain path centerline at all times

General Operating Procedures (4)

During the RNP APCH operation:

Cross-track deviation limited to:

- ±½ times the required navigation accuracy → example: 0.15 nm during the final approach segment (½ × 0.30 = 0.15)
- 1 times the required navigation accuracy during and after turns → up to maximum of 1.0 nm during and immediately after turns

General Operating Procedures (5)

During the RNP APCH operation:

- When using barometric vertical navigation (baro-VNAV) for vertical path guidance, vertical deviations must not exceed:
  - +100 feet above the depicted vertical path
  - -50 feet below the depicted vertical path
- If deviation exceeds a lateral or vertical limit, the pilot must initiate a missed approach procedure
  - Pilot may continue visually if the required visual references are available
- Barometric-VNAV discussed later in greater detail

General Operating Procedures (6)

During an RNP APCH missed approach operation:

- Fly the published missed approach procedure, and
- If available, use the RNAV path extracted from the on-board navigation database
- Interim Summary:
  - GNSS is needed to begin the approach.
  - If GNSS is lost, execute the missed approach.
    - If appropriate, pilot may continue visually if required visual references are available

RNP APCH Contingency Procedures

- The flight crew must notify ATC of any loss of RNP APCH navigation capability
  - Flight crew should propose an alternate course of action
  - The operator's contingency procedures should enable a safe response to the loss of RNP APCH capability
- In event of lost communication, the flight crew should comply with published lost communication procedure (general or procedure-specific)

RNP APCH Pilot Knowledge and Training (1)

Pilot knowledge and training should include:

- Characteristics of RNP APCH procedures
- Depiction of waypoint types and path terminators
- The required navigation equipment → at least 1 (one) GNSS-based RNP system
- Compliance with the operator-recommended levels of automation for phase of flight
- Phraseology for RNP APCH applications
- The ability to conduct contingency procedures when facing RNP system failures and alerts

RNP APCH
Pilot Knowledge and Training (2)

Knowledge of RNAV equipment operating procedures:

- How to verify the currency of navigation database and retrieve an RNP APCH in its entirety
- How to complete RNP system self-tests and initialize aircraft position
- How to verify waypoints and program the flight plan
- How to intercept an initial or intermediate approach segment of an RNP APCH
- How to monitor lateral and vertical deviations within operational tolerances

RNP APCH
Pilot Knowledge and Training (3)

RNP system-specific knowledge and training:

- Levels of automation, mode annunciations, alerts, interactions, reversions, and systems degradation
- Functional integration with other aircraft systems
- Knowledge of the meaning of route discontinuities
- Pilot monitoring procedures and interpretation of electronic displays
- Types of navigation sensors used for RNP and their operation

Navigation Database Requirements for RNP APCH Operations

- Operators should obtain the navigation database from a supplier complying with public criteria
  - RTCA DO-200A / EUROCAE document ED 76, *Standards for Processing Aeronautical Data*
- The supplier should hold a database integrity Letter of Acceptance (LOA) (for example, Transport Canada, FAA or EASA)

Navigation Database Requirements for RNP APCH Operations

Descriptions of Letters of Acceptance can be found in:

- EASA IR 21 subpart G, or EASA Opinion Letter dated 01/2005
- FAA AC 20-153, *Acceptance of Data Processes and Associated Navigation Databases*
- Transport Canada (TCCA) "Acknowledgement Letter of an Aeronautical Data Process"

Navigation Database Requirements for RNP APCH Operations

- If an operator or flight crew discovers database discrepancies that invalidate a procedure:
  - Immediately report the discrepancy to the supplier
  - Prohibit the procedure's use by the operator's flight crews through an advisory notice until corrected
- Operators should consider employing ongoing checks of database to ensure data quality
  - Automated tools may be available to assist in this task

Barometric Vertical Navigation

Baro-VNAV addressed in PBN Manual, Volume II, Attachment A

Baro-VNAV Systems in PBN Manual

- Background
  - RNP APCH final approach segment*: vertical path guidance computed by the on-board RNAV system

LNAV/VNAV	DA	1224/40 385 (400-¼)

  - Other flight phases: vertical path information that can be defined by vertical angles or altitudes at procedure fixes
- Reference PANS-OPS
  - Application: Doc 8168, Volume I
  - Obstacle Clearance: Doc 8168, Volume II

*** Currently used by RNAV systems today**

Aircraft Eligibility

- Two steps
  - Recognize qualifications of aircraft and equipment
  - Determining the acceptability for operations
    - Should consider acceptance of manufacturer documentation of compliance (e.g., FAA AC 20-129)
- Systems demonstrated and qualified for RNP AR APCH operations including VNAV are considered qualified
  - No further examination of aircraft capability, operator training, maintenance, operating procedures, databases, etc. is necessary
- Private operators should operate using practices and procedures identified in Attachment A, section 1.4.6 (Pilot Knowledge and Training)

System Performance

- Based on use of RNAV equipment automatically determining aircraft position in vertical plane using inputs from equipment which can include:
  - FAA TSO-C106 (Air Data Computer)
  - Air Data System (see references in PBN Manual)
  - Barometric altimeter system (see references in PBN Manual)
  - Type certified integrated systems providing an Air Data System capability
- System accuracy
  - Error demonstrated to be less than 99.7% probability
  - Vertical flight technical (pilotage) errors demonstrated to be less than shown in PBN on a 3-sigma basis

Key Vertical Navigation Functions

- Path definition:
  - Vertical path defined by a flight path angle to a fix
  - Specifies a vertical path between altitude constraints at two fixes
- Vertical constraints: altitudes/speeds must be automatically extracted from navigation data base
- Capability to load procedures from navigation database:
  - Load and modify entire procedure(s) to be flown based upon ATC instruction
  - Preclude modification of procedure data in nav data base

Key Vertical Navigation Functions

- Temperature limits:
  - Cold temperatures reduce actual glidepath angle
  - High temperatures increase actual glidepath angle
  - Aircraft using temperature compensation or alternate means (e.g., SBAS) may disregard temperature restrictions

⚠ Baro-VNAV NA below -16°C (4°F).
For inoperative ALSF, increase LPV all Cats visibility to RVR 5000, increase LNAV/VNAV Cat E visibility to 1½, increase LNAV Cat E visibility to 2¼.

Path Deviation and Monitoring

- Recommend appropriately-scaled non-numeric deviation display located in pilot's field of view
  - For example, some existing systems may not be appropriate with vertical deviation scaling of +/- 500 ft
- Numeric display may be acceptable depending on flight crew workload and display characteristics
- Eligible aircraft must also be equipped with and operationally using either a flight director or autopilot capable of following the vertical path

Operating Procedures

- Altimeter setting
  - Flight crews obtain current setting, particularly during times of rapid change. Remote settings not allowed.
- Cold temperature
  - Check chart, or use AFM approved temperature compensation system
- Contingency procedures
  - Consistent with operator practices
- Pilot knowledge and training
  - If using temp comp system, understand where compensated altitudes are being applied in radar/non-radar environment for that country
- Database

Summary

- Relationship between RNP APCH and Basic GNSS approaches
  - GNSS approach equipment meets RNP APCH performance
- Aircraft and operator eligibility requirements for RNP APCH
  - Systems meeting RNP APCH performance requirements include appropriately installed GNSS stand-alone systems and multi-sensor systems incorporating GNSS
- Aircraft/operator requirements for barometric-VNAV
  - Baro-VNAV systems used in current flight procedures
  - Temperature limits and path deviation and monitoring are key factors in procedural implementation and operation
    - Altimeter settings and cold temperature limitations must be considered

Audience Response System Questions