Approach Specifications

RNP Approach (RNP APCH) and Baro-VNAV
Overview

• 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 performance requirements for barometric-VNAV
Background: RNP APCH

• RNPSORSG recognized capability of Basic GNSS aircraft was consistent with PBN RNP
  – RNAV 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)
• Foundation for Aircraft Eligibility → existing GNSS-based RNAV performance & functionality
• Criteria reflects both existing stand-alone & multi-sensor RNAV systems using GNSS
  – Implementing RNP APCH does not require new airworthiness demonstrations & documentation
  – Charts will continue to be labeled RNAV\textsubscript{(GNSS)}
• Keys on compliance to European & US performance & functional specifications
  – Ensures compliance to ICAO specification
  – Simplifies operational implementation for States
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
Key Elements of Operational Approval: RNP APCH

Operational Approval

- Procedure Design Criteria
- Equipment/System Standards
- Operational Procedures and Standards
RNP APCH Procedure Design

- Characteristics of RNP APCH
  - Straight segments, fly-by turns
  - Allows for two-dimensional (2-D) non-precision approach (NPA) and,
  - 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)
  - 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
Key Elements of Operational Approval: RNP APCH

Operational Approval

- Procedure Design Criteria
- Operational Procedures and Standards
- Equipment/System Standards
System Performance (1)

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)
System Performance (2)

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 < $1 \times 10^{-5}$

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 & missed approach segments, navigation system shall alert:
  - Probability of SIS error causing a lateral position error greater than 2.0 NM exceeds $1 \times 10^{-7}$, or

- During the final approach segment:
  - Probability of SIS error causing a lateral position error greater than 0.6 NM exceeds $1 \times 10^{-7}$
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 $1 \times 10^{-5}$

• 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 $1 \times 10^{-5}$
On-Board Performance Monitoring & Alerting Function

• On-board performance monitoring and alerting should comprise:
  – Navigation System Error monitoring & alerting, and
  – Automatic monitoring of flight technical error (FTE) or Lateral Deviation Display enabling the flight crew to monitor FTE
Systems Meeting
Accuracy, Integrity & 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 & 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
  – Navigation map *may* meet the requirement
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
- Equipment/System Standards
- Operational Procedures and Standards
RNP APCH Operational Approval Overview

- RNP APCH Pre-Flight Planning
- General Operating Procedures
- Contingency Procedures
- Pilot Knowledge & Training
- Navigation Database Requirements
RNP APCH Pre-flight Planning (1)

- Flight plan suffixes should reflect the navigation capability of the aircraft
- Flight crew must confirm the aircraft navigation database is current & contains desired procedures
- Navigation data must be current for flight duration
  - Operators’ & pilots’ procedures must ensure data integrity & accuracy when the AIRAC cycle changes during flight
RNP APCH Pre-flight Planning (2)

• Operators & pilots must confirm:
  – Availability of GNSS required for the intended RNP APCH operation (RAIM, SBAS, etc)
    • May be a prediction service offered by the State ANSP 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.
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 & 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 & being used by the navigation system
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
During the RNP APCH operation:

Cross-track deviation limited to:

- $\pm \frac{1}{2}$ times the required navigation accuracy → example: 0.15 nm during the final approach segment ($\frac{1}{2} \times 0.30 = 0.15$)

- 1 times the required navigation accuracy during & after turns → up to maximum of 1.0 nm during & immediately after turns
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
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
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
Pilot knowledge & training should include:

- Characteristics of RNP APCH procedures
- Depiction of waypoint types & path terminators
- The required navigation equipment → at least 1 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 & alerts
RNP APCH
Pilot Knowledge & Training (2)

Knowledge of RNAV equipment operating procedures:

• How to verify the currency of navigation database & retrieve an RNP APCH in its entirety
• How to complete RNP system self-tests & initialize aircraft position
• How to verify waypoints & program the flight plan
• How to intercept an RNP APCH at an intermediate approach segments
• How to monitor lateral & vertical deviations within operational tolerances
RNP APCH
Pilot Knowledge & Training (3)

RNP system-specific knowledge & training:

• Levels of automation, mode annunciations, alerts, interactions, reversions, & systems degradation
• Functional integration with other aircraft systems
• Knowledge of the meaning of route discontinuities
• Pilot monitoring procedures & interpretation of electronic displays
• Types of navigation sensors used for RNP & their operation
Navigation Database Requirements for RNP APCH Operations (1)

- 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 an Transport Canada, FAA or EASA Type 2 Letter of Acceptance (LOA)
Descriptions of Letters of Acceptance can be found in:

- EASA IR 21 subpart G, or EASA Opinion Letter Letter dated 01/2005
- Transport Canada (TCCA) "Acknowledgement Letter of an Aeronautical Data Process"
Navigation Database Requirements for RNP APCH Operations (3)

- 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
Background of Baro-VNAV Systems in PBN Manual

- **Background**
  - RNP APCH final approach segment*: vertical path guidance computed by the on-board RNAV system
  - 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 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 (1)

• 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 (2)

• 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 2½.
Path Deviation and Monitoring

• Recommend appropriately-scaled non-numeric deviation display located in pilot’s field of view
  – Existing systems provide for vertical deviation scaling with a range 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 temp comp system

• Contingency procedures
  – Consistent with operator practices

• Pilot knowledge and training
• 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
Feedback and Questions

Bearing in mind the target audience in ICAO Regions