



**QUALIFICATION CRITERIA FOR
BAROMETRIC VERTICAL NAVIGATION (BARO-VNAV)**

SECTION 1 POLICY & GENERAL INFORMATION

1.1 PURPOSE

- A. This specification is intended to facilitate operational approvals for existing Baro-VNAV systems that have demonstrated their capabilities and obtained regulatory approval for usage.
- B. An operational approval based upon this standard allows an operator to conduct Baro-VNAV operations globally.

This specification provides airworthiness and operational criteria for the approval of an RNAV system using barometric altimetry as a basis for its vertical navigation capability.

Section 1 Policy & General Information 1

 1.1 Purpose 1

 1.2 Status of this AC 2

 1.3 Background 2

 1.4 Applicability 2

 1.5 Related Publications 2

 1.6 Definitions & Acronyms 3

Section 2 Barometric VNAV Approvals 4

 2.1 Application of BARO-VNAV 4

 2.2 Monitoring & Investigation of Navigation & System Errors 4

 2.3 Navigation Error Reports 4

Section 3 APV-BARO VNAV Navigation Specification 4

 3.1 Background 4

 3.2 Approval Process 5

Section 4 Summary of Applicable Criteria 5

 4.1 Aircraft Eligibility 5

 4.2 Description of Aircraft Equipment 5

 4.3 Minimum Equipment List (MEL) Considerations 5

 4.4 Training Documentation 6

 4.5 Operations Manuals & Checklists 6

- Advisory Circulars are intended to provide advice and guidance to illustrate a means, but not necessarily the only means, of complying with the Regulations, or to explain certain regulatory requirements by providing informative, interpretative and explanatory material.
- Where an AC is referred to in a 'Note' below the regulation, the AC remains as guidance material,
- ACs should always be read in conjunction with the referenced regulations.

4.6 Contingency Procedures	6
Section 5 Aircraft System Requirements	6
5.1 Barometric Vertical Navigation (VNAV) System Performance	6
5.2 Vertical Navigation Functions	8
5.3 Capability to Load Procedures from the Navigation Database	9
5.4 User Interface	10
5.5 Path Deviation & Monitoring	10
Section 6 Pilot Knowledge & Training	11
Section 7 Database Considerations	12

1.2 STATUS OF THIS AC

This AC is an original issuance.

1.3 BACKGROUND

- A. This navigation specification addresses those systems based upon the use of barometric altitude and RNAV information in the definition of vertical flight paths, and vertical tracking to a path.
- B. The final approach segment of VNAV instrument flight procedures are performed using vertical guidance to a glide path computed by the on-board RNAV system.
- C. The glide path is contained in the specification of the instrument procedure within the RNAV system navigation database.
- D. For other phases of flight, barometric VNAV provides vertical path information that can be defined by vertical angles or altitudes at fixes in the procedure.

1.4 APPLICABILITY

The requirement for RCAA approval before operations using Baro-VNAV applies to operators of Rwanda-registered aircraft involved in general aviation, aerial work and commercial air transport.

This approval requirement also applies to Rwanda AOC holders when authorized to use aircraft of another State's registry.

1.5 RELATED PUBLICATIONS

- A. Rwanda Civil Aviation Authority
 - AC 10-014 – Application & Process: Performance Based Navigation
- B. These ICAO publications are source documents for this advisory circular—
 - Doc 9613-AN/937 – Performance Based Navigation Manual (PBN)
 - Annex 6, Part 1, International Commercial Air Transport – Aeroplanes
 - Annex 6, Part 3, International Operations – Helicopters
 - PANS-OPS (Doc 8168, Volume 1).

Copies may be obtained from the RCAA-FSS.

Copies may be obtained from Document Sales Unit, ICAO, 999 University Street, Montreal, Quebec, Canada H3C 5H7.

1.6 DEFINITIONS & ACRONYMS

1.6.1 DEFINITIONS

The following definitions apply to this advisory circular—

- 1) **Approach procedure with vertical guidance (APV).** An instrument procedure which utilizes lateral and vertical guidance but does not meet the requirements established for precision approach and landing operations.
- 2) **Navigation Specification.** A set of aircraft and air crew requirements needed to support Performance based navigation operations within a defined airspace.
 - ◆ There are two kinds of navigation specification: RNAV and RNP.
 - ◆ A RNAV specification does not include requirements for on-board performance monitoring and alerting.
 - ◆ A RNP specification includes requirements for on-board performance monitoring and alerting.
- 3) **RNAV Operations.** Aircraft operations using area navigation for RNAV applications. RNAV operations include the use of area navigation for operations which are not developed in accordance with the PBN Manual.
- 4) **RNAV System:** A navigation system which permits aircraft operation on any desired flight path within the coverage of station-referenced navigation aids or within the limits of the capability of self-contained aids, or a combination of these.
 - ◆ A RNAV system may be included as part of a Flight Management System (FMS).
- 5) **RNP Route:** An ATS Route established for the use of aircraft adhering to a prescribed RNP Specification
 - ◆ RNP System: An area navigation system which supports on-board performance monitoring and alerting.
 - ◆ RNP Operations: Aircraft operations using a RNP System for RNP applications.

1.6.2 ACRONYMS & ABBREVIATIONS

The following acronyms apply to this advisory circular—

- 1) **AC** – Advisory Circular
 - 2) **AOC** – Air Operator Certificate
 - 3) **APV** – Approach Procedure with Vertical Guidance
 - 4) **EASA** – European Aviation Safety Agency
 - 5) **ECAC** – European Civil Aviation Conference
 - 6) **EUROCAE** – European Organization for Civil Aviation Equipment
 - 7) **FAA** – Federal Aviation Administration
 - 8) **FMS** – Flight Management System
 - 9) **GNSS** – Global Navigation Satellite System
 - 10) **GPS** – Global Positioning System
 - 11) **GRAS** – Ground-based Regional Augmentation System
 - 12) **IRU** – Inertial Reference Unit
 - 13) **LNAV** – Lateral Navigation
 - 14) **MEL** – Minimum Equipment List
-

- 15) **PBN** – Performance Based Navigation
- 16) **RNAV** – Area Navigation
- 17) **RNP** – Required Navigation Performance
- 18) **RTCA** – Radio Technical Commission on Aeronautics

SECTION 2 BAROMETRIC VNAV APPROVALS

2.1 APPLICATION OF BARO-VNAV

- A. Baro-VNAV is intended to be applied where vertical guidance and information is provided to the flight crew on instrument approach procedures containing a vertical flight path defined by a vertical path angle.
- B. Barometric VNAV may also be defined by altitude constraints but only for flight phases other than

2.2 MONITORING & INVESTIGATION OF NAVIGATION & SYSTEM ERRORS

If an observation/analysis indicates that a loss of separation or obstacle clearance has occurred, the reason for the apparent deviation from track or altitude must be determined and steps taken to prevent a recurrence.

2.3 NAVIGATION ERROR REPORTS

- A. The RCAA may consider any navigation error reports in determining remedial action.
- B. Information that indicates the potential for repeated errors may require modification of an operator's training program.
 - Information that attributes multiple errors to a particular pilot crew may necessitate remedial training or license review.

Repeated navigation error occurrences attributed to a specific piece of navigation equipment may result in cancellation of the approval for use of that equipment.

SECTION 3 APV-BARO VNAV NAVIGATION SPECIFICATION

3.1 BACKGROUND

- A. This section identifies the operational requirements for VNAV in conjunction with RNP APCH operations.
 - This section assumes the airworthiness approval of the aircraft and systems have been completed.
 - The airworthiness basis for the VNAV function and performance must have already been established and approved based upon appropriate levels of analysis, testing and demonstration.
 - B. Additionally, as part of this activity, the normal procedures, as well as any limitations for the function, have been documented as appropriate to aircraft flight and operations manuals.
 - C. Compliance with the operational requirements herein is addressed in the RCARs, and may require a specific operational approval in some cases.
 - D. General aviation and corporate operators of Rwanda-registered aircraft must apply to the RCAA for operational approval.
-

3.2 APPROVAL PROCESS

- A. The following steps must be completed before the use of BARO-VNAV in the conduct of basic RNP approach operations—
- 1) Aircraft equipment eligibility must be determined and documented;
 - 2) Operating procedures must be documented;
 - 3) Flight crew training based upon the operating procedures must be documented;
 - 4) The documentation must be accepted by the RCAA; and
 - 5) Operational approval is then be processed in accordance with the RCARs and RCAA certification guidance.
- B. Following the successful completion of the above steps, operational approval for the use of VNAV, letter of authorization or appropriate operations specification (Ops Spec), or amendment to the Operations Manual, if required, will then be issued by the RCAA.

SECTION 4 SUMMARY OF APPLICABLE CRITERIA

4.1 AIRCRAFT ELIGIBILITY

- A. Relevant documentation acceptable to the RCAA must be available to establish that the aircraft is equipped with an RNAV system with a demonstrated VNAV capability.
- B. Eligibility may be established in two steps—
- 1) Recognizing the qualities and qualifications of the aircraft and equipment, and
 - 2) Determining the acceptability for operations.
 - ◆ The determination of eligibility for existing systems must consider acceptance of manufacturer documentation of compliance e.g. as with FAA AC 20-129.

- RNP AR Systems— RNAV systems demonstrated and qualified for RNP AR operations including VNAV are considered qualified with recognition that the RNP approaches are expected to be performed consistent with the operators RNP AR approval..
- No further examination of aircraft capability, operator training, maintenance, operating procedures, databases, etc is necessary.

4.2 DESCRIPTION OF AIRCRAFT EQUIPMENT

The operator must have a configuration list detailing pertinent components and equipment to be used for approach operation.

Barometric altimetry and related equipment such as air data systems are a required basic capability and already subject to minimum equipment requirements for flight operations.

4.3 MINIMUM EQUIPMENT LIST (MEL) CONSIDERATIONS

- A. Any unique minimum equipment list (MEL) revisions necessary to address VNAV for approach provisions must be approved.
- B. The applicant must have adjusted their MEL and specify the required dispatch conditions.
- C. Barometric altimetry and related systems are minimum equipment for all operations.
 - Any unique dispatch or operational assumptions must be addressed in the operator documentation.

4.4 TRAINING DOCUMENTATION

- A. AOC holders must have a training program addressing the operational practices, procedures and training items related to VNAV in approach operations (e.g. initial, upgrade or recurrent training for flight crew, dispatchers or maintenance personnel).
- B. The operator may not be required to establish a separate training program or regimen if RNAV and VNAV training is already an integrated element of a training program.
 - But it must be possible to identify what aspects of VNAV are covered within a training program.

Private operators must operate using the practices and procedures identified the training section of this AC.

4.5 OPERATIONS MANUALS & CHECKLISTS

- A. Operations manuals and checklists for AOC holders must address information/guidance on the standard operating procedures detailed in this navigation specification.
- B. The appropriate manuals must contain navigation operating instructions and contingency procedures where specified.
- C. Manuals and checklists must be submitted for review as part of the application process.

4.6 CONTINGENCY PROCEDURES

Where the contingency procedure requires reversion to a conventional procedure, necessary preparation must be completed before commencing the RNAV procedure, consistent with operator practices.

SECTION 5 AIRCRAFT SYSTEM REQUIREMENTS

5.1 BAROMETRIC VERTICAL NAVIGATION (VNAV) SYSTEM PERFORMANCE

- A. Barometric VNAV approach operations are based upon the use of RNAV equipment that automatically determines aircraft position in the vertical plane using inputs from equipment that can include—
 - FAA TSO-C 106, Air Data Computer
 - Air data system, ARINC 706, Mark 5 Air Data System
 - Barometric altimeter system, DO-88 Altimetry, ED-26 MPS for Airborne Altitude Measurements and Coding Systems, ARP-942 Pressure Altimeter Systems, ARP-920 Design and Installation of Pitot Static Systems for Transport Aircraft.
 - Type certified integrated systems providing an Air Data System capability comparable to item b).
- B. Positioning data from other sources may be integrated with the barometric altitude information provided it does not cause position errors exceeding the track keeping accuracy requirements.
- C. Altimetry system performance must be demonstrated separately through the static pressure systems certification (e.g. FAR or CS 25.1325), where performance must be 30 feet per 100 KIAS.

● Altimetry systems meeting such a requirement will satisfy the Altimetry System Error (ASE) requirements for Baro-VNAV.
 ● No further airworthiness demonstration or compliance is necessary

5.1.1 SYSTEM ACCURACY

- A. For instrument approach operations, the error of the airborne VNAV equipment, excluding altimetry, must have been demonstrated to be less than that shown below on a 99.7 percent probability basis—

	Level Flight Segments and Climb/Descent Intercept Altitude Region of Specified Altitudes	Climb/Descent Along Specified Vertical Profile (angle)(ft)
At or below 5,000 ft	50	100
5,000 ft to 10,000 ft	50	150
Above 10,000 ft	50	220

- Maximum operating altitudes to be predicated on a compliance with total accuracy tolerance.
- VNAV guidance may be used in level flight en route as in the case of altitude hold control laws, which are integrated with speed control laws to provide an energy trade.
- The incremental error component contributed by the VNA equivalent must be offset by a corresponding reduction in other error components, such as flight technical error, to ensure that the total error budget is not exceeded.

5.1.2 ALTIMETRY ERROR

This error refers to the electrical output and includes all errors attributable to the aircraft altimetry installation including position effects resulting from normal aircraft flight attitudes.

- In high performance aircraft, it is expected that altimetry correction will be provided.
- Altimetry correction must be done automatically. In lower performance aircraft, upgrading of the altimetry system may be necessary.

5.1.3 VNAV EQUIPMENT ERROR

- A. This error includes all errors resulting from the vertical guidance equipment installation.
- It does not include errors of the altimeter system but does include any additional errors resulting from the addition of the VNAV equipment.
- B. This error component may be zero in level en route flight if the operation is limited to guidance by means of the altimeter only.
- This error must not be disregarded in terminal and approach operations where the pilot is expected to follow the VNAV indications.
- C. The vertical error component of along track positioning error is bounded by the following equipment qualification requirements for Baro-VNAV, and is directly reflected in the along track tolerance offset used in Baro-VNAV procedure design criteria for—
- GNSS navigation systems certified for approach or
 - Multi-sensor systems using IRU in combination with GNSS or
 - RNP systems approved for RNP 0.3 or less and
 - Serviceable VNAV equipment and
 - VNAV system certified for Baro-VNAV approach operations and
 - Equipped with integrated LNAV/VNAV system with accurate source of barometric altitude and
 - VNAV altitudes and procedure information from navigation database, with integrity through quality assurance

5.1.4 FLIGHT TECHNICAL (PILOTAGE) ERRORS

- A. With satisfactory displays of vertical guidance information, flight technical errors must have been demonstrated to be less than the values shown below on a three-sigma basis.

	Level Flight Segments and Climb/Descent Intercept Altitude Region of Specified Altitudes (ft)	Climb/Descent Along Specified Vertical Profile (angle) (ft)
At or below 5,000 ft	150	200
5,000 ft to 10,000 ft	240	300
Above 10,000 ft	240	300

- B. Sufficient flight tests of the installation must have been conducted to verify that these values can be maintained.

- Smaller values for flight technical errors may be achieved especially in the cases where the VNAV system is to be used only when coupled to an autopilot or flight director.

However, at least the total system vertical accuracy shown below must be maintained.

- C. If an installation results in larger flight technical errors, the total vertical error of the system (excluding altimetry) may be determined by combining equipment and flight technical errors using the root sum square (RSS) method. The result must be less than the values listed below.

	Level Flight Segments and Climb/Descent Intercept Altitude Region of Specified Altitudes (ft)	Climb/Descent Along Specified Vertical Profile (angle) (ft)
At or below 5,000 ft	158	224
5,000 ft to 10,000 ft	245	335
Above 10,000 ft	245	372

- D. An acceptable means of complying with these accuracy requirements is to have an—

- RNAV system approved for VNAV approaches in accordance with the criteria of FAAAC 20-129; and
- Altimetry system approved in accordance with FAA CFR 25.1325 or equivalent.

For continuity of function; at least one RNAV system is required for operations predicated on the use of barometric VNAV capability.

5.2 VERTICAL NAVIGATION FUNCTIONS

5.2.1 PATH DEFINITION

- A. The requirements for defining the vertical path are governed by the two general requirements for operation—
- Allowance for aircraft performance; and
 - Repeatability and predictability in path definition.
- B. This operational relationship leads to the specifications in the following sections that are based upon specific phases of flight and flight operations

- C. The navigation system must be capable of defining a vertical path by a flight path angle to a fix. The system must also be capable of specifying a vertical path between altitude constraints at two fixes in the flight plan.
- D. Fix altitude constraints must be defined as one of the following—
 - 1) An “AT or ABOVE” altitude constraint (for example, 2400A, may be appropriate for situations where bounding the vertical path is not required);
 - 2) An “AT or BELOW” altitude constraint (for example, 4800B, may be appropriate for situations where bounding the vertical path is not required);
 - 3) An “AT” altitude constraint (for example, 5200); or
 - 4) A “WINDOW” constraint (for example, 2400A3400B).

For RNP AR approach procedures, any segment with a published vertical path will define that path based on an angle to the fix and altitude.

5.2.2 VERTICAL CONSTRAINTS

Altitudes and/or speeds associated with published procedures must be automatically extracted from the navigation database upon selecting the approach procedure.

5.2.3 PATH CONSTRUCTION

The system must be able to construct a path to provide guidance from current position to a vertically constrained fix.

5.2.4 TEMPERATURE LIMITS

- A. For aircraft using barometric vertical navigation without temperature compensation to conduct the approach, low-temperature limits are reflected in the procedure design and identified along with any high temperature limits on the charted procedure.
- B. Cold temperatures reduce the actual glidepath angle while high temperatures increase the actual glidepath angle.
- C. Aircraft using barometric vertical navigation with temperature compensation or aircraft using an alternate means for vertical guidance (e.g., SBAS) may disregard the temperature restrictions.

5.2.5 GUIDANCE & CONTROL

For the vertical performance requirements, the path steering error budget must reflect altitude reference as well as other factors such as roll compensation and speed protection, as applicable

5.3 CAPABILITY TO LOAD PROCEDURES FROM THE NAVIGATION DATABASE

- A. The navigation system must have the capability to load and modify the entire procedure(s) to be flown, based upon ATC instruction, into the RNAV system from the onboard navigation database.
- B. This includes the approach (including vertical angle), the missed approach and the approach transitions for the selected airport and runway.
- C. The navigation system must preclude modification of the procedure data contained in the navigation database.

5.4 USER INTERFACE

5.4.1 DISPLAY & CONTROLS

The display readout and entry resolution for vertical navigation information must be as follows—

Parameter	Display Resolution	Entry Resolution
Altitude	Flight level or 1 foot	Flight level or 1 foot
Vertical Path Deviation	10 feet	Not Applicable
Flight Path Angle	0.1 degree	0.1 degree
Temperature	1 degree	1 degree

5.5 PATH DEVIATION & MONITORING

- A. The navigation system must provide the capability to continuously display to the pilot flying, on the primary flight instruments for navigation of the aircraft, the aircraft position relative to the vertically defined path.
- The display must allow the pilot to readily distinguish if the vertical deviation exceeds +100/-50 feet.
 - The deviation must be monitored, and action taken to minimize errors.
- B. The appropriately-scaled non-numeric deviation display (i.e. vertical deviation indicator) be located in the pilot's primary optimum field of view.
- A fixed-scale deviation indicator is acceptable as long as it demonstrates appropriate scaling and sensitivity for the intended operation.
- C. Any alerting and annunciation limits must also match the scaling values.
- D. In lieu of appropriately scaled vertical deviation indicators in the pilot's primary optimum field of view, a numeric display of deviation may be acceptable depending on the flight crew workload and the numeric display characteristics.
- A numeric display may require additional initial and recurrent flight crew training.
- E. Since vertical deviation scaling and sensitivity varies widely, eligible aircraft must also be equipped with and operationally using either a flight director or autopilot capable of following the vertical path.

- Existing systems provide for vertical deviation scaling with a range of +/- 500 feet.
- Such deviation scaling must be assessed consistent with the above requirement on discernibility.

5.5.1 BAROMETRIC ALTITUDE

The aircraft must display barometric altitude from two independent altimetry sources, one in each pilots' primary optimum field of view.

- Operator procedures must ensure current altimeter settings for the selected instrument procedure and runway.

5.5.2 OPERATING PROCEDURES

- A. Airworthiness certification alone does not authorize operator to utilize VNAV capability during the conduct of flight operations.
- B. Operational approval is required to confirm the adequacy of the operator's normal and contingency procedures for the particular equipment installation.
- C. Pilots must use a flight director or autopilot when flying a vertical path based on VNAV.

5.5.3 GENERAL OPERATING PROCEDURES

The pilot must comply with any instructions or procedures identified by the manufacturer as necessary to comply with the performance requirements in this navigation specification.

5.5.3.1 Altimeter Setting

Flight Crews must take precautions to switch altimeter settings at appropriate times or locations and request a current altimeter setting—



Remote altimeter settings are not allowed.

- 1) If the reported setting may not be recent, and
- 2) At times when pressure is reported or is expected to be rapidly decreasing.

5.5.3.2 Cold Temperature

- A. When cold weather temperatures exist, the pilot must check the chart for the instrument approach procedure to determine the limiting temperature for the use of Baro-VNAV capability.
- B. If the airborne system contains a temperature compensation capability, manufacturer instructions must be followed for use of the Baro-VNAV function.

SECTION 6 PILOT KNOWLEDGE & TRAINING

- A. The training program must provide sufficient training (for example, simulator, training device, or aircraft) on the aircraft's VNAV capability to the extent that the pilots are not just task oriented.
 - 1) The information in this navigation specification.
 - 2) The meaning and proper use of aircraft systems.
 - 3) Procedure characteristics as determined from chart depiction and textual description.
 - 4) Depiction of waypoint types (fly-over and fly-by) and path terminators and any other types used by the operator) as well as associated aircraft flight paths.
 - 5) RNAV system-specific information—
 - (a) Levels of automation, mode annunciations, changes, alerts, interactions, reversions, and degradation.
 - (b) Functional integration with other aircraft systems.
 - (c) The meaning and appropriateness of vertical path discontinuities as well as related flight crew procedures.
 - (d) Monitoring procedures for each phase of flight (for example, monitor “PROGRESS” or “LEGS” page).
 - (e) Turn anticipation with consideration to speed and altitude effects.
 - (f) Interpretation of electronic displays and symbols.
 - 6) VNAV equipment operating procedures, as applicable, including how to perform the following actions—
 - (a) Adhere to speed and/or altitude constraints associated with an approach procedure.
 - (b) Verify waypoints and flight plan programming.

There must be a clear understanding for crew requirements for

- Comparisons to primary altimeter information, altitude crosschecks (e.g. altimetry comparisons of 100 feet),
- Temperature limitations for instrument procedures using VNAV, and
- Procedures for altimeter settings for approach.

- (c) Fly direct to a waypoint.
 - (d) Determine vertical-track error/deviation.
 - (e) Insert and delete route discontinuity.
 - (f) Change arrival airport and alternate airport.
- 7) Contingency procedures for VNAV failures
 - 8) Discontinuation of a procedure based upon loss of systems or performance and flight conditions e.g. inability to maintain required path tracking, loss of required guidance, etc

SECTION 7 DATABASE CONSIDERATIONS

- A. The navigation database must be obtained from a supplier holding an EASA or FAA Letter of Acceptance (LOA).
 - This LOA demonstrates compliance with EUROCAE/RTCA document ED-76/DO-200A, Standards for Processing Aeronautical Data.
 - FAA AC 20-153/EASA IR 21 sub-part G provides additional guidance on Type 1 and Type 2 LOA's.
- B. Discrepancies that invalidate a procedure must be reported to the navigation database supplier and affected procedures must be prohibited by an operator's notice to its flight crew.
- C. The operators must have policy and procedures for the conduct of periodic checks of the operational navigation databases in order to meet existing quality system requirements.

End of Advisory Circular

This Page Intentionally Left Blank
