CASA’s Methodology for Validation of Baro-VNAV Instrument Approaches
CASA’S METHODOLOGY FOR VALIDATION OF BARO-VNAV INSTRUMENT APPROACHES

Audience

This document will be of interest to:

- Aerodrome Operators
- Aircraft operators
- Airservices Australia
- Australian Strategic Air Traffic Management Group (ASTRA)
- CASR Part 173 certified instrument flight procedure design organisations
- ICAO Flight Procedures Program Office, Beijing China

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Version 1.0

Unless specified otherwise, all subregulations, regulations, Divisions, Subparts, Parts referenced in this document are references to the Civil Aviation Safety Regulations 1998 (CASR).
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1 Reference material

1.1 Acronyms and abbreviations

The acronyms and abbreviations used in this document are listed in the table below.

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<tr>
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<th>Description</th>
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<tbody>
<tr>
<td>AIP</td>
<td>Aeronautical Information Publication</td>
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<tr>
<td>APCH</td>
<td>Approach</td>
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<tr>
<td>APV</td>
<td>Approach Procedure with Vertical Guidance</td>
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<tr>
<td>AR</td>
<td>Authorisation Required</td>
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<td>ATIS</td>
<td>Automatic Terminal Information Service</td>
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<td>AWIS</td>
<td>Aerodrome Weather Information Service</td>
</tr>
<tr>
<td>AWS</td>
<td>Automatic Weather Station</td>
</tr>
<tr>
<td>Baro</td>
<td>Barometric</td>
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<td>Baro-VNAV</td>
<td>Barometric Vertical Navigation</td>
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<tr>
<td>CAO</td>
<td>Civil Aviation Order</td>
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<td>CAR</td>
<td>Civil Aviation Regulations 1988</td>
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<td>CASA</td>
<td>Civil Aviation Safety Authority</td>
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<td>CASR</td>
<td>Civil Aviation Safety Regulations 1998</td>
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<tr>
<td>DA</td>
<td>Decision Altitude</td>
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<tr>
<td>Doc</td>
<td>Document (ICAO)</td>
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<tr>
<td>ENR</td>
<td>En-route</td>
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<tr>
<td>FAA</td>
<td>Federal Aviation Administration (USA)</td>
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<tr>
<td>FAF</td>
<td>Final Approach Fix</td>
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<td>FAP</td>
<td>Final Approach Point</td>
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<td>FAS</td>
<td>Final Approach Surface</td>
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<td>FIS</td>
<td>Flight Inspection Services (FAA)</td>
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<tr>
<td>FMS</td>
<td>Flight Management System</td>
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<tr>
<td>GNSS</td>
<td>Global Navigation Satellite System</td>
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<td>ICAO</td>
<td>International Civil Aviation Organization</td>
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<td>IFP</td>
<td>Instrument Flight Procedure</td>
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<tr>
<td>LNAV</td>
<td>Lateral Navigation</td>
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<td>MDA</td>
<td>Minimum Descent Altitude</td>
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<td>MOS</td>
<td>Manual of standards</td>
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<td>PANS-OPS</td>
<td>Procedures for Air Navigation Services – Aircraft Operations (ICAO)</td>
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<tr>
<td>Acronym / abbreviation</td>
<td>Description</td>
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<tr>
<td>PBN</td>
<td>Performance Based Navigation</td>
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<td>RNAV</td>
<td>Area Navigation</td>
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<td>RNP</td>
<td>Required Navigation Performance</td>
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<tr>
<td>TCH</td>
<td>Threshold Crossing Height</td>
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<tr>
<td>TIFP</td>
<td>Terminal Instrument Flight Procedure</td>
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<tr>
<td>VHF</td>
<td>Very High Frequency</td>
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<tr>
<td>VNAV</td>
<td>Vertical Navigation</td>
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<td>VPA</td>
<td>Vertical Path Angle</td>
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### 1.2 References

#### Legislation

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<th>Document</th>
<th>Title</th>
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<tr>
<td>CAO 20.91</td>
<td>Instructions and Directions for Performance-Based Navigation</td>
</tr>
<tr>
<td>MOS Part 173</td>
<td>Standards Applicable to Instrument Flight Procedure Design</td>
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<td>Part 173</td>
<td>Instrument Flight Procedure Design</td>
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#### Other documents
- CAA UK: Policy Statement - Validation of Instrument Flight Procedures
- ICAO Doc 8168 Procedures for Air Navigation Services Aircraft Operations
2 Background

2.1 Procedure Design Regulation in Australia

Terminal Instrument Flight Procedure (TIFP) design in Australia is regulated by the Civil Aviation Safety Authority (CASA) under Civil Aviation Safety Regulation (CASR) Part 173. Procedures are designed in accordance with ICAO Doc 8168 PANS-OPS criteria, ICAO Doc 9905 or standards set out by CASA in the CASR 173 Manual of Standards (MOS Part 173).

When issued by CASA under CASR 173 a procedure design certificate authorises an organisation to carry on design work on a TIFP of a type that is included on its certificate. The certificate may have certain conditions that the design organisation must adhere to. CASA may also exempt a designer from certain provisions of CASR 173. For quality assurance purposes CASR 173 requires that a number of processes be completed in the course of designing an instrument procedure. These processes are supported by PANS-OPS and ICAO Doc 9906 Quality Assurance Manual for Flight Procedure Design and include:

- independent verification of the design by a second qualified designer;
- validation flight check of the procedure by CASA;
- on-going maintenance of the published procedure;
- revalidation by CASA every three years.

ICAO Doc 9906, Volume 5 covers the validation of instrument flight procedures and provides guidance for conducting validation of instrument flight procedures, including safety, flyability and design accuracy. However it does not include specific details regarding the validation methodology for Baro-VNAV approaches.

2.2 Purpose of Flight Validation

Flight validation is one of the final quality assurance steps in the TIFP design process prior to publication. The purpose of flight validation as shown in MOS Part 173 and ICAO Doc 9906 is to:

- Verify database information;
- Check all obstacles (including the identification of any unforeseen obstacles) that affect the safety of the procedure;
- Assess the ‘flyability’ of the procedure; and
- Check chart presentation of the TIFP is clear, suitable and in accordance with the current charting conventions.

2.3 CASA Flight Validation Requirements

Flight validation is required for new instrument flight procedures as well as revised procedures where significant changes have been made, such as where the final course has been re-aligned by 3° or more. The procedure design organisation must ensure that each procedure designed under its certificate is validated by CASA in accordance with the requirements set out in the MOS Part 173. A qualified flight procedure designer must be part of the validation crew. Following completion of the validation flight, the pilot completes a report and flight validation certificate. The procedure designer must complete any follow-up actions required by the validation pilot’s report prior to publication of the procedure.
3 Baro-VNAV Approach Procedures

3.1 General

Baro-VNAV approach procedures provide lateral and vertical guidance for the final approach segment. Ideally, the lateral path should be identical to the standard LNAV approach procedure. These types of LNAV approach procedures have been in use for many years in Australia, previously known as RNAV GNSS procedures (lateral navigation 2D procedures). RNAV GNSS procedures are now known as RNP APCH with LNAV minima under the Performance Based Navigation (PBN) navigation specifications. RNP APCH LNAV procedures provide descent to a Minimum Descent Altitude (MDA) before requiring visual reference to the runway. An aircraft may continue level flight at the MDA until reaching the missed approach point where the missed approach procedure must be initiated.

A Baro-VNAV approach is an LNAV/VNAV (3D procedure, lateral and vertical navigation) procedure. The vertical path is ‘coded’ in the aircraft navigation database based on the procedure design. The aircraft Flight Management System (FMS) utilises a barometric altimetry system to compare the aircraft’s barometric altitude against the coded final approach path providing vertical guidance to the pilot. LNAV/VNAV (3D) procedures provide descent to a Decision Altitude (DA), at which a missed approach must be initiated if the required visual reference to continue to land has not been established. A DA differs from a MDA as upon reaching the DA the missed approach must be initiated, where as an aircraft may continue level flight at an MDA until reaching the missed approach point before the missed approach is commenced.

It should be recognised that as the DA is the point at which the missed approach is initiated, the lag in aircraft response time results in descent below the DA until a point where the aircraft starts to climb. This is a known phenomenon and is catered for in the PANS-OPS design parameters of Baro-VNAV approaches through the height loss allowance for each respective aircraft category.

Appendix 1 shows an example approach chart with LNAV and LNAV/VNAV (Baro-VNAV) minima. As shown in the profile section of the chart the LNAV/VNAV DA is lower than the LNAV MDA and the missed approach must be initiated at the DA.

Baro-VNAV procedures utilise the functionality of modern FMS equipped aircraft. Therefore, the correct functioning of an FMS referencing a suitable navigation database must also be validated for these types of procedures. Flight validation must therefore incorporate validation in a simulator or aircraft which is equipped and approved to fly Baro-VNAV procedures.

Australia has a number of RNP AR approaches, which are a specialised type of approach procedure utilising a more accurate Baro-VNAV system. The aircraft’s systems provide vertical guidance for RNP AR approaches in a similar manner to Baro-VNAV procedures. Validation of RNP AR procedures also includes individual validation of each instrument flight procedure by those operators authorised to conduct RNP AR approaches before an approach can be flown under normal operations.

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1 CASA acknowledges that validation utilising a single aircraft type and FMS combination does have limitations, but it is considered a suitable method to validate Baro-VNAV (LNAV/VNAV) procedures.
3.2 Aircraft and Operational Requirements

The Baro-VNAV requirements for use in conjunction with RNP APCH operations are detailed in CAO 20.91 Appendix 8.

Aircraft requirements include but are not limited to:

- A barometric VNAV system that meets the technical requirements;
- A navigational database that permits the lateral and vertical path to be defined.

Baro-VNAV system functionality includes but is not limited to:

- System must be able to load the entire procedure to be flown into the navigation system from the on-board navigation database;
- The vertical path must be defined by a waypoint and a vertical angle.

Operating standards include but are not limited to:

- Operations must be conducted using an approved local barometric pressure source;
- A stabilised approach must be flown to a DA indicated on an approach chart by an LNAV/VNAV minima;
- Temperature limitations, as published on the relevant approach chart, must be applied (where the on-board systems do not compensate for temperature).

Flight crew are also required to have knowledge of and completed training in how to safely conduct a Baro-VNAV operation.

3.3 Aerodrome Requirements

An approved local barometric pressure source is required at the aerodrome to allow accurate setting of the QNH in the aircraft. The QNH is measured by a pressure sensor on an Automatic Weather Station (AWS) and provided to the aircraft through an Aerodrome Weather Information Service (AWIS) with a VHF broadcast capability (referred to as an AWIS-VHF) or through an Automatic Terminal Information Service (ATIS) generally associated with Control Tower operations. These QNH sources meet the requirement of AIP ENR 1.5 - 5.3 to use an approved source to receive the actual QNH. The AWIS also provides temperature information which allows the temperature limits published on the approach chart to be checked against actual conditions. The Baro-VNAV approach may only be flown if the actual temperature is within the limits published on the chart for those aircraft not equipped with temperature compensation systems.

While the Bureau of Meteorology currently installs and maintains the majority of AWS and AWIS, where a VHF broadcast capability is installed, the VHF broadcast is typically operated by the aerodrome operator rather than the Bureau of Meteorology. The Bureau of Meteorology’s aviation AWS and AWIS service is mainly funded by the aviation industry through the Meteorological Service Charge on a cost recovery basis, with some individual AWIS locations funded on a user-pays basis. Other locations requiring an AWIS with VHF broadcast functionality are the responsibility of the aerodrome owner.

Ongoing obstacle monitoring by the aerodrome operator is also required to safeguard the obstacle assessment surfaces of each TIFP.
3.4 Baro-VNAV Flight Procedure Design and Obstacle Assessment

3.4.1 Design General

Baro-VNAV (LNAV/VNAV) procedures are an addition to an LNAV procedure. The lateral dimensions of the LNAV/VNAV procedure are the same as the underlying LNAV procedure. Baro-VNAV adds different (sloping), more complex surfaces in the vertical dimension for the assessment of obstacles. Refer to the Baro-VNAV example in Appendix 2.

The Approach Procedure with Vertical guidance (APV) segment of a Baro-VNAV approach contains the final descent segment for landing and the initial and intermediate segments of the missed approach.

The APV obstacle assessment surfaces start at the Final Approach Point (FAP) located at the intersection of the vertical path and the procedure altitude of the preceding segment. In the Baro-VNAV example in Appendix 2 the FAP is located near to the LNAV Final Approach Fix (FAF). The APV obstacle assessment surfaces end at the missed approach holding fix, turn fix or turn altitude. The APV (Baro-VNAV) surfaces are different to the LNAV surfaces and are often at lower altitudes.

New APV obstacle assessment surfaces:
The Final Approach Surface (FAS) and final approach side surfaces protect the descent from the FAP for Baro-VNAV approaches. A ground plane surface, at the runway threshold (ground) level, bounded by LNAV primary area (increasing in height above the threshold to the LNAV secondary area boundary) exists between the FAS and start of the missed approach surface.

The Baro-VNAV missed approach (Z) surface is different to LNAV missed approach and may be at a lower altitude.

3.4.2 Baro-VNAV Example Design

Appendix 2 depicts the plan and profile views of a hypothetical Baro-VNAV procedure design and a detailed view of the ground plane surfaces. Appendix 2 also includes LNAV obstacle clearance surfaces for comparison. The following is a brief summary of the example design.

In the example profile view, the final approach surface is shown in dark purple and sits below the nominal Vertical Path Angle (VPA) of 3° (magenta line). The surface runs approximately parallel to the nominal vertical profile (in this example) until it reaches ground level at a point on the nominal lateral track where the surface connects to the ground plane (this point is called XFAS). The ground plane starts at the XFAS point and ends where the missed approach (Z) surface starts (this point is called Xz). The Baro-VNAV Z surface is slightly below the LNAV missed approach surface. The LNAV obstacle clearance surfaces are shown in dark cyan for comparison and the red obstacles are numbered one to five.

The APV segment for the Baro-VNAV approach starts at the FAP (the LNAV FAF location in this example). The step down fix at 4 NM does not apply to the Baro-VNAV approach, the FAS clears obstacle two. The LNAV MDA is controlled by obstacle three at 150 ft, therefore the slightly lower obstacle four is not considered. In comparison, the Baro-VNAV FAS clears obstacle three but obstacle four penetrates this surface and must be considered when calculating the LNAV/VNAV obstacle clearance height. Obstacle four has no impact on the LNAV procedure but is critical to the Baro-VNAV procedure. In cases where Baro-VNAV has
been added to existing LNAV procedures the critical obstacles may differ and therefore previous flight validation of obstacles may not be sufficient.

Similarly, in the missed approach segment obstacle five penetrates the Baro-VNAV Z surface but is below the LNAV missed approach surface. Obstacle five is critical to the Baro-VNAV procedure but not a controlling obstacle for the LNAV procedure.

The ground plane is a new surface applicable to Baro-VNAV design but it is not part of any existing LNAV design. It covers the area between where the FAS meets ground level (on the nominal track) and where the Z surface starts. It consists of an area at the threshold (ground) level that extends either side of the nominal track to the LNAV primary area boundary (up to 1,087 m in this example). The ground plane side surfaces rise from the threshold elevation extending to the LNAV secondary area boundary at an elevation of 75 m (above the threshold) at the approach end and 30 m at the missed approach end of the ground plane (in this example). The ground plane side surfaces are relatively complex as the surfaces twist to connect to the various points. The ground plane must be monitored and obstacles that penetrate the surfaces need to be assessed as they may affect the Baro-VNAV procedure (LNAV/VNAV minima).

3.4.3 Obstacle Monitoring and Aerodrome Operators

Baro-VNAV adds new obstacle assessment surfaces lower to the ground which aerodrome operators are not currently familiar with (e.g. ground plane). Ground survey of these surfaces may be difficult and expensive. Obstacles that do not penetrate the LNAV surfaces may penetrate the Baro-VNAV surfaces, particularly obstacles closer to the runway. CASA Aerodrome Inspectors have not had training covering Baro-VNAV surfaces to provide advice to aerodrome operators.

MOS Part 173 requires the procedure designer to provide diagrams (e.g. obstacle assessment surfaces) and obstacle data sufficient to enable the aerodrome operator to fulfil their obligations to report and monitor obstacles in the vicinity of an aerodrome as required by CASR Part 139. Current information provided to aerodrome operators would not be sufficient to manage Baro-VNAV surfaces.

As detailed above, the ground plane surfaces are relatively complex. CASA would not expect an aerodrome operator to be intimately familiar with these types of PANS-OPS surfaces based on a simple plan view of the procedure design. Greater detail of the location of these surfaces would need to be provided to the aerodrome operators by the procedure design organisations to allow the surfaces to be monitored.
4 ICAO Validation Process

Guidance for conducting validation of instrument flight procedures is contained in ICAO Doc 9906 Volume 5, Validation of Instrument Flight Procedures.

The ICAO data integrity and navigation data encoding requirements depend on the types of procedures being validated.

Doc 9906 1.5.3 states; instrument procedures that are to be validated should be contained in a suitable navigation system (i.e. FMS). If no other means exist, manual entry is permissible if sufficient mitigation means have been considered and implemented. All procedure coding data must originate from the official data source.

A custom navigation database is ICAO’s preferred method and most desirable source. Doc 9906 section 1.5.3.4 states; manual entry of data should be limited to LNAV procedures only.

Section 2.3.2.1 states; to assess flyability and human factors issues, at least one on-course/on-path assessment of the proposed procedure should be flown in an appropriate aircraft capable of conducting the procedure. If different minima are provided for the same final segment (e.g. LNAV and LNAV/VNAV) the evaluation of the final segment must be accomplished on separate runs.

To conduct an on–path LNAV/VNAV approach a pilot requires vertical guidance which the FMS derives using the barometric VNAV system in combination with the navigation database, which includes the coded flight path angle (3° in most cases). Without a coded flight path angle and Baro-VNAV system an on–path approach cannot be flown accurately. The Australian aircraft equipment requirements for Baro-VNAV are contained in CAO 20.91.

The instrument flight procedure package provided by the procedure design service provider must contain a range of information (refer Doc 9906 section 1.5.1). This includes a list of relevant obstacles, identification and description of controlling obstacles and obstacles otherwise influencing the design of the procedure. There will be cases where the controlling obstacles differ between the LNAV and LNAV/VNAV procedures for the same runway, refer to section 3.4.
5 Other States Validation Processes

The following is a brief summary of elements related to the validation of Baro-VNAV procedures conducted by other states as understood by CASA.

5.1 United States

It is understood the Federal Aviation Administration (FAA) flight checks all procedures in accordance with the United States Standard Flight Inspection Manual (FAA Order 8200.1) and the FAA’s Aviation System Standards Flight Inspection Handbook (TI 8200.52). Current guidance requires the flight inspection and validation of Area Navigation (RNAV) procedures, specifically mandating the flight inspection of all final and missed approach segments.²

Flight Inspection Services (FIS) is a division within the FAA that oversees and conducts all flight inspection of US instrument flight procedures. FIS developed a “Gold Standard” inspection process specifically to tackle the unique nature of ARINC-coded flight procedures. The Gold Standard is a unique process to assure data integrity throughout the instrument flight procedure design, validation, and inspection cycle. The Gold Standard is a comprehensive assessment incorporating the analysis and comparison of:

- Instrument Flight Procedure (IFP) development;
- ARINC 424 coded data and IFP charting;
- Custom FAA navigation database (proprietary FMS database with pending data);
- Simulator validation (check fly-ability of custom FAA navigation database);
- Coding pre-flight validation (extensive desktop review of the IFP, ARINC 424 code, charting, custom FAA database and document 8200.1 guidance/tolerances);
- Flight inspection/validation of the IFP.

Current guidance regarding Baro-VNAV requires the flight inspection/validation of all final approach courses, including vertical navigation. Published vertical descent angles must keep the aircraft clear of obstacles to the minimum descent altitude or decision altitude.

Instrument flight procedures will be evaluated in a FAA-qualified Level “C” or Level “D” flight simulator capable of flying the procedure when deemed necessary by FAA Flight Standards. In addition to an in-flight evaluation, a simulator evaluation is recommended for complex procedures or procedures not compliant with standard criteria. A simulator evaluation can provide an assessment of database coding and flyability.³

RNAV approach charts provide separate minima for LNAV and LNAV/VNAV. Inspection of an RNAV procedure with vertical guidance requires an appropriately equipped flight inspection aircraft.⁴

When using aircraft avionics to validate ARINC 424 coding, an appropriately equipped aircraft would include a suitable RNAV system capable of displaying and identifying, to the flight inspector, each type of ARINC 424 path and terminator of the flight procedure.⁵

Refer to the US Standard Flight Inspection Manual, FAA Order 8200.1, for further details.

² Advice from the FAA received March 2015
³ FAA Order 8200.1: Chapter 6, Section 3, Paragraph c
⁴ FAA Order 8200.1: Chapter 13, Section 2, Paragraph a
⁵ FAA Order 8200.1: Chapter 13, Section 2, Paragraph d (3)
5.2 United Kingdom

It is understood the United Kingdom’s policy statement document, Validation of Instrument Flight Procedures⁶, allows for LNAV only procedures to be manually coded into a FMS/RNAV system in the aircraft and validated. For Baro-VNAV, the procedure is coded into a navigation database, and to date this validation (flyability assessment) has been conducted in full flight simulators.

During the assessment of the procedure, the crew assesses that the vertical profile of the final approach segment is consistent with the recommended profile as published at standard atmospheric conditions. Then the profile is assessed to ensure that at the published minimum temperature the VPA is not below 2.5°.⁷

**Policy Statement Validation of Instrument Flight Procedures document:**
Validation comprises a ground validation element and may comprise a flight validation element. In the case of RNAV procedures, a navigation database validation is also required. For ground validation in the case of a RNAV IFP, a test database for the full flight simulator produced by an appropriate navigation data provider for use in the FMS shall be used.

For flight validation of a RNAV IFP a test database produced by an appropriate navigation data-coding provider for use in the RNAV system is used. However, in the case of RNAV (GNSS) IAPs (T- or Y-bar design) (LNAV), manual entry of the procedure into the RNAV system is acceptable. The key element of a navigation database validation is to ensure that the coding of the procedure in the RNAV/FMS system does not compromise the flyability of the procedure.

5.3 New Zealand

New Zealand has a number of LNAV/VNAV approaches published. In response to enquiries, CASA received general information from the Civil Aviation Authority of New Zealand regarding Baro-VNAV flight validation. It is understood by CASA that:⁸

- Flight simulators were used for the first few LNAV/VNAV approaches but it is not standard practice.
- A custom navigation database was used for the first few procedures but is no longer used. The waypoints are entered manually into the aircraft and then into the flight inspection systems to ensure data integrity.
- The flight validation aircraft is not required to be Baro-VNAV equipped and is also used for navigation aid calibration/inspection. A ground station is setup and the flight inspection aircraft is locked to an independent point that verifies the altitudes and waypoints to survey accuracy. This method provides an independent assessment of the procedure, pilot error and flight deck instruments for quality control as the aircraft undertakes the validation.
- The standard for the flight validation is to fly 100 ft below the published profile and check any critical obstacles identified by the Procedure Designer or flight validation pilot, which is different from flying the sloping Baro-VNAV surfaces. This also identifies any significant masking in high terrain environments.

See also, discussion regarding other states validation methods in section 7.3.

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⁶ CAA United Kingdom: Policy Statement - Validation of Instrument Flight Procedures
http://publicapps.caa.co.uk/docs/33/DAP_IFPValidationPolicy.pdf
⁷ Advice received from the UK CAA April 2015
⁸ Advice received from the NZ CAA April 2016
6 Baro-VNAV Flight Validation Process

6.1 General

CASA’s flight validation process for Baro-VNAV procedures in Australia is conducted in two stages:

1. Validation of the flyability and navigation database coding is performed in an aircraft simulator (or in an appropriately equipped aircraft when available).
2. Validation of obstacles and aerodrome infrastructure is checked in an aircraft at the aerodrome.

6.2 Flyability and Navigation Database Coding

To test the flyability and correct coding the procedure must be coded in the aircraft or simulator navigation database. A custom database can be arranged as required but as the current flight validation aircraft fleet are not equipped to conduct Baro-VNAV approaches a simulator needs to be used. Utilising an aircraft simulator as part of the validation process also has the following advantages:

- Several procedures can be validated per hour as the ‘aircraft’ can be quickly positioned at the commencement of the approach;
- No transit time is required to fly to/from different aerodromes;
- Baro-VNAV capable simulators are readily available;
- Using a custom database allows the procedure to be tested and approved prior to publication in the public aircraft navigation databases;
- The cold temperature limit can be programmed to simulate the lowest VPA which also allows testing for ground proximity warnings;
- The hot temperature limit can also be programmed to simulate the steepest VPA testing for high rates of descent, particularly if the maximum VPA has been designed;
- Validating procedures in a simulator allows the Regulator’s pilots to gain experience flying Baro-VNAV approaches in a no-risk environment.

The simulator should meet the following requirements:

- Certified Level D simulator for an aircraft approved to fly the procedure;
- Terrain Avoidance and Warning System (TAWS);
- Valid terrain database.

The validation crew includes a CASA validation pilot occupying either a control seat or an observer position allowing observation of and access to all flight instrumentation and ‘outside’ visual reference.

Information required for flight validation of the procedures includes a complete set of flight procedure charts and a navigation database with the corresponding description of the ARINC 424 coding.

The flight validation task assesses the following:

- Procedure tracks;
- Descent gradients;
- Bank angle during turns;
- Runway alignment on final;
- PAPI ‘on-slope’ indication appropriate for temperature conditions;
• Missed approach;
• Database coding corresponds to the design requirements;
• Accurate and complete charting of the procedure;
• Aircraft manoeuvring consistent with safe operating procedures;
• Acceptable cockpit workload;
• Compatibility with TAWS/EGPWS.

As the tracks and coding are checked in the simulator, it is not necessary to validate the coding again in the aircraft.

**MOS Part 173 Requirements and ICAO Guidance:**
MOS Part 173 section 7.1.18 includes a number of items to be covered by the flyability check. Items that may differ between the LNAV and LNAV/VNAV procedures include:

• Descent gradients: The descent gradient for an on-path LNAV/VNAV can change with temperature. The LNAV/VNAV charts include limiting high and low temperatures, which may affect flyability, e.g. the published high temperature limit may result in a descent gradient which makes the procedure difficult to fly. The temperature limits have not been validated, and are likely to not have been experienced in real world operations.
• Distance from the runway at the minima: LNAV/VNAV introduces new minima often lower than the LNAV minima. The distance to the runway for the LNAV/VNAV minima will be different to the LNAV.
• The missed approach: An LNAV procedure is flown to an MDA, the aircraft may fly at the MDA until reaching the missed approach point before commencing the missed approach (refer section 3.1). The LNAV/VNAV approach is flown to a DA and the missed approach must be commenced at the DA. The missed approaches are commenced at different locations and are flown in a different manner by the pilot.

ICAO Doc 9906 Volume 5 covers validation of instrument flight procedures (refer section 4) and includes:

• Flyability: The ability to keep an aircraft within the predefined tolerances of the designed lateral and vertical flight track.
• To assess flyability and human factors issues, at least one on-course/on-path assessment of the proposed procedure should be flown in an appropriate aircraft capable of conducting the procedure. If different minima are provided for the same final segment (e.g. LNAV and LNAV/VNAV) the evaluation of the final segment must be accomplished on separate runs.

To check the flyability of an on-course (lateral) and on-path (vertical) approach a Baro-VNAV equipped aircraft or simulator with the procedure coded in the navigation database is required.

**LNAV Coding of VNAV Path Angles:**
Vertical path angles have been coded into aircraft navigation databases by the navigation database providers for LNAV (2D) procedures for some time and are often used by flight crew for advisory information (also referred to as LNAV+V) during a 2D approach. The availability of vertical path advisory information (coded vertical path angle) for a LNAV (2D) approach may only be used as advisory vertical information, the flight crew remain responsible for ensuring none of the minimum segment altitudes are infringed and for controlling the vertical profile (refer to AIP ENR 1.5 2.3.4). The on-path vertical profile as coded has also not been validated by CASA. In comparison, a Baro-VNAV procedure is designed around the published vertical path angle and provides full vertical guidance.
The navigation data suppliers (coders) apply guidelines contained in the ARINC Specification 424 when coding the VNAV Path\(^9\) angle for LNAV (2D) procedures. The navigation database coders project VNAV Path angles upward from the Threshold Crossing Height (TCH) above the landing threshold, up to the altitude at the final approach fix. VNAV Path angle determinations can be influenced by many factors, including the existence of a stepdown fix. The TCH from which the VNAV path (for LNAV procedures) is calculated is generally the default value (50 ft). If no procedure TCH is specified by the source, database coders may use 40 or 50 ft (as specified in ARINC 424). The actual TCH of the procedure is not published on LNAV charts therefore; there may be discrepancies between what TCH has been applied in the database compared to what was designed by the Procedure Designer.

For those procedures where the missed approach point was previously located before the threshold (usually charted at 0.3 NM before the threshold) and has now been relocated the database coding will change with the addition of the LNAV/VNAV minima. Moving the missed approach point to the threshold alters the missed approach point’s latitude and longitude and decreases the coded altitude at the missed approach point (approximately 95 ft lower for a rounded 0.3 NM change at a 3° vertical path angle).

### 6.3 Obstacle Validation

All obstacles that affect the safety of the procedure are validated by flight validation to ensure the required tolerances are satisfied. The minimum crew consists of a CASA validation pilot and a qualified procedure designer, the designer prepares the necessary data prior to the flight. Where the lateral tracks of an LNAV and a LNAV/VNAV approach are the same, the lateral dimensions of the obstacle protection areas and therefore the critical obstacles will be the same for the initial, intermediate and holding segments. However, different criteria is used to derive the minimum PANS-OPS surface heights for the final and missed approach segments of the LNAV and LNAV/VNAV procedures and therefore these segments must be validated independently (refer to section 3.4).

A procedure without vertical guidance has a minimum altitude that provides obstacle protection for each segment of the approach. A Baro-VNAV approach has the same obstacle protection up until approximately the FAP. At the FAP, the obstacle assessment surface becomes a sloped surface underlying the coded vertical path angle, the final approach surface.

During flight validation each procedure segment of an LNAV approach is flown at the Minimum Obstacle Clearance Altitude (MOCA) – a level segment that can be easily identified by the designer and pilot. The controlling obstacle in each segment is identified and checked and no obstacles should penetrate the floor of the MOCA.

For the Baro-VNAV final approach segment the obstacle assessment surfaces are sloping surfaces that cannot be easily identified or displayed to the pilot using the aircraft systems. These surfaces also differ from the LNAV surfaces and are generally lower.

CASA has refined the use of geo-referenced charts for flight validation of such surfaces. These charts are able to depict the protection area boundaries, critical obstacles and sloped surfaces. The equipment required is inexpensive and easy to use by the pilot alone (e.g. iPad with suitable software and an external GPS antenna). This equipment is not suitable for providing on-

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\(^9\) ARINC Specification 424: Attachment 5, section 8.9 Vertical Navigation Path (VNAV Path) or Descent Gradient Considerations

\(^{10}\) ARINC 424 Glossary: VNAV Path - The Vertical Navigation or VNAV Path is the term used to identify the angular data provided on non-precision Final Approach Coding.
course/on-path LNAV/VNAV guidance for the flyability assessment. Alternative methods are possible but use trained personnel and highly specialised equipment developed for the flight inspection and checking of navigation aids (as used by New Zealand, refer to section 5.3).

Obstacle validation confirms the following:
- The controlling obstacles in procedure segments and holding patterns;
- Vegetation allowance is suitable;
- Absence of obstacles extending through the floor of the MOCA;
- No penetrations of the FAS or missed approach obstacle surfaces;
- Previously unknown obstacles are observed with location and height noted for further analysis by the procedure designer;
- Confirmation that the Visual Segment Surface (VSS) is not penetrated\(^\text{11}\);
- Critical navigational data such as runway ends is validated.

Each controlling obstacle and/or procedure segment must be checked at a specified altitude(s) to validate the obstacle data used and to determine whether there are any unforeseen obstacles extending above the specified altitude. Such a case would indicate that the unforeseen obstacle is higher than the controlling obstacle and that it may affect the procedure (refer MOS Part 173 7.1.9).

Figure 1 depicts the basic flight profile of a validation aircraft conducting obstacle validation of the FAS. Electronic geo-referenced charts overlayed with the procedure design are used by the validation crew to remain at or above the FAS altitude and controlling obstacles.

![Figure 1: Final Approach Segment Obstacle Validation Flight Path](image)

Flight validation will also confirm that the aerodrome infrastructure supports the approach (confirming the details published in En Route Supplement Australia), including:
- A broadcast weather service providing current temperature and QNH (as required for Baro-VNAV approaches);
- The runway meets the standards required for instrument approach runways;
- Adjacent airspace meets the requirements of MOS Part 173.

\(^{11}\) Obstacles with a height less than 15 m above the threshold may be disregarded when assessing the VSS (refer PANS-OPS Volume II).
6.4 Validation Report

A flight validation report must be completed by the validation pilot certifying that the procedure design assumptions are valid. In addition to the aerodrome and procedure details the report may in include:

- Copies of the simulator test cards;
- GNSS data logs;
- Records of any relevant data collected;
- Records of observations and obstacles checked;
- Any observed differences in obstacle data;
- Any unsatisfactory elements requiring rectification.

6.5 CASA’s Rationale

The aircraft utilised for CASA flight validations are currently not Baro-VNAV capable and a custom navigation database is not currently used for validation of new LNAV procedures (manual entry of coordinates occurs and no flight path angle is available), therefore:

- Existing LNAV procedures have not had their coded final approach path angles validated by CASA (ICAO recommends manual entry of procedure data for flight validation be limited to LNAV procedures only).
- CASA is currently unable to validate the final approach path angle for new procedures in the aircraft; therefore, a simulator will be used initially. CASA will reevaluate the need to use a simulator should the validation aircraft become Baro-VNAV capable taking into consideration experience gained in the initial validations utilising the simulator.
- The design of some existing LNAV procedures where Baro-VNAV is being added will change (as they will be updated to the current PANS-OPS design criteria) resulting in the existing coding not being valid.
- Existing LNAV coded VNAV Path angles (refer section 6.2) are based on guidelines in the ARINC specification 424 which may be subtly different to the procedure design.
- Although some LNAV procedures have been flown utilising advisory vertical information by industry (with pilots monitoring minimum segment altitudes; refer AIP ENR 1.5 2.3.4), this does not constitute validation by CASA of the 3D LNAV/VNAV procedure.
- Validating these procedures in a simulator initially may identify previously unknown issues with navigation database coding and flyability (e.g. aircraft rapid descent to the FAF to intercept the coded path angle).
- Baro-VNAV adds new (generally lower) obstacle assessment surfaces to existing LNAV procedures, therefore the controlling obstacles may differ between the LNAV and LNAV/VNAV procedures. These obstacles must be validated during flight validation.
7 Discussion Topics

This section considers feedback and other comments from industry and other relevant stakeholders regarding CASA’s Baro-VNAV validation methodology. Comments are show in italics with CASA comments below.

7.1 Application of LNAV Validation Method

*Strong arguments for adopting the LNAV validation with some small additions is already strong (speed to market is important to progress this much delayed initiative).*

*The requirement to conduct a flight validation for a Baro-VNAV approach that is identical to an existing LNAV approach is excessive. Validation requirements for a Baro-VNAV procedure should closely resemble those for a LNAV procedure with the addition of criteria accounting for minimum and maximum temperature.*

*Support a validation methodology that does not require unnecessary duplication of validations already completed for existing LNAV approaches if they meet APV safety assessments.*

CASA understands industry’s desire for the roll out of Baro-VNAV procedures to be as efficient as possible given the safety enhancements that come with approaches with vertical guidance. While the Baro-VNAV procedure chart/nominal track is the same as the underlying LNAV procedure, Baro-VNAV adds new obstacle assessment surfaces which may result in changes to the existing navigation database coding (refer to sections 3.4 and 6.2).

The obstacle validation for the Baro-VNAV surfaces will be rolled into the validation of the existing LNAV procedures. The validation pilot always plans to conduct the validation flight as efficiently as possible while ensuring all the requirements are met.

7.2 RNP-AR like Validation

*Do not believe that the RNP-AR flight validation requirements outlined in the document are warranted because there are already States which have validated without the need for RNP-AR flight validation; there are no significant changes from the current LNAV procedures; there are no significant changes in aerodrome meteorological minima; and validation documentation tabled by the Chair of PBNWG at ASTRA.*

*Don’t accept that the process for validation for Baro-VNAV approaches should be the same as the process to validate a RNP-AR approach.*

RNP AR and Baro-VNAV utilise the same method for providing vertical guidance in the final approach (the design parameters and obstacle assessment methodology does differ). As the aircraft used for flight validation are not currently equipped for Baro-VNAV and the existing LNAV procedures were validated using manual waypoint data entry (ICAO recommends manual entry should be limited to LNAV procedures only, refer section 4) CASA will conduct flyability and database validations in a simulator initially. There are no procedure validation requirements for individual operators before flying each Baro-VNAV procedure in instrument meteorological conditions as there are for RNP AR procedures.
CASA will continue to review the validation method for initial and revalidations of Baro-VNAV approaches with the objective of streamlining the methodology on the basis of operational experience gained.

7.3 Other States Validation Method

The validation methodology used by the New Zealand Civil Aviation Authority (NZCAA) should be adopted by CASA, as it would be both cost effective/beneficial whilst ensuring that safety is enhanced by earlier validation of these approaches.

Advice received from the CAA NZ indicates flight validation of Baro-VNAV procedures in NZ initially involved use of flight simulators and custom navigation databases, but this is not normal practice. The NZ flight validation aircraft is not required to be Baro-VNAV equipped. However, CASA understands a flight inspection aircraft is used to conduct procedure validations which is equipped with sophisticated flight inspection equipment (also used for the inspection of navigation aid performance) capable of verifying altitudes and waypoints to a survey level accuracy.

CASA does not use flight inspection aircraft to conduct instrument flight procedure validations. Utilisation of flight inspection aircraft to achieve this level of accuracy would require ground equipment to be setup at each location and potentially require additional personnel, equipment and training which would increase validation time and cost.

7.4 Validation Elements

The lateral coding is common for the LNAV and the LNAV/VNAV. The coding of VNAV is already in the database and used for Baro-Advisory but not guidance. Vertical path has been encoded in databases for many years; the vertical path is routinely flown as “Advisory”.

All aspects of database management are subject to systematic management and audit. Database management is mature and has been proved over a protracted period.

The descent gradient of a standard 3 degrees to touchdown is used unless obstacles dictate otherwise. It is already encoded and used for an “Advisory”.

Although the coded vertical path angle has been part of published LNAV (2D) procedures for some time and used as advisory information by crew this does not constitute validation by CASA of the LNAV/VNAV (3D) procedure. The availability of vertical path advisory information (coded vertical path angle) for a LNAV (2D) approach is not full vertical guidance (advisory only) (refer AIP ENR 1.5 2.3.4). In comparison, a Baro-VNAV (LNAV/VNAV) procedure is designed around the published vertical path angle and provides full vertical guidance.

There may also be subtle differences between the existing LNAV and new LNAV/VNAV coding as database coders have applied the guidance in the ARINC specification 424 for the existing vertical path. This may be different to or not based on all available state source information (e.g. the threshold crossing height on which the path angle was coded for the LNAV procedure is not shown on the LNAV chart).
Temperature limits - Maximum and Minimum temperature limits are published on the Approach plate of RNP-APCH (LNAV/VNAV) Procedures.

The temperature limits on the approach charts are calculated using formulas contained in PANS-OPS. Simulating these temperature limits in a simulator will allow testing for high rates of descent (high path angle/temperature) and terrain warnings (low path angle/temperature). This will allow CASA to gain confidence in the published temperature limitations which will be considered during the review of the validation process.

The missed approach is the same lateral path for both RNP-APCH (LNAV) and RNP-APCH LNAV/VNAV) and is addressed in the existing RNP-APCH (LNAV) validation process and practice.

While the Baro-VNAV nominal track is the same as the LNAV procedure the Baro-VNAV missed approach obstacle clearance surface (Z surface) may lie below the LNAV surface. Therefore, the Z surface will need to be considered during the flight validation and any relevant obstacles verified.

Flight validation cannot provide accurate confirmation of subtle obstacle penetration of surfaces. Flight validation provides a gross error check. Gross error check of penetration of surfaces is addressed in existing RNP-APCH (LNAV) validation process and practice.

The use of geo-referenced charts for flight validation allows for good presentation of the sloped surfaces to the validation pilot. Although this cannot confirm subtle obstacle penetration of surfaces, any areas of concern would be referred back to the procedure designer for re-assessment. The Baro-VNAV obstacle assessment surfaces (final and missed approach) may be lower than the LNAV surfaces and must be considered during flight validation.
8 Conclusions

8.1.1 Baro-VNAV approaches introduce new (generally lower) obstacle assessment surfaces that differ from the LNAV surfaces on which the LNAV/VNAV procedure is based. Therefore, the controlling obstacles may differ between the LNAV and LNAV/VNAV procedures. Obstacles relevant to each procedure must be validated.

8.1.2 The Baro-VNAV obstacle assessment surfaces require ongoing monitoring by aerodrome operators. Details regarding these surfaces will need to be provided to the aerodrome operators by the procedure design organisations and a monitoring method established.

8.1.3 The current validation aircraft fleet is not equipped to fly Baro-VNAV approaches and a custom navigation database is not currently used during flight validation of LNAV procedures. Therefore, a simulator with a custom navigation database will be used for validations initially.

8.1.4 CASA will consider how the provision of Baro-VNAV equipment in the flight validation aircraft may increase validation efficiency but anticipates a custom navigation database will still be required (as recommended by ICAO).

8.1.5 As the roll out of Baro-VNAV approaches continues and as CASA and operators (particularly those who have not been conducting RNP AR operations) gain more experience with Baro-VNAV, CASA will continue to review the validation method for initial and revalidation of Baro-VNAV approaches with the objective of streamlining the methodology on the basis of operational experience gained.

8.1.6 CASA’s review of the validation methodology will be based on the experience and data gathered during the initial validations, and may also consider:
   - Incorporating a suitable risk based method into the validation process to identify what level of validation is required for individual procedures where appropriate;
   - Use of software tools to evaluate the navigation database and flyability where appropriate; and
   - Use of ground validation (survey) of obstacles where appropriate.
Appendix 1: Example Chart

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<th>B</th>
<th>C</th>
<th>D</th>
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<td>1670 (1108-4.0)</td>
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<td>(1608-6.0)</td>
<td>(1608-7.0)</td>
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Notes:
1. MAX IAS: INITIAL = 210Kt, HOLDING: 210Kt.
2. HOLDING NOT CONTAINED IN CTA.
3. COLOUR: SEE SPEC NOTICES.

Changes: SD FIX, BARO-VNAV, PLAN AND PROFILE VIEW, MAPS, TCH.

MLTGN02-144

USE QNH

RNAV-Z(onsd), RWY 32L

LAUNCESTON, TAS (YMLT)

LNAV/VNAV RQMTS:
- YMLT QNH and TEMP RQ
- PROC TEMP RANGE
-5°C TO +61°C.

HOLDING at MLTSH

AD ELEV 562
Bearings are Magnetic Elevations in FEET AMSL

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<th>1.9</th>
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<th>4</th>
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<td>2510</td>
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Appendix 2: Baro-VNAV Example Design

Plan and Profile View of Example Baro-VNAV Procedure
Appendix 2: Baro-VNAV Example Design

Baro-VNAV Ground Plan Detail

Obstacles penetrating the ground plane surfaces must be assessed.
Additional information is available from:

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