GREPECAS/21 — NE/09
06/11/23

Vigésima Primera Reunión del Grupo Regional de Planificación y Ejecución del Caribe y Sudamérica (GREPECAS/21)

Santo Domingo, República Dominicana, 15 al 17 de noviembre de 2023

Cuestión 3 del Orden del Día: **Desarrollos Globales e Interregionales**

3.3 Nivel de Implementación de los Servicios de Navegación Aérea (ANS) CAR/SAM

IMPLEMENTACIÓN DE PBN EN FRANCIA: UN RETORNO DE EXPERIENCIA

(Presentada por Francia)

RESUMEN EJECUTIVO

En los últimos años, Francia ha implementado procedimientos de navegación basados en el rendimiento a gran escala (PBN) en los espacios aéreos de la Francia metropolitana, en particular para las operaciones de aproximación y aterrizaje. Estos proyectos están en consonancia con la normativa de la UE, cuyo objetivo es el uso exclusivo de la PBN en el espacio aéreo de los Estados miembros de la UE para todas las operaciones, incluidos los aterrizajes de categoría I, de aquí a junio de 2030.

En este contexto, Francia se beneficia de un importante retorno de experiencia en aproximación PBN operada a través del Sistema de Aumentación Basado en Satélites (SBAS) y la Navegación de Guiado Vertical Barométrico (Baro-VNAV).

La integridad y precisión de la señal SBAS utilizada tanto en el guiado lateral como en el vertical garantizan un alto nivel de seguridad de las aproximaciones PBN SBAS dentro de una amplia zona geográfica. SBAS también tiene la capacidad de apoyar las operaciones Cat I cuando los sistemas de navegación convencionales como ILS no están disponibles.

La guía vertical barométrica en Baro-VNAV se basa en la referencia barométrica-altimétrica introducida manualmente por el piloto. Recientemente, Francia ha observado un aumento de incidentes graves de aproximación Baro-VNAV debidos a errores humanos.

Basándose en un documento de trabajo presentado por Francia sobre los incidentes Baro-VNAV, el Grupo de Planificación del Sistema de Aviación de Europa (EASPG) EURNAT de la OACI ha publicado el Boletín EUR_OPS 2023_001 sobre los riesgos relacionados con los errores de ajuste del altímetro durante las operaciones APV Baro-VNAV y de aproximación de no precisión.

Acción:	Ver párrafo 3.
Objetivos Estratégicos:	• Objetivo Estratégico 1 – Seguridad Operacional • Objetivo Estratégico 2 – Capacidad y Eficiencia de la Navegación Aérea
Referencias:	• ICAO Annex 10 Volume I • Manual PBN • GANP ASBU elemento NAVS

1. Introducción

1.1 La implementación de la Navegación Basada en el Rendimiento (PBN) es de gran interés para apoyar trayectorias precisas y avanzadas dentro de los espacios aéreos. La OACI ha definido una estrategia específica para las aproximaciones en su Anexo 10 Volumen I: *"e) promover el uso de las operaciones de aproximación con guía vertical (APV), en particular las que utilizan la guía vertical del Sistema Mundial de Navegación por Satélite (GNSS), para mejorar la seguridad y la accesibilidad"*.

1.2 Francia suscribe plenamente la estrategia específica de la OACI para las aproximaciones en la aplicación de la PBN y ha publicado aproximaciones PBN para la mayoría de sus extremos de pista IFR siguiendo la reglamentación de la UE.

1.3 En la Unión Europea, el Reglamento (UE) 2018/1048 sobre requisitos de uso del espacio aéreo y procedimientos operativos relativos a la navegación basada en el rendimiento (PBN) requiere que los Estados miembros:

i. implementar PBN para todas las fases de vuelo en aproximación y en ruta antes del 25 de enero de 2024,,
ii. Reducir la infraestructura de navegación convencional,
iii. Implementar la regla de *"uso exclusivo de PBN"* para todas las operaciones, incluyendo aterrizajes de Categoría I, antes de junio de 2030.

1.4 El último requisito significa que, para junio de 2030, los Estados miembros de la UE garantizarán aterrizajes de Categoría I con SBAS y ya no con ILS.

1.5 En los últimos años, bajo el reglamento de la UE, Francia ha desarrollado e implementado ampliamente procedimientos PBN en el espacio aéreo de la Francia metropolitana, en particular para operaciones de aproximación y aterrizaje.

1.6 La implementación de operaciones de aproximación PBN se apoya en la publicación de cartas de Navegación Requerida para el Rendimiento en Aproximación (RNP APCH) en aeropuertos con mínimos de LNAV (Navegación Lateral) o LNAV/VNAV (Navegación Lateral/Vertical). Se utilizan dos soluciones técnicas, el Sistema de Aumentación Basado en Satélites (SBAS) y la Navegación de Guía Vertical Barométrica (Baro-VNAV), para cumplir con los requisitos de operaciones de aproximación PBN.

1.7 Francia tiene el mayor número de extremos de pista IFR en Europa y ha experimentado recientemente un aumento en el número de usuarios del espacio aéreo que realizan aterrizajes PBN. Como resultado, Francia se beneficia de una amplia experiencia en el uso tanto de SBAS como de Baro-VNAV en operaciones de aproximación PBN.

2. Discussion

Sistema de Aumentación Basado en Satélites (SBAS)

2.1 El SBAS es un sistema de aumento de señal GNSS (Sistema de Navegación por Satélite Global) de área amplia que utiliza satélites geoestacionarios. Puede transmitir datos GNSS primarios en vastas áreas, proporcionados por una red de estaciones terrestres con información de alcance, integridad y corrección

2.2 La señal SBAS está diseñada con un alto nivel de requisitos de integridad, tal como se define en el Anexo 10, Volumen I de la OACI (Organización de Aviación Civil Internacional). La integridad y precisión de la señal SBAS, tanto en la guía lateral como vertical, garantizan un alto nivel de seguridad en las aproximaciones PBN con SBAS en espacios aéreos de gran amplitud. SBAS tiene la capacidad de respaldar operaciones de Categoría I, lo que es muy útil cuando no se dispone de sistemas de navegación convencionales, como ILS. Para pistas y aeropuertos secundarios, SBAS aporta un alto nivel de mejora en términos de seguridad de las operaciones de aterrizaje y accesibilidad al aeródromo, sin necesidad de infraestructuras locales.

2.3 Fuera del ámbito de la aviación, el uso de SBAS se puede extender, por ejemplo, al ámbito marítimo, transporte por carretera y ferrocarril, agricultura de precisión. Siendo una infraestructura multimodal con beneficios de amplio alcance para los ciudadanos, la experiencia ha demostrado que las señales SBAS se proporcionan de forma gratuita, sin cargos directos para todos los usuarios, incluyendo la aviación. Esta característica hace que SBAS sea más rentable en comparación con otras tecnologías de aterrizaje basadas en satélites, como el Sistema de Aumentación Basado en Tierra (GBAS), para el cual los usuarios de la aviación deben cubrir los costos de adquisición, instalación y certificación de las estaciones terrestres.

Navegación de Guía Vertical Barométrica (Baro-VNAV)

2.4 Baro-VNAV se basa en la combinación de un Sistema de Gestión de Vuelo (FMS) a bordo y un Sistema de Aumentación Basado en Satélites (ABAS) de GPS para la guía lateral, con guía vertical barométrica. La guía vertical barométrica depende de la referencia altimétrica barométrica (generalmente QNH) introducida manualmente por el piloto. La aproximación PBN Baro-VNAV no cumple con los requisitos de precisión necesarios para garantizar aterrizajes de Categoría I.

2.5 Recientemente, se han producido varios incidentes graves en las aproximaciones Baro-VNAV en Francia. Estos incidentes en importantes aeropuertos franceses se deben a errores humanos al ingresar la referencia local de altímetro barométrico (QNH) en la aviónica de la aeronave (consulte el **Anexo A**).

2.6 Cabe destacar que Francia no es el único país donde se han producido incidentes graves relacionados con el uso de Baro-VNAV; de hecho, en los últimos años, eventos similares han generado investigaciones de seguridad en otros lugares, en particular:

2.6.1 El 06/06/2020, un 787 que se aproximaba a mínimos de LNAV/VNAV en Abu Dhabi configuró incorrectamente el QNH (1009 en lugar de 999) y se aproximó 280 pies por debajo de lo deseado, lo que activó una alerta MSAW.

2.6.2 El 22/12/2022, un DHC 8 que se aproximaba a un LOC/DME en Noruega con Baro-VNAV definiendo la trayectoria vertical, configuró incorrectamente el QNH en la referencia estándar (987 hPa), lo que generó una advertencia TAWS.

2.7 En Francia, se han tomado varias medidas para comprender mejor y documentar el nivel de riesgo asociado al aumento del uso de Baro-VNAV:

2.7.1 Se creó un grupo de trabajo sobre altimetría (autoridad de supervisión, proveedores de servicios de navegación aérea, aerolíneas y expertos de la industria). Esta experiencia conjunta llevó, en particular, a la publicación de un folleto de seguridad de la Autoridad de Aviación Civil de Francia y a la contribución al boletín de seguridad de la OACI para la región de Europa, como se menciona en la sección 2.8.

2.7.2 Se está llevando a cabo un análisis de todos los eventos de QNH (incluyendo eventos no reportados) mediante la comparación de datos registrados en vuelo y en tierra durante varios años (aún no hay resultados disponibles).

2.7.3 Se completó un análisis de los eventos de QNH reportados en los espacios aéreos franceses de 2020 a 2022, y se identificaron más eventos de los inicialmente esperados (se identificaron 138 eventos de QNH durante el período de 2020 a 2022). Este estudio también mostró que una gran proporción de estos errores de QNH ocurrieron en aproximaciones ILS, con la detección del QNH configurado incorrectamente solo una vez que la aeronave ya estaba en tierra. Se recuerda que la configuración incorrecta del QNH en una aproximación geométricamente guiada, como ILS, no cambia la trayectoria de la aeronave, a diferencia de las operaciones guiadas barométricamente. Un análisis estadístico también confirmó que el error más frecuente fue dejar el QNH en la referencia estándar, como se observó en Noruega, y un error de 10 mb en el QNH, como se observó en París CDG y Abu Dhabi. La mayoría de los eventos de configuración incorrecta fueron realizados por la tripulación, y alrededor del 10% por los controladores de tránsito aéreo.

2.8 Después del análisis de estos incidentes, Francia presentó un documento de trabajo **(consulte el Anexo A)** durante la reunión del Grupo de Planificación del Sistema de Aviación de Europa de la OACI (EASPG/4) a finales de noviembre de 2022. Este documento de trabajo resume los hechos principales y hallazgos de estos incidentes de vuelo controlado hacia terreno (CFIT) en las aproximaciones PBN Baro-VNAV. Como conclusión de la reunión, el EASPG publicó el Boletín ICAO EUR_OPS 2023_001 sobre los riesgos relacionados con los errores en la configuración del altímetro durante las operaciones APV Baro-VNAV y de aproximación no precisa en julio de 2023 **(consulte los Anexos B y C)**.

2.9 Es importante destacar que recientemente se han publicado varios otros documentos de seguridad relacionados con Baro-VNAV en Europa, con el objetivo de concienciar a la comunidad, en particular:

2.9.1 Boletín de Información de Seguridad de la Agencia Europea de Seguridad Aérea (EASA) 2023/03, emitido el 09 de marzo de 2023, Presión Altimétrica Barométrica Incorrecta.

2.9.2 Safety First, la revista de seguridad de Airbus, diciembre de 2022, Utilice la configuración barométrica correcta para las aproximaciones..

2.9.3 Folleto de Seguridad DGAC n° 2023/02, Riesgos relacionados con errores en la configuración del altímetro, en particular durante las operaciones APV Baro-VNAV y de aproximación no precisa.

2.9 Finalmente, es importante señalar que una de las principales áreas de actividad en Francia, como respuesta a las recomendaciones preliminares de seguridad del *Bureau d'Enquêtes et d'Analyses* (BEA) en relación con el incidente LNAV/VNAV en París CDG, en ausencia de orientación específica de la OACI, fue diseñar medios de mitigación adicionales de emergencia, con la expectativa de que podrían aumentar el nivel de seguridad en las aproximaciones PBN realizadas con Baro-VNAV (consulte el Apéndice D). Uno de los hallazgos importantes de esta área de actividad fue que abordar y mitigar los riesgos de las operaciones Baro-VNAV no se había abordado de manera suficientemente coordinada por la comunidad de aviación y que se necesita un mayor trabajo en esta dirección.

3. **Acciones sugeridas**

3.1 Se invita al GREPECAS a:

a) considerar el contenido de esta Nota de Estudio;

b) considerar el Boletín ICAO EUR_OPS 2023_001 sobre los riesgos relacionados con los errores en la configuración del altímetro durante las operaciones APV Baro-VNAV y de aproximación no precisa;

c) considerar la necesidad de documentar más a fondo los riesgos de configuración incorrecta del QNH y la necesidad de coordinar un trabajo adicional en esta área.

d) considerar las capacidades de integridad y precisión de SBAS y los problemas latentes de seguridad de Baro-VNAV en la implementación y operaciones de las aproximaciones PBN en las Regiones CAR/SAM.

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EASPG/04 – WP/22
08/11/2022

European and North Atlantic Office

EUROPEAN AVIATION SYSTEM PLANNING GROUP

FOURTH MEETING

(Paris, France, 29 November - 1 December 2022)

Agenda Item 3: Safety

Agenda Item 4: Air Navigation Planning and Implementation

BARO-VNAV APPROACHES

(Presented by France)

SUMMARY

Baro-VNAV approaches provide significant safety benefits over legacy LOC, NDB and VOR approaches. They can also enhance safety at unequipped runway ends.

Baro-VNAV approaches are however significantly less robust than geometric PBN approaches enabled by SBAS, and GBAS, as evidenced by several Baro-VNAV related issues in France.

The main vulnerability of baro-VNAV approaches lies in their dependence on correct altimeter setting, which involves multiple human interventions. Other vulnerabilities exist, such as the risk of overestimating the precision of the vertical guidance.

It is proposed that an ICAO EUR bulletin be published, and also sent to States and international organizations, with a view to sensitizing the EUR aviation community to vulnerabilities of baro-VNAV approaches, in particular their dependence on correct altimeter setting.

1. Introduction

1.1 The use of baroVNAV to fly vertically guided PBN approaches is currently supported by the PBN Manual as RNP APCH down to LNAV or LNAV/VNAV minima and is included in GANP ASBU element NAVS-B03. The navigation technologies used for these approaches are GPS ABAS for lateral guidance, and a barometric system for vertical guidance.

1.2 This approach and landing capability is available over a large segment of the transport category aircraft (mostly Airbus/Boeing).

1.3 It is one of the enablers of PBN with vertical guidance approaches, and brings real safety benefits over LOC, NDB and VOR approaches.

1.4 Baro-VNAV based approaches are however significantly less robust than geometric PBN approaches enabled by GBAS (GANP ASBU element NAVS-B01) and SBAS (GANP ASBU element NAVS-B02).

2. Discussion

2.1 Barometric vertical guidance was initially designed to fly continuous descents within TMAs. It was later promoted as an advisory system during laterally guided approaches, and eventually a final approach landing PBN system, in the mid-2000, as an opportunity to address some pressing safety shortcomings (such as suboptimal vertical situational awareness along LOC, NDB, VOR approaches, and unequipped runway ends).

2.2 Baro-VNAV was not designed as a self-standing approach and landing system, by contrast to geometric vertical guidance systems such as ILS, GBAS and SBAS.

2.3 In the same way that VOR and NDB in their time brought progress at runway ends with no landing aids, barometric guidance represents another step of progress at this point in aviation history.

2.4 As evidenced by several serious incidents, baro-VNAV approaches are however significantly less robust than ILS approaches and geometric PBN approaches enabled by GBAS and SBAS.

2.5 The main vulnerability of baro-VNAV approaches lies in their dependence on correct altimeter setting.

2.6 Correct altimeter setting involves multiple human interventions (e.g. determination of the local QNH by the meteorological service provider, publication of the local QNH in ATIS, transmission of the local QNH by ATC to the flight crew, altimeter setting by the flight crew, correction for the effects of temperature on the atmospheric pressure at aircraft altitude).

2.7 It is noteworthy that ILS, GBAS and SBAS are required by ICAO Standards to be designed and certified to meet an integrity risk lower than 10^-7 per approach (which means that these systems should not create an out of tolerance positioning error, without alerting the air crew, more frequently than once every 10 million approaches). The inherent integrity risk of baro-VNAV approaches is certainly on a much lower level. For instance, a 1998 study (Judith Bürki-Cohen https://flightsafety.org/ao/ao_jan_feb98.pdf) published by the Flight Safety Foundation showed that the altimeter setting error rate was on the order of a few percentage points, depending on factors such as the complexity of the clearance.

3. Examples of baro-VNAV related issues experienced in France.

3.1 Example 1:

On June 25th, 2021 a Vueling flight crew to Nantes Atlantique Airport miscopied as 1017 mb the 1007 mb ATIS QNH. The flight crew stated having experienced adverse weather conditions, with cumulonimbus clouds, during descent and approach, and been very focused on weather avoidance. The flight crew correctly readback 1007 QNH to the air traffic controller, without correcting the altimeter setting. The MSAW system alarmed. The air traffic controller used the emergency MSAW phraseology. The flight crew, who was in VMC conditions by then, immediately corrected the altimeter setting and was able to stabilize the approach.

3.2 Example 2:

In 2013, the French meteorological service provider misset the QNH measuring unit at Biarritz Pays Basque airport during a routine maintenance operation. As a result, the local ATC broadcast, during half a day, QNH with a 7 mb error up. The weather conditions were good on that particular day, and the error was detected by airspace users who were too low on approach (NB: 7 mb error = 196 ft error). No incidents/accidents occurred.

3.3 Example 3 :

On October 10, 2021, before starting the RNP approach to runway 21 at Nantes Atlantique Airport, the air traffic control unit cleared the crew of an Air France Hop CRJ 1000 aircraft to descend to 3 000 ft QNH 1002. The flight crew read back QNH 1021. During the final approach, the MSAW alarmed, and an investigation by the French Civil Aviation Safety Investigation and Analysis Bureau (BEA) into this serious incident is underway.

3.4 Example 4 :

a) An Air Hub Airbus A320 flight performed on May 23, 2022 a baro-VNAV approach to Paris CDG Runway 27R. The air traffic controller erroneously advised the flight crew that the QNH was 1011, while it was correctly broadcast 1001 on the ATIS. The aircraft performed its approach about 280 ft below the nominal descent profile, in clouds according to the flight crew.

b) At an indicated altitude of 891 ft QNH 1011 (617 ft actual altitude QNH 1001), 1.53 NM from the runway threshold, the MSAW system alarmed.

c) At 1.2 NM from the runway threshold, and with a vertical speed of -717 ft/min, the aircraft passed the indicated altitude of 802 ft QNH 1011 (537 ft QNH 1001, 122 ft RA), which corresponded to the Decision Altitude (DA) for the crew (Point 2 Figure 1).

d) The flight crew stated that arriving at the minima, they did not acquire visual references and consequently performed a go-around.

e) At an indicated altitude of 735 ft QNH 1011 (461 ft QNH 1001, 52 ft Radio Altimeter), and at 1 NM from the runway threshold, the autopilot was disengaged, and the captain pitched up.

f) Three seconds later, at an indicated altitude of 679 ft QNH 1011 (405 ft QNH 1001), and 0.8 NM from the runway threshold, the minimum radio-altimeter height was recorded at 6 ft above the ground, and an investigation by the French Civil Aviation Safety Investigation and Analysis Bureau (BEA) into this serious incident is underway:

BEA

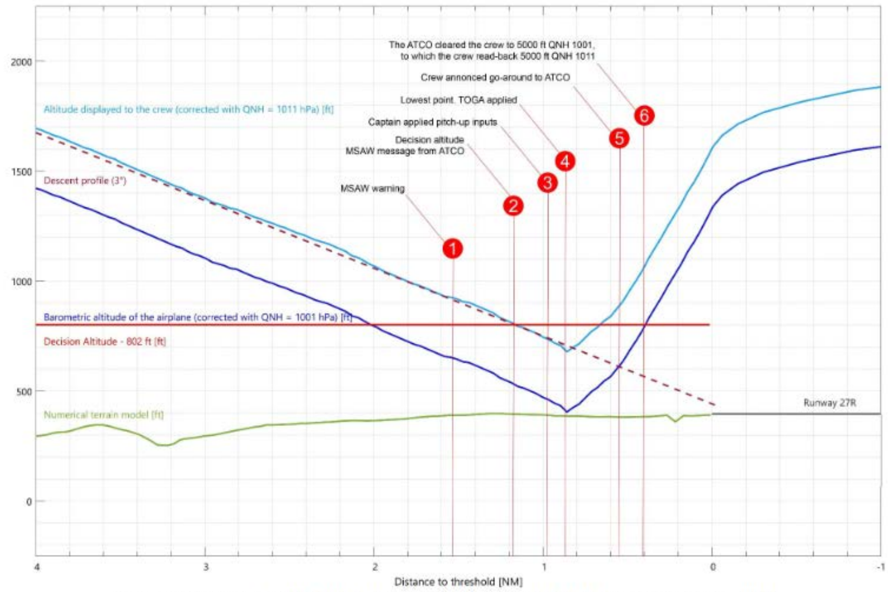

Figure 1: First approach profile, flight path computed from recorded flight parameters (source: BEA)

4. Conclusion

4.1 The safety of baro-VNAV approaches is dependent on correct altimeter setting, a process which requires multiple human interventions, and can lead to serious incidents as stated above.

4.2 Other vulnerabilities of the baro-VNAV technology, such as the risk that flight crews overestimate the precision of the baro-VNAV vertical guidance and conduct an unstabilized approach path, exist.

4.3 By contrast, ILS, SBAS and GBAS geometric approaches are not dependent on altimeter setting, are designed and certified to meet a 10^-7 integrity risk, and have logically proven safer in operations, by eliminating the type of errors involved in the above mentioned incidents, than baro-VNAV approaches.

4.4 In Europe, and other regions of the world, a non-exhaustive search through databases (BEA, Skybrary, NASA ASR, …) reveal occurrences of altimeter setting related incidents/accidents such as reported here for France.

4.5 Proactive safety management is about looking for safety weaknesses and preventing accidents before they occur.

4.6 France is of the view that in the mid/long terms only geometric vertical guidance enabled by ILS, GBAS and SBAS can provide the needed level of safety for the expected traffic growth and increased use of PBN approaches.

4.7 Based on the foregoing, the following is proposed:

Why	Avoid baro-VNAV incidents and accidents
What	Publish, and send to States and international organizations, an ICAO regional bulletin with a view to sensitizing the EUR aviation community to vulnerabilities of the baro-VNAV technology, in particular its dependence on correct altimeter setting.
Who	The Regional Director
When	In 2023

Draft EAPSG Decision 4/#_easpg04wp22/1 – Publication of a Regional Bulletin on baro-VNAV approaches

That the ICAO Regional Director, Europe and North Atlantic:

Publish, and send to States and international organizations, an ICAO EUR bulletin with a view to sensitizing the EUR aviation community to vulnerabilities of baro-VNAV approaches, in particular their dependence on correct altimeter setting.

5. Action by the Meeting

5.1 The meeting is invited to:

a) note the information provided;

b) amend as necessary and endorse the Decision in paragraph 4.7; and

c) provide direction as deemed necessary.

— END —

INTERNATIONAL CIVIL AVIATION ORGANIZATION
European and North Atlantic Office

ORGANIZACIÓN DE AVIACIÓN CIVIL INTERNACIONAL
Oficina Europa y Atlántico Norte

ORGANISATION DE L'AVIATION CIVILE INTERNATIONALE
Bureau Europe et Atlantique Nord

МЕЖДУНАРОДНАЯ ОРГАНИЗАЦИЯ ГРАЖДАНСКОЙ АВИАЦИИ
Европейское/Североатлантическое бюро

3 bis villa Emile Bergerat, 92522 Neuilly-sur-Seine Cedex, France

When replying please quote
Reference : EUR/NAT 23-0252.TEC (NIA/HOI) 28 July 2023

Subject : **EUR OPS Bulletin 2023_001 on risks related to altimeter setting errors during APV Baro-VNAV and non-precision approach operations**

Action required : *Please refer to paragraph 3*

Dear Madam/Sir,

1. I wish to refer to the outcome of discussions of the Fourth Meeting of the European Aviation System Planning Group (EASPG/4) which was held in the ICAO EUR/NAT Premises, from 29 November to 1 December 2022, and more specifically to the EASPG Decision 4/14 "**Development of a Regional Bulletin on Baro-VNAV Approaches**".

2. The EASPG Performance Based Navigation Consolidation Task Force (EASPG PBNC TF) developed the **EUR OPS Bulletin 2023_001 on risks related to altimeter setting errors during APV Baro-VNAV and non-precision approach operations**, which was endorsed by the EASPG Programme Coordination Group (EASPG PCG) through correspondence in June 2023.

3. The endorsed Bulletin was published on the ICAO European and North Atlantic Office website and can be downloaded via the following link EUR and NAT Documents (icao.int) for your perusal and distribution to other stakeholders, as appropriate.

Yours faithfully,

Nicolas Rallo
Regional Director
European and North Atlantic Office

Distribution: ICAO EUR/NAT States of Accreditation, International Organisations, EASPG Members and Observers

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EUR OPS BULLETIN

Serial Number: **2023_001** Effective: **27 July 2023**

Subject: Risks related to altimeter setting errors during APV Baro-VNAV and non-precision approach operations

1. Introduction and scope

1.1 Recent incidents have highlighted that an erroneous altimeter setting can have serious consequences on flight safety during final approach operations. After recalling how aircraft barometric altitude is determined and used in certain approach operations, this bulletin lists a set of recommendations to mitigate altimeter setting errors.

2. Barometric altitude

2.1 Barometric altitudes are widely used in aviation today:

- to ensure vertical separation between aircraft and terrain on instrument flight procedures.
- to define certain vertical approach paths.
- to determine all the minimum altitudes, in particular the MDA/DA (Minimum Descent Altitude/Decision Altitude) on non-precision, APV and CAT I precision approaches.

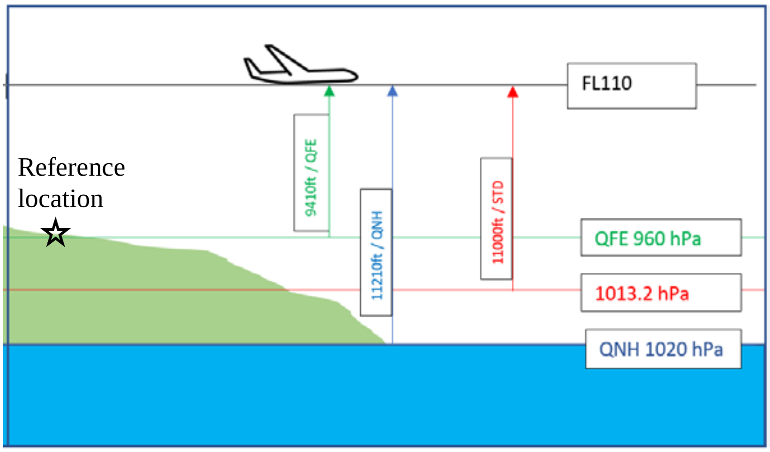

Figure 1 – Altimeter setting

2.2 Aircraft pressure altimeters are calibrated according to the International Standard Atmosphere, to indicate the elevation of the aircraft above a selected datum. The selected datum depends on the barometric reference pressure set on the altimeter sub-scale, which can be:

- QNH or local pressure at a reference location, converted to Mean Sea Level: in this case the altimeter will indicate the altitude of the aircraft.
- 1013.2 hPa: in this case the altimeter will indicate the Flight Level of the aircraft.
- QFE or local pressure at a reference location: in this case the altimeter will indicate the height of the aircraft above that reference location

3. Risks

3.1 The technical characteristics of the altimeter induce two risks that could lead to the determination of an erroneous altitude:

1) The incorrect altimeter setting
2) The temperature effect (difference between the real atmosphere and the standard atmosphere)

3.2 Barometric altimeter setting errors can lead to significant altimeter deviations. Each 1hPa error equates to approximately 30 ft of height difference; therefore, an altimeter setting error of 10 hPa would result in an altitude error of about 300 ft.

3.3 The effects of temperature can be anticipated because they are directly related to the deviation from the standard ISA temperature. They can lead to a reduction of safety margins, but technical solutions exist, as well as operational procedures, already in place, which allow to limit these effects, in particular by cold temperature corrections.

Note – Further guidance on the "RNP approach and RNP AR approach operations in non-standard temperature conditions" is available in the Performance-Based Navigation (PBN) Manual (Doc 9613), Fifth Edition, Volume II, Attachment B.

4. Final approach operations

4.1 The consequences of an erroneous altimeter setting will be more severe on the final segment of the approach for which the obstacle clearance margins are reduced. Most final approach operations can be affected by an erroneous altimeter setting. But they will not all be affected in the same manner.

4.2 ILS CAT I, GLS CAT I, RNP APCH down to LPV minima provide vertical guidance to the runway that is not dependent on barometric altitude. Therefore, once established on the glide path, an altimeter setting error will not affect the vertical profile. As a result, only the Decision Altitude (DA) based on barometric altitude, may still be subject to an error, such that the crew might make the decision either to land or go around higher or lower than expected, depending on the error of the altimeter setting.

4.3 On the other hand, the entire vertical path of non-precision approaches operated as either Dive & Drive (stepdown) or using a Continuous Final Descent Approach (CDFA) technique, as well as RNP APCH to LNAV or LNAV/VNAV minima and RNP AR operations can all be highly impacted by altimeter setting error.

4.4 If the altimeter setting is set incorrectly on the altimeter sub-scale, the aircraft could be significantly above or below the safe vertical profile as determined by the procedure design. The barometric altimeter setting error will also affect the MDA/DA and the possible check of altitude versus distance to the threshold made by the crew will not allow them to detect this type of error.

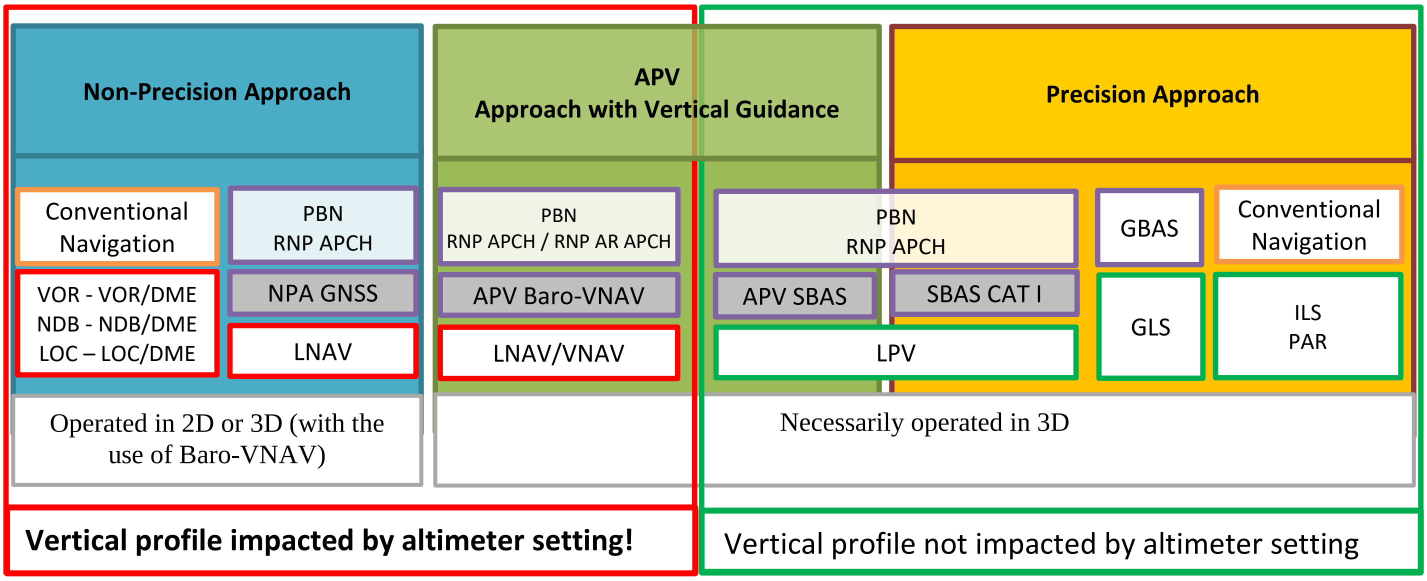

Figure 2 – Approach procedures and Altimeter setting

Note – APVs (Approaches with Vertical Guidance) are usually materialized under two different minima lines on a single RNP approach chart: LNAV/VNAV (using Baro-VNAV technology) versus LPV (using the Satellite Based Augmentation System, SBAS). However, the minima are associated to two different approach technologies since Baro-VNAV relies on barometric altitude to define the vertical path, whereas SBAS is based on geometric altitude. ICAO therefore recommends that the term APV is not used anymore in an operational context. Operators and pilots should be aware of these differences in order to avoid any confusion when considering the minima line.

Focus on Baro-VNAV

4.5 Baro-VNAV offers vertical guidance based on the aircraft's barometric altitude and a vertical profile encoded in the navigation database. It simplifies the CDFA flight technique and provides the same operating mode for crew to perform all non-precision approaches and Baro-VNAV approaches. The way Baro-VNAV information is integrated in the cockpit may make Baro-VNAV operations look like precision approach operations. However, unlike precision approach operations, Baro-VNAV operations are based on barometric references, that is why the altitude versus distance checks, which may allow detection of a final segment vertical path error when operating an ILS, GLS or RNP with LPV minima, are ineffective for Baro-VNAV operations, as the same erroneous information is being used for the vertical profile definition and the altitude check.

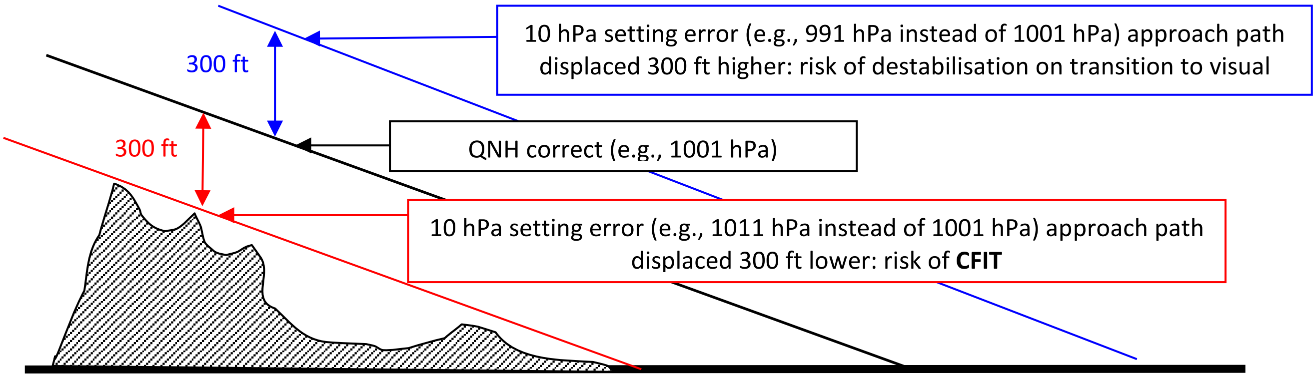

Figure 3 – Example of altitude deviation resulting from altimeter setting error

4.6 As with any non-precision approach operation, it is therefore imperative to ensure the correct altimeter setting when using Baro-VNAV, keeping in mind that both the vertical profile and the DA would be impacted in case of error.

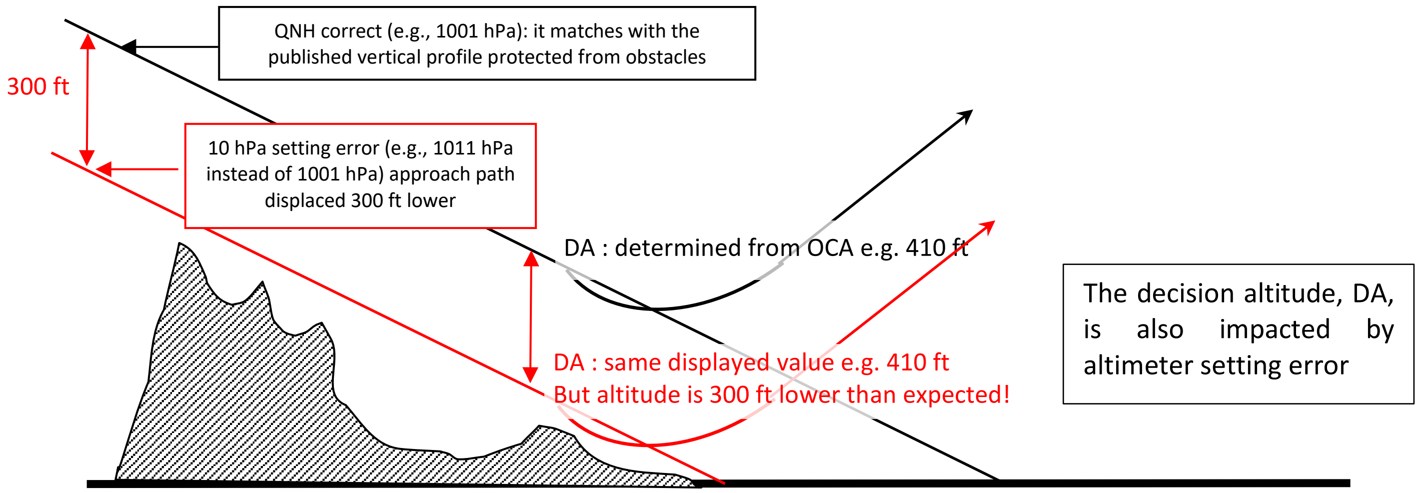

Figure 4 – Example of the impact of an altimeter setting error on DA

5. Root causes

5.1 The altimeter setting involves several steps, which may be subject to errors:

- Incorrect determination of the local barometric pressure, use of regional pressure instead of local barometric pressure values or transmission of a wrong value by the meteorological service provider,
- Provision of incorrect QNH through ATIS (where available)
- Ineffective ATC-Pilot communication, such as: wrong value given by ATC, incorrect read back not detected by ATC, radio/frequency issue, etc.
- Incorrect selection of the altimeter setting by the crew due to different factors such as: high workload, confusion in the unit of the barometric setting (Inch Hg instead of hPa), confusion between QNH and QFE, absence of effective crosscheck between crew members, flight deck system failure, etc.

Transition altitude/level

5.2 The transition level is the lowest flight level available for use above the transition altitude, where altimeter setting is set to 1013.2 hPa. The transition altitude is the level below which the vertical position of an aircraft is controlled by reference to altitudes, where altimeter setting is set to QNH.

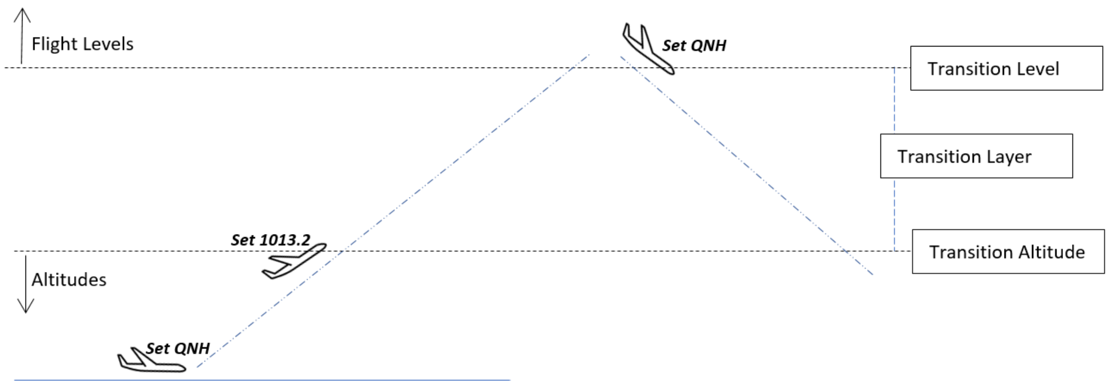

Figure 5 – Transition Altitude/Level

5.3 Altimeter setting error in approach can occur when the crew switches from 1013.2 hPa to QNH and vice versa. Depending on operators' usual area of operation, using variable transition altitude instead of fixed transition altitude may cause crew confusion and result in a premature or late setting of the correct altimeter reference. Furthermore, as the crew's workload intensifies during the descent and landing phase, a low transition altitude/level may require the crew to adjust the altimeter settings when their workload is already high, which can increase the likelihood of altimeter setting errors. In addition, a low transition altitude/level can reduce the opportunity to detect a possible altimeter setting error before the aircraft intercepts the final approach segment.

6. Proposed Mitigations

6.1 Aircraft operators and ANSPs are reminded of the importance of ensuring that the correct barometric altimeter setting is provided and entered in the aircraft's systems.

6.2 Some mitigations are as follows:

<u>At aircraft operator's level</u>

- Encourage the use of those 3D operations where final segment profiles cannot be impacted by wrong barometric altimeter setting (ILS, RNP APCH down to LPV minima, GLS).
- Establishment and strict adherence to the standard operating procedures for the use of the VNAV function.
- Consider adjusting the operating minima by taking into account the operational exposure and/or crew experience with approach procedures that are vulnerable to QNH errors.
- Apply Crew Resource Management techniques, such as cross-checking and monitoring.
- Consider altitude callouts, whereby the aircraft's radio altimeter can provide height callouts to the pilot when passing specific values (e.g. 500 ft and 1000 ft), which can be interpreted to assess whether the

aircraft is deviating from the intended vertical profile. This mitigation is more effective when the terrain is relatively flat.

- Configure correct QNH in all altimeters (main, standby) and FMS. The flight crew should pay attention to a barometric reference that significantly differs from the one used for approach preparation. That could be the symptom of a barometric reference error. The flight crew should consider cross-checking of the barometric references from all available sources (METAR, ATIS and ATS).
- Apply standard communication and phraseology between the pilot and air traffic services.
- Pilots should use effective Threat & Error Management (TEM) techniques to identify and mitigate against incorrect altimetry when preparing to fly an approach that relies directly on an accurate pressure altimeter sub-scale setting (e.g. use of Baro-VNAV, non-precision approaches).

<u>At ANSP level</u>

- Consider fixed and harmonized transition altitudes/levels which can harmonize the switch from 1013.2 hPa to QNH.
- Consider using the barometric pressure settings provided by Mode S EHS (Enhanced Surveillance) and ADS-B equipped aircraft, to enable the timely identification of aircraft operating with incorrect barometric altimeter setting.
- Consider introducing procedures to provide aircraft with the QNH at different phases of approach, including when clearing an aircraft for the approach or at first contact with the tower.
- Apply standard communication and phraseology between the pilot and air traffic services.

<u>Technical solutions</u>

- Consider using those 3D approach procedures where the final segment cannot be impacted by wrong QNH setting (ILS, RNP APCH down to LPV minima or GLS).
- Use of recovery safety nets, such as Minimum Safe Altitude Warning (MSAW) and Approach Path Monitor (APM) by ATC and Terrain Avoidance and Warning System (TAWS) by pilots, which can alert actors and thus lead to recovery actions associated with operational procedures.

  Note – these safety nets are not available in all aircraft or ATS units and their technology varies from one site to another. Their intrinsic characteristics, in particular resulting from choices intended to limit the false alarm rate, lead them, in certain cases, not to be triggered, without this being a malfunction. To get the most consistent alerts, aircraft operators should ensure that the latest available software version and the latest terrain and obstacle database are loaded in the TAWS.
- Consider the use of datalink for transmission of MET information, including QNH, to aircraft.
- Consider other emerging monitoring solutions that would offer comparison between barometric altitude with GNSS-driven altitude.

7. Recommendations

7.1 In order to better manage the risks related to altimeter setting errors, in particular during APV Baro-VNAV and non-precision approach operations, the followings are recommended:

a) General recommendations:

- to ensure that awareness of the risk of altimeter setting errors and their consequences is shared;
- to assess the robustness of the mitigation measures described in the previous point, and to consider implementing them, when relevant;
- to report all situations that have generated deviations in order to improve the visibility of this type of event, preferably with a perspective of the appropriate treatment in each case;
- to contribute collectively to training on this risk, to disseminate best practices and to promote exchanges between domains in order to better understand the limits of the systems;
- MET Service providers to ensure provision of quality-assured MET information to users;
- aircraft operators, to investigate methods to identify incorrect altimeter setting with the Flight Data Monitoring (FDM) Program; and

- Relevant ANC Panel(s), to assess the potential review of APV Baro-VNAV criteria concerning the likelihood of QNH errors.

b) Recommendations on Training:

- Barometric altitude setting is largely dependent on human factors. Therefore, it is recommended to consider appropriate initial and recurrent training subjects to pilots and ATCOs, including the following:

  For pilots:

  - Initial and recurrent training should address the limits of barometric altimetry, and the impact of incorrect barometric pressure settings on vertical position including those factors outlined in this bulletin.
  - Training and/or promotional initiatives on altimeter setting procedures, different impacts of QNH errors between geometric and barometric approaches and possible mitigation measures, use of standard phraseologies, adhering to read back and hear back, etc.
  - Training on 3D operations including the difference between 3D depending on Baro-VNAV and other 3D approach operations, highlighting the critical importance of Barometric setting for Baro-VNAV operations.
  - Training on 3D RNP operations highlighting the RNP chart layout where LNAV/VNAV and LPV minima co-exist.

  For ATCO:

  - Initial and recurrent training should address the limits of barometric altimetry, and the impact of incorrect barometric pressure settings on vertical position including those factors outlined in this bulletin.
  - Training and/or promotional initiatives on altimeter setting procedures, different impacts of QNH errors between geometric and barometric approaches and possible ATC mitigation measures on erroneous setting of altimeter setting by flight crew, use of standard phraseologies for transmitting QNH information to pilots, paying attention to pilots' read back and hear back, etc.

- END -