Organización de Aviación Civil Internacional
Oficina Regional Sudamericana
Décimo Séptima Reunión de Autoridades de Aviación Civil de la Región Sudamericana (RAAC/17)
(Santiago, Chile, 10 al 14 de abril de 2023)

RAAC/17-NE/14
21/01/23

Cuestión 4A del Orden del día: **Iniciativas para el desarrollo y sostenimiento del transporte aéreo en la Región**

Implantación PBN en Francia: una experiencia de retorno

(Presented by France)

RESUMEN

En los últimos años, Francia ha implantado en gran escala procedimientos PBN en los espacios aéreos de Francia Metropolitana, en particular para las operaciones de aproximación y aterrizaje. Estos proyectos están en consonancia con la normativa de la UE que tiene como objetivo el uso exclusivo de la navegación basada en performance (PBN) en el espacio aéreo de los Estados Miembros de la UE para todas las operaciones, incluidos los aterrizajes Cat I, para junio de 2030.

En este contexto, Francia se beneficia de un importante retorno de experiencia en el enfoque PBN operado a través del Sistema de aumentación basado en satélites (SBAS) y de la Navegación con guía vertical barométrica (BaroVNAV).

La integridad y precisión de la señal SBAS, utilizada tanto en la guía lateral como la 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 BaroVNAV se basa en la referencia barométrica-altimétrica introducida manualmente por el piloto. Recientemente, Francia ha observado un aumento de incidentes graves de aproximación BaroVNAV debidos a errores humanos.

Con base en una nota de estudio presentada por Francia sobre los incidentes BaroVNAV, el Grupo de Planificación del Sistema de Aviación de Europa (EASPG) EURNAT de la OACI ha decidido preparar un Boletín OACI OPS EUR sobre las vulnerabilidades de las aproximaciones BaroVNAV.

Se invita a la RAAC a:

a) Tomar nota del contenido de este documento de trabajo;
b) considerar el Boletín OACI EUR OPS relativo a las vulnerabilidades de BaroVNAV cuando se publique;
c) considerar las capacidades de integridad y precisión de SBAS y los problemas de seguridad de BaroVNAV en la implementación y operaciones de aproximaciones PBN en la Región SAM.

Referencias:

- Anexo 10 de la OACI, Volumen I
- Manual PBN
- GANP ASBU elemento NAVS

Objetivo Estratégico de la OACI:	- Seguridad Operacional - Capacidad y Eficiencia de la Navegación Aérea

1. Introducción

1.1 La implantación de la navegación basada en la performance (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 las operaciones con aproximación con guía vertical (APV), en particular las que utilizan la guía vertical del Sistema Mundial de Navegación por Satélite (GNSS), para fortalecer la seguridad y el acceso accesibilidad"*.

1.2 Francia suscribe plenamente la estrategia específica de la OACI para las aproximaciones en la implantación 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 los requisitos de utilización del espacio aéreo y los procedimientos operativos en relación a la PBN exige a los Estados Miembros que:

i. Desplieguen la PBN para todas las fases de vuelo en aproximación y en ruta antes del 25 de enero de 2024;
ii. reduzcan la infraestructura de navegación convencional;
iii. implementar la norma de "*uso exclusivo de PBN*" para todas las operaciones, incluidos los aterrizajes Cat I, para junio de 2030.

1.4 Este último requisito significa que, para junio de 2030, los Estados miembros de la UE garantizarán los aterrizajes Cat I con SBAS y ya no con ILS[1].

1.5 En los últimos años, bajo la normativa de la UE, Francia ha desarrollado e implantado a gran escala procedimientos PBN en los espacios aéreos de Francia metropolitana, en particular para las operaciones de aproximación y aterrizaje.

1.6 La implantación de las operaciones de aproximación PBN se respalda en la publicación de cartas de aproximación con performance de navegación requerida (RNP APCH) en los aeródromos con mínimos LNAV (Navegación Lateral) o LNAV/VNAV (Navegación Lateral/Vertical). Dos soluciones técnicas, el Sistema de Aumentación Basado en Satélites (SBAS) y la Navegación de Guiado Vertical Barométrico (BaroVNAV), se utilizan para cumplir los requisitos de las operaciones de aproximación PBN.

1.7 Francia cuenta con el mayor número de extremos de pista IFR de Europa y ha experimentado recientemente un aumento del número de usuarios del espacio aéreo que realizan aterrizajes PBN. Por consiguiente, Francia se beneficia de una amplia experiencia en el uso tanto de SBAS como de BaroVNAV en las operaciones de aproximación PBN.

2. Discusión

Sistema de aumentación basado en satélites (SBAS)

2.1 El SBAS es un sistema diferencial de aumento de la señal GNSS de área amplia que utiliza satélites geoestacionarios. Puede difundir en vastas áreas datos GNSS primarios, proporcionados por una red de estaciones terrestres con información de alcance, integridad y corrección.

[1] The European Union Aviation Safety Agency (EASA) has recently warned aircraft operators of the risk of losing Cat I landings capability in Europe after June 2030 unless they upgrade their aircrafts avionics (https://www.easa.europa.eu/en/newsroom-and-events/news/easa-publishes-communication-aircraft-operators-pbn-implementation).

2.2 La señal SBAS está diseñada con un nivel muy alto de requisitos de integridad, tal como se define en el Anexo 10 Volumen I de la OACI. La integridad y precisión de la señal SBAS, tanto en la guía lateral como en la vertical, garantiza un alto nivel de seguridad para las aproximaciones SBAS PBN dentro de espacios aéreos de área amplia.

SBAS tiene la capacidad de respaldar operaciones Cat I, lo que resulta muy útil cuando los sistemas de navegación convencionales, como ILS, no están disponibles. Para las pistas secundarias y los aeródromos secundarios, SBAS aporta un alto nivel de mejora en términos de seguridad de las operaciones de aterrizaje y de accesibilidad al aeródromo, sin necesidad de infraestructuras locales.

2.3 Fuera del ámbito de la aviación, el uso del SBAS puede extenderse, por ejemplo, al ámbito marítimo, a los transportes por carretera y ferrocarril y a la agricultura de precisión. Al tratarse de una infraestructura multimodal con amplios beneficios para los ciudadanos, la experiencia ha demostrado que las señales SBAS se suministran libres de cargos directos a todos los usuarios, incluidos los de la aviación. Esta característica hace que el SBAS sea más rentable en comparación con otras tecnologías de aterrizaje por satélite, como el Sistema de aumentación basado en tierra (GBAS), para el que los usuarios de la aviación tienen que sufragar los costes de adquisición, instalación y certificación de las estaciones terrestres.

Navegación con Guía Vertical Barométrica (BaroVNAV)

2.4 BaroVNAV se basa en la combinación del Sistema de Gestión de Vuelo (FMS) de a bordo y el Sistema de aumentación basado en la aeronave (ABAS) GPS para la guía lateral con guía vertical barométrica. La guía vertical barométrica se basa en la referencia de altitud barométrica (QNH principalmente) introducida manualmente por el piloto.

2.5 Recientemente se han producido en Francia varios incidentes graves de aproximación BaroVNAV. Estos incidentes en los principales aeródromos franceses se deben a errores humanos al introducir la referencia de altitud barométrica local (QNH) en la aviónica de la aeronave.

2.6 Tras el análisis de estos incidentes, Francia presentó una nota de estudio (véase el **Apéndice A**) durante la reunión del Grupo de Planificación del Sistema de Aviación EuropEO (EASPG/4) de la OACI a finales de noviembre de 2022. Esta nota de estudio resume los principales hechos y conclusiones de estos cuasi impactos contra el suelo sin pérdida de control (CFIT) en el uso de aproximaciones PBN BaroVNAV. Como conclusión de la reunión, el EASPG ha decidido redactar un Boletín OACI EUR OPS sobre las vulnerabilidades de las aproximaciones BaroVNAV. También se presentó un documento de trabajo "*Situación con la implantación del PBN en Francia*" a la reunión del Panel de Sistemas de Navegación de la OACI (NSP/7) en enero de 2023. El NSP concluyó que la comunicación en torno a temas específicos de tecnologías PBN, como BaroVNAV, era clave y que debería ponerse a consideración de la Comisión de Navegación Aérea de la OACI.

2.7 Además, la aproximación BaroVNAV PBN no cumple con los requerimientos de precisión para garantizar aterrizajes Cat I.

3. Acción sugerida

3.1 Se invita a la RAAC a:

a) Tomar nota del contenido de esta nota de estudio;
b) considerar el Boletín OACI EUR OPS relativo a las vulnerabilidades de BaroVNAV cuando se publique;

c) considerar las capacidades de integridad y precisión de SBAS y los problemas de seguridad de BaroVNAV en la implementación y operaciones de aproximaciones PBN en la Región SAM.

- - - - - -

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

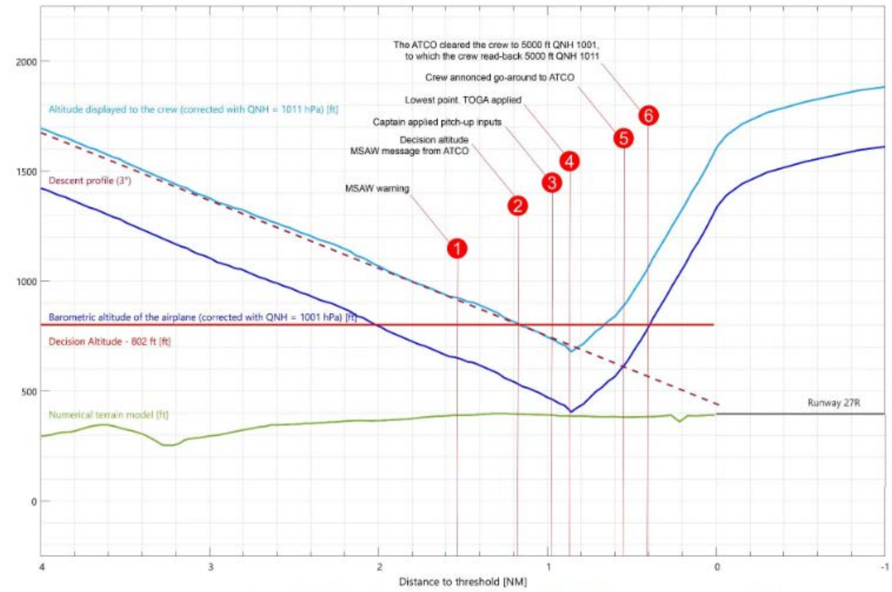

Figure 1: First approach profile, flight path computed from recorded flight parameters (source: BEA)

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 —

APPENDIX B

PBN implementation in France: return of experience

Mitigation measures implemented following serious incidents in BaroVNAV operations

1.1 It should be noted that APPENDIX A documents a few examples only of the three main types of categories of incidents with significant impact in the operations of BaroVNAV PBN approaches: error within the ATC system, error transmitted by ATC, error made by the aircrew.

1.2 Many other less severe incidents are also documented by the French civil aviation authority and in other incident databases.

1.3 Given the EU regulation requirements on PBN implementation and in particular the exclusive use of PBN phase from June 2030, aircrafts that are not equipped with SBAS will have to rely on BaroVNAV as an alternative to ILS. It is expected that more and more operators will use BaroVNAV PBN operations in Europe, and possibly in other regions as well. Consequently, an increase in the occurrence of such incidents is to be foreseen in the future.

1.4 From what is observed in France, BaroVNAV may be useful in the first phase of introduction of vertical guidance at runway-ends where it was not available previously. Nonetheless, the return of experience shows that the latent failures of BaroVNAV will require significant additional operational mitigation measures which make it difficult to identify BaroVNAV as a long-term primary landing aid.

1.5 In the same time, the European Union Aviation Safety Agency (EASA) has recently warned aircraft operators of the risk of losing Cat I landings capability in Europe after June 2030 unless they upgrade their aircrafts avionics (https://www.easa.europa.eu/en/newsroom-and-events/news/easa-publishes-communication-aircraft-operators-pbn-implementation).

<u>Additional operational mitigation measures are implemented for BaroVNAV operations in France</u>

1.6 Following the analysis of the serious incidents in the use of BaroVNAV PBN approaches, France decided to implement additional operational mitigation measures to increase the level of safety in operating PBN LNAV and LNAV/VNAV approaches.

1.7 While determining the mitigation measures, several significant issues were raised and pointed out in the working paper "*Issue with PBN implementation in France*" proposed to the ICAO Navigation System Panel in the NSP/7 meeting in January 2023:

i. the absence of ICAO standards describing the failure modes of BaroVNAV,
ii. the absence of guidance material for States on the appropriate mitigation measures to implement in relation to the limitations in performance of a technology.

1.8 In the absence of ICAO standards, France defined additional mitigation measures:

i. Reinforcement of QNH information exchanges at all aerodromes between ATCOs and Aircrews

QNH is now announced 3 times by Air Traffic Control (ATC): 1- ATIS, 2- approach ATCO (ITM), 3- tower ATCO (LOC),

ii. Additional operational requirements at aerodromes using a Minimum Safe Altitude Warning (MSAW) safety net
ATC is now required to issue a go around instruction in case of MSAW alert, whatever its cause.

1.9 In addition to the above, the most frequently observed QNH error being a confusion of 10 millibars equivalent to 280 ft, the decision has been made to increase by 300 ft the operational minima of Nantes airport runway 21, subject to several MSAW alerts recently as the approach trajectory overflies the city of Nantes. This specific mitigation measure is implemented only at Nantes airport for the time being[1].

1.10 It is still too early to confirm whether these operational mitigation measures need to be maintained, reinforced, or alleviated as their implementation also has an operational impact.

1.11 In addition, France currently:

i. investigates other technologies to mitigate the safety issues raised by BaroVNAV such as the mode S downlink of the on-board QNH. This will enable the ATC system to compare its value with the QNH known by ATC, and possibly to alert the ATCO in case of divergence.

ii. monitors evolutions in new generation aircrafts that are not yet widely available, where on-board QNH errors are automatically detected.

- END -

[1] It may be noted within the BEA AirHub CDG report that the involved airline had a policy of an “add-on” of 50 ft over the published LNAV/VNAV minima. Since at the lowest point of its vertical trajectory the aircraft was only 6 ft above the ground ahead of the runway, this minima add-on probably saved the aircraft that day. Increasing LNAV/VNAV or LNAV minima is a potentially useful safety mitigation.