SAFETY RECOMMENDATIONS

Note: in accordance with the provisions of Article 17.3 of Regulation No 996/2010 of the European Parliament and of the Council of 20 October 2010 on the investigation and prevention of accidents and incidents in civil aviation, a safety recommendation in no case creates a presumption of fault or liability in an accident, serious incident or incident. The recipients of safety recommendations shall report to the safety investigation authority which issued them, on the measures taken or being studied for their implementation, as provided for in Article 18 of the aforementioned regulation.

Overall reassessment of the CFIT risk and the associated mitigation measures, in connection with the threat of an incorrect altimeter setting for Baro-VNAV approach operations

The CFIT risk due to the threat of an incorrect altimeter setting for barometric approaches has been known about since practically the beginning of aviation. The predominant use of non-precision approach operations and the virtual absence of ground collision avoidance systems until the 1970s gave rise to a high CFIT risk, due in part to incorrect altimeter settings, which was tolerated in view of the overall safety requirements at the time.

The significant development of commercial air transport over the following decades greatly increased societal expectations both in terms of safety and weather-related airport accessibility. ILS installations, offering lateral and vertical guidance that is not affected by incorrect altimeter settings, as well as improved accessibility due to lower approach minima, thus became widely used, becoming an equipment standard worldwide even to this present day.

The development, from the 1990s onwards, of Baro-VNAV functions (offering conventional or satellite-based lateral guidance, and barometric vertical guidance based on the altimeter setting) made it possible to carry out descents, then approaches, and in the 2000s final approaches using Performance Based Navigation (PBN) down to minima close to those of Category I precision approaches.

Baro-VNAV approaches have thus played a major role in improving safety, and continue to do so, by providing vertical guidance on non-precision approaches and on runways without radio navigation equipment. They reduce the CFIT risk.

However, the Baro-VNAV function was not designed to be an autonomous approach and landing system, unlike precision approach systems such as the ILS, or approaches using GNSS positioning augmentation systems (GBAS ou SBAS). The vertical guidance of a Baro-VNAV approach is based solely on the aeroplane's internal data, in particular the barometric altitude, which depends on the altimeter setting. However, the latter potentially relies on multiple human inputs that are prone to error (by the meteorological services, air traffic controllers and pilots).

The approach operations that use the Baro-VNAV function in order to have the lowest minima are the RNP APCH down to LNAV/VNAV minima type PBN operations. With these operations, it is possible to have a decision height as low as 250 ft, close to the minima for a Category I ILS approach at 200 ft. However, one of the most frequent incorrect altimeter settings in hectopascal is with an error of 10 hPa. This offsets the altitude and therefore the vertical profile by 280 ft to the theoretical vertical profile, which could ultimately lead to a collision with the ground before the indicated decision altitude has been reached by the crew.

It should also be noted that in the design of the operations, the method of calculating decision heights for RNP APCH down to LNAV/VNAV minima, notably based on obstacle clearance margins in the ICAO PANS-OPS, was revised in 2004 to increase airport accessibility, and results in lower decision altitudes. The threats inherent in the Baro-VNAV function, such as an incorrect altimeter setting, were not taken into account when this revision was introduced, and the reduction in minima for these approaches did not give rise to a safety study by ICAO.

The various risk analyses carried out on Baro-VNAV approaches by different international institutions have not sufficiently taken into account the threat that an incorrect altimeter setting represents for the CFIT risk, whether in the design of these IFR procedures, in their implementation by crews, in air traffic controllers' procedures or in on-board or ground systems. It should also be noted that the risk analyses regarding Baro-VNAV approaches carried out in the United States concerned a context and airspace organisation that greatly differ from those in other parts of the world and Europe in particular. In the United States, for example, altimeter settings are in in Hg, the transition level is at FL180, and the mother tongue for air traffic controllers is English. Comparisons may therefore be inappropriate, and discussions at international level must take these differences into account.

In a context of the increasing use of satellite approaches with barometric vertical guidance, the threat of an incorrect altimeter setting, although known about for decades, has become preponderant again. This risk was probably not sufficiently taken into account by the aviation community as a whole because the majority of approaches in commercial air transport have for several decades been carried out using ILS precision approaches and their vertical profiles are not affected by incorrect altimeter settings, thus masking most of these errors and their consequences.

In the light of this serious incident and the many similar occurrences of incorrect altimeter settings, it can be considered that the hypothesis that current training, procedures and systems are sufficient to limit the CFIT risk when a Baro-VNAV approach is being carried out with an incorrect altimeter setting is not true and that this risk is incompatible with the overall safety level expected today in commercial air transport.

The various measures taken by different aviation stakeholders during the investigation aimed to improve safety. However, these measures are either actions taken by certain organisations that have not been generalised, or reminders of good practice or recommendations that do not lead to systemic changes or only have short-term effects.

Therefore, the BEA recommends that:

- ***whereas the threat represented by a barometric approach flown with an incorrect altimeter setting giving rise to a CFIT risk in particular;***
- ***whereas the large number of similar occurrences of approaches carried out with an incorrect altimeter setting;***
- ***whereas the design of barometric approach operations and the associated minima do not take into account the possibility of an incorrect altimeter setting;***
- ***whereas the standard operating procedures of crews and air traffic controllers are not sufficiently robust to systematically prevent and detect an altimeter setting error;***
- ***whereas ground and on-board systems for detecting an incorrect altimeter setting are currently only marginally deployed;***

- ***whereas the current limited availability on board aeroplanes, of LPV capabilities, which are not vulnerable to incorrect altimeter settings, and which could be difficult and costly to retrofit;***
- ***whereas CFIT prevention barriers, both procedural and system-based, are neither always present nor always effective;***
- ***whereas ICAO EUR OPS bulletin No 2023_001 "*Risks related to altimeter setting errors during APV Baro-VNAV and non-precision approach operations*" contains recommendations that should be maintained, extended or formalised;***

ICAO, in collaboration with the manufacturers, authorities and operators, carry out an overall reassessment of the CFIT risk and the associated mitigation measures, in connection with the threat of an incorrect altimeter setting for Baro-VNAV approach operations. These measures could consist of updating the standards and recommended practices and associated documents and defining incentives, or even stipulations, to ensure the development of new safety barriers or the improvement of existing ones.
[Recommendation FRAN-2024-006].

Maintaining the safety level of approach operations in Europe in 2030

Commission Implementing Regulation (EU) 2018/1048 of 18 July 2018 laying down airspace usage requirements and operating procedures concerning performance-based navigation, known as the "IR-PBN" regulation, requires that European air navigation service providers exclusively use PBN up to CAT I precision approach operations by 30 June 2030. Consequently, approach operations using conventional navigation systems such as the ILS, will no longer be proposed from that date onwards except as an emergency measure.

GBAS approach operations are excluded from the scope of the IR-PBN regulation and will therefore still be permitted after 6 June 2030. However, not only is the percentage of aircraft equipped to perform this type of approach, although higher than the percentage of aircraft equipped for LPV, still low at present, but only a few aerodromes in Europe have the infrastructure required to perform GBAS approaches (CDG is not one of them), so very few GLS (GBAS landing system) procedures are published.

The introduction of the requirement to exclusively use PBN in IR-PBN regulation 2018/1048 was made at the very end of the regulatory process, and did not give rise to a specific assessment of its impact on safety before the regulation was adopted. In particular, there was no assessment of the impact of the transition from commercial air operations under IFR predominantly conducted using the ILS to commercial air operations conducted solely using PBN type approaches (excluding CAT II/III operations), and no definition of criteria for adjusting this provision if the development of LPV capabilities has not progressed as expected by 2030. One of the assumptions, also an objective, was that air operators would modernise their fleets and equip themselves for RNP APCH operations down to LPV minima, the only PBN procedure offering a level of safety and accessibility comparable to CAT I precision approaches.

The investigation found that the development of LPV capabilities is still in its infancy in commercial air transport. For example, at the end of 2022, less than 500 Airbus aeroplanes out of a fleet of over 10,000 were equipped to perform RNP APCH operations down to LPV minima and at the time of writing this report, no Boeing aeroplane had been certified to perform these operations. Depending on the aeroplane type and the serial number, the retrofit to obtain this capability seems to be prohibitive. Lastly, there is no planned requirement to impose this capability in the years to come.

In the absence of the LPV capability, aircraft air operators will privilege Baro-VNAV approaches in a context where the exclusive use of PBN is imposed.

The investigation found numerous weaknesses in the aviation system, both in terms of the threat posed by the use of an incorrect altimeter setting, which particularly affects a Baro-VNAV approach and also in terms of the CFIT risk which can be a consequence of this.

The findings of this investigation suggest that, in the absence of a clear change of direction in Europe between now and 2030, there will be a substantial decline in the level of safety on approach. The European Commission and EASA indicated during the consultation period for the final report that the impact of Art.5 of the IR-PBN regulation restricting the use of conventional approaches will be assessed in 2024 and may lead to proposals for amendments to the IR-PBN regulation.

Therefore, the BEA recommends that:

- ***whereas in Europe the current level of safety for final approaches in scheduled commercial air transport is mainly based on precision approaches using ILS;***
- ***whereas by 2030, with the implementation of the IR-PBN regulation, in Europe the level of safety for final approaches will be mainly based on RNP approaches;***
- ***whereas of the three RNP approach minima, only RNP APCH operations down to LPV minima have a level of safety similar to the ILS in terms of vulnerability to incorrect altimeter settings;***
- ***whereas the current availability of on-board LPV capabilities is limited and that manufacturers indicate that retrofitting could be difficult and costly;***
- ***whereas by 2030, with the implementation of the IR-PBN regulation, operators with no LPV capabilities will carry out barometric RNP APCH operations down to LNAV or LNAV/VNAV minima that are vulnerable to incorrect altimeter settings;***
- ***whereas the weaknesses of the aviation system with regard to the threat posed by the use of an incorrect altimeter setting, as highlighted by this serious incident and by many other similar occurrences;***
- ***whereas there has been no assessment of the impact of the transition from commercial air operations predominantly conducted using ILS-based IFR approaches to commercial air operations conducted solely using RNP approaches during the IR-PBN regulation process;***
- ***whereas the other measures planned or in progress, including those resulting from the other recommendations issued by the BEA as part of this investigation to minimise the risk associated with an incorrect altimeter setting, do not make it possible to achieve a level of safety equivalent to that of ILS, GLS, or RNP APCH approaches down to LPV minima;***

the European Commission, in collaboration with EASA, analyse and reassess the risks associated with the changes induced by the IR-PBN regulation 2018/1048 and in particular those linked to the use of an incorrect altimeter setting during a barometric approach, and take appropriate measures to maintain the targeted level of safety of final approach operations in Europe in 2030. [Recommendation FRAN-2024-007].

Ground system for detecting an incorrect altimeter setting

At the time of the 9H-EMU serious incident, there was no ground system to enable air traffic controllers to detect an incorrect altimeter setting at CDG. Some air navigation service providers, such as the NATS in the United Kingdom or the LVNL in the Netherlands, have installed a ground system which compares the altimeter setting transmitted by aircraft via EHS or ADS-B downlink data with the QNH value in force locally, in order to inform the air traffic controller of a potential incorrect altimeter reference on board the aeroplane. The data provided by Eurocontrol shows that of the forty-one Eurocontrol Member States, six have a system alerting air traffic control that an aircraft is transmitting an incorrect altimeter setting and eleven have a system enabling the aircraft altimeter setting to be displayed on air traffic controller screens. However, no comparable system is currently in place in France. Furthermore, there are no standards for these systems, nor any standard operating procedures or phraseology.

Commission Implementing Regulation (EU) No 1207/2011, then Commission Implementing Regulation (EU) 2023/1770 repealing the latter and laying down requirements for the performance and the interoperability of surveillance for the Single European Sky and its amendments requires aircraft flying in European airspace with a mass greater than 5,700 kg or with a maximum cruising speed greater than 250 kt to be equipped with a secondary transponder that transmits Enhanced Surveillance mode S (EHS) and ADS-B protocol information. The mandatory information to be transmitted includes the altimeter setting on board the aircraft via the Barometric Pressure Setting (BPS).

Commercial air transport operators have complied with this requirement and the BPS information is available for use by the approach units and control towers. In the absence of a requirement to impose its use on the ground, the majority of air navigation service providers have not made this investment.

The investigation found that crews frequently perform approaches with an incorrect altimeter setting without being aware of it, and that this serious incident is not an isolated case. A large proportion of these similar occurrences took place during ILS approaches where the vertical profile is not affected by an incorrect altimeter setting and did not give rise to significant incidents. Conversely, several significant incidents, even serious incidents or accidents occurred during barometric approaches.

Therefore, the BEA recommends that:

- ***whereas the threat represented by a barometric approach flown with an incorrect altimeter setting giving rise to a CFIT risk in particular;***
- ***whereas the large number of similar occurrences of approaches carried out with an incorrect altimeter setting;***
- ***whereas the standard operating procedures of crews and air traffic controllers are not sufficiently robust to systematically prevent an approach being carried out with an incorrect altimeter setting;***
- ***whereas on-board systems for detecting an incorrect altimeter setting are currently only marginally deployed;***
- ***whereas ground systems for detecting an incorrect altimeter setting are currently only marginally deployed and they are an effective means of preventing the risk of an approach being carried out with an incorrect altimeter setting;***

- ***whereas the BPS information is included in the aircraft downlink data, a function made compulsory for the near-majority of aircraft operated in commercial air transport;***
- ***whereas there is no obligation for the air navigation services to use this data;***
- ***whereas the ATM safety nets need clear, standardised procedures and phraseologies;***

EASA require that air traffic control units can systematically detect an incorrect altimeter setting, in particular in the towers and approach units and define the associated phraseology for the air traffic controllers.
[Recommendation FRAN-2024-008].

On-board Terrain Awareness Warning System (TAWS)

A TAWS alert is one of the last barriers to prevent CFIT-type accidents and has proved its worth in this respect. However, the system must both warn crews of the CFIT risk and not generate false alerts that could result in crews losing confidence in the system.

In the light of lessons learned and accidents, Minimum Operational Performance Standards (MOPS) were introduced and required for certification. These standards are only applicable during the individual certification of the aeroplane, and operationally, there is no requirement to update the TAWS, which can therefore remain in a version applicable when the aeroplane was manufactured, without taking into account the various existing upgrades.

In this serious incident, in accordance with its design, the TAWS on 9H-EMU did not generate an alert even though the minimum recorded and corrected radio-altimeter height was 6 ft and the aeroplane was about 0.9 NM from the runway threshold. In fact, as the aeroplane was configured for landing and in a standard rate of descent, no TAWS basic and reactive alert or warning were triggered. What is more, the GLIDE SLOPE alert is not available for barometric approaches. Lastly, since the predictive Premature Descent Alert (PDA) mode includes an inhibition zone before the runway to avoid untimely alerts on each landing, no alert was generated, despite the aeroplane's low height, because the EGPWS software version was an old version and did not use GNSS positioning.

The investigation estimated that around 1,600 Airbus and Boeing aeroplanes in service at the time of publication of this report, are flying with a TAWS software version that will not trigger an alert in the conditions of the serious incident.

In addition, the investigation found that a nominal vertical profile on a 3° slope, offset by around 280 ft, representing an incorrect altimeter setting of 10 hPa which is one of the most frequent errors, is not covered by the MOPS currently in force.

Therefore, the BEA recommends that:

- ***whereas the importance of the TAWS in preventing CFIT;***
- ***whereas, in compliance with its design, the TAWS equipping the aeroplane involved in the serious incident did not generate a CFIT alert;***
- ***whereas it was estimated that at the time of publication of the report, around 1,600 Airbus and Boeing aeroplanes in service, are flying with a TAWS that will not trigger an alert in the conditions of the serious incident;***

- ***whereas a nominal vertical profile on a 3° slope, offset by around 280 ft to the published vertical profile, representing an incorrect altimeter setting of 10 hPa which is one of the most frequent errors, is not covered by the certification requirements currently in force via the MOPS applicable to TAWS;***
- ***whereas the revision of the standardisation requirements is a necessary step in order to be able to impose standards in operation at a later date;***

EASA, in coordination with the FAA and RTCA, study the revision of the Minimum Operational Performance Specifications (MOPS) applicable to TAWS for Premature Descent Alerts (PDA), in order to take into account at least a standard 3° vertical profile offset by around 280 ft to the published vertical profile, representing an error of 10 hPa on a barometric approach.
[Recommendation FRAN-2024-009].

MSAW training

During the serious incident and on both approaches, two different tower controllers used an incorrect and inappropriate phraseology in response to the triggering of the MSAW alert. The phraseology used did not convey the urgency of the situation, did not allow the crew to understand what was expected of them, and did not include the crucial information of the QNH value which could have enabled the crew to realise that they had an incorrect altimeter setting.

In addition, the air traffic controller's reaction time to the alert during the first approach left the crew very little time to react.

The investigation found that a CDG controller may well never have reviewed in practice, the expected reaction to a MSAW alert since his initial training at the ENAC.

The study of various similar occurrences found in France, that the MSAW emergency phraseology was only partially correctly used, that the use of an incorrect and inappropriate MSAW phraseology was not an isolated case, and that a lack of reaction was observed a certain number of times.

At the time of the preliminary report, the BEA issued a recommendation regarding the MSAW phraseology. In its response, the DSNA focused on the procedures to be used when such an alert is triggered, accompanied by feedback and reminders. However, no overall national action was taken in terms of the continuation training of air traffic controllers to ensure on a permanent and continuous basis, that emergency phraseology is immediately used in the event of a MSAW alert.

Therefore, the BEA recommends that:

- ***whereas the importance of the MSAW in preventing CFIT;***
- ***whereas the importance of the reaction time and the phraseology to be used in response to a MSAW alert;***
- ***whereas the number of similar occurrences in France involving the use of incorrect MSAW phraseology;***
- ***whereas at national level, the continuation training of air traffic controllers is insufficient and does not guarantee that they will be able to immediately use the expected phraseology in the event of a MSAW alert;***

the DSNA ensure that, at national level, the continuation training of air traffic controllers guarantees that they master the emergency procedure relating to a MSAW alert.
[Recommendation FRAN-2024-010].

DSNA safety management system

The incident involving 9H-EMU highlighted a succession of errors during normal operations, by different controllers, at different positions, in a short space of time.

The DSAC's study of similar events found that in France, air traffic control contributes to about a quarter of the events linked to incorrect altimeter settings.

In addition to these errors in normal conditions, the emergency phraseologies associated with MSAW alerts were not correctly used during the serious incident.

At the time of the incident involving 9H-EMU, the risk of "near-CFIT" was identified as an undesirable occurrence in the DSNA risk map. However, the DSNA had not developed an analysis table for "near-CFIT" occurrences and had not set up a local or national CFIT risk management process - in particular based on the analysis of safety events - as would be expected in a safety and compliance management system. The DSNA thus deprived itself of an overall assessment of the CFIT risk (going beyond the selective analysis of each occurrence) and the possible quantification of "near-CFITs" recorded in its database.

Furthermore, the collection of data for the DSNA's safety management system was still essentially based on safety occurrences alone (reactive approach), and no other means or methods had been put in place at the DSNA to better apprehend weak signals, threats, errors and undesirable events that could have an impact on safety in a given operational context, and to identify good practices for maintaining safety (proactive or predictive approach).

Since the serious incident, the DSNA has accelerated the implementation of a risk management system based on a safety barriers model and has reinforced the consideration it gives to the CFIT risk. The DSNA is also working on the implementation of an observation process at air traffic controller positions.

Therefore, the BEA recommends that:

- ***whereas the various control errors identified during the investigation;***
- ***whereas the DSNA management system is based solely on the analysis of safety occurrences and does not identify weak signals, threats, errors and occurrences during normal air traffic controller operations;***
- ***whereas the DSNA has initiated a process to modify its risk analysis and management methods;***

the DSNA introduce methods or tools for the objective assessment of air traffic controllers' on-the-job work for the purpose of improving the safety management system.
[Recommendation FRAN-2024-011].