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Washington, D. C., United States, 19 – 21 September 2017

Agenda Item 5: **NAM/CAR Regional Safety/Air Navigation/Aviation Security Implementation Matters**
5.2 Effectiveness of air navigation implementation mechanisms

STATUS OF PERFORMANCE BASED NAVIGATION (PBN) IMPLEMENTATION IN FRANCE

(Presented by France)

EXECUTIVE SUMMARY	
This paper presents a status report of the PBN deployment in France, highlighting benefits and opportunities now provided to airspace users. France and is implementing PBN for all phases of flight while also proposing specific innovations such as ground navigation infrastructure reduction by using the best available PBN technologies. This large scale implementation positions France as a PBN European leader, and lessons learned and areas of progress to be made are also shared within this paper.	
Actions:	• Refer to section 5
Strategic Objectives:	• Safety • Air Navigation Capacity and Efficiency
References:	• ICAO A37-11 resolution

1. Introduction

1.1 During the ICAO 36th and 37th Assemblies, several resolutions where expressed to increase the PBN (Performance Based Navigation) deployment within states. In particular, the resolution A37-11 asked states to establish a PBN implementation plan in consultation with airspace users, and to deploy PBN approach procedures with vertical guidance at all instrument runway ends with specific target dates.

1.2 The French Civil Aviation Authority's PBN plan has been designed in view to meet these ICAO objectives, and it also aims to improve capacity, reduce delays, increase environmental efficiency by reducing fuel burn, and to increase economic efficiency. Another major objective of the PBN plan is at least matching and quite often, where possible, increasing the pre-PBN era level of safety.

2. Highlights of the PBN deployment in France

2.1 GNSS (Global Navigation Satellite Systems) infrastructure available in Europe, through GPS ABAS (Aircraft based Augmentation System) and EGNOS SBAS (Satellite Based Augmentation System), is used France to support PBN navigation specifications for En-route, Terminal areas and Approach and Landing phases of flight (GPS ABAS only in the French West Indies). As will be discussed in the following, France recognizes EGNOS as an excellent PBN technology with an increased performance with respect to GPS ABAS, in particular for approach and landing phases of flight. But since EGNOS SBAS avionics are not yet available over all avionics and aircraft in Europe, France PBN implementation also takes due consideration of all airspace users avionics configuration.

2.1.1 Continental En-route PBN network

France relies over the PBN RNAV 5 specification which requires that the on-board equipment keeps lateral and longitudinal navigation accuracy on route of 5 NM or better during at least 95% of the total flight time. It does not include requirements for on-board performance monitoring and alerting, and this function is currently provided by our national surveillance infrastructure. The network based on the RNAV 5 specification (previously known as BRNAV in Europe) exists since 1998. To fly within the French airspace, an RNAV 5 compatible avionic is required above FL 115. This PBN network is quite mature now and is not expected to evolve significantly. **As for the Caribbean area, RNAV5 is being deployed.**

2.1.2 Terminal area PBN network

France relies over the PBN RNAV 1 specification which requires lateral and longitudinal navigation accuracy of 1 NM or better during at least 95% of the total flight time. On board performance monitoring and alerting are not required, and this function is currently provided by our national surveillance infrastructure. RNAV 1 trajectories (previously known as PRNAV in Europe) are now implemented for SID and STARs within more than 60% of DGAC terminal areas, but the implementation over the main airports (Paris, Nice) is already close to 100%. **As for the French West Indies and French Guiana, SID and STAR RNAV will be implemented in 2018**. Constant Descent Operations (CDOs) are supported by RNAV1 over the 10 main French airports. A RNAV 1 equipment mandate has been published to access Paris airports and found helpful to support, in addition to PBN Standard Initial Departures (SID) now used on a routine basis, some specific ATM innovations such as a Point Merge TMA Extended and a new network of night trajectories at Paris CDG (see figure 1), or a new converging sequence to the ILS alternative to radar vectoring at Paris Orly (not yet published).

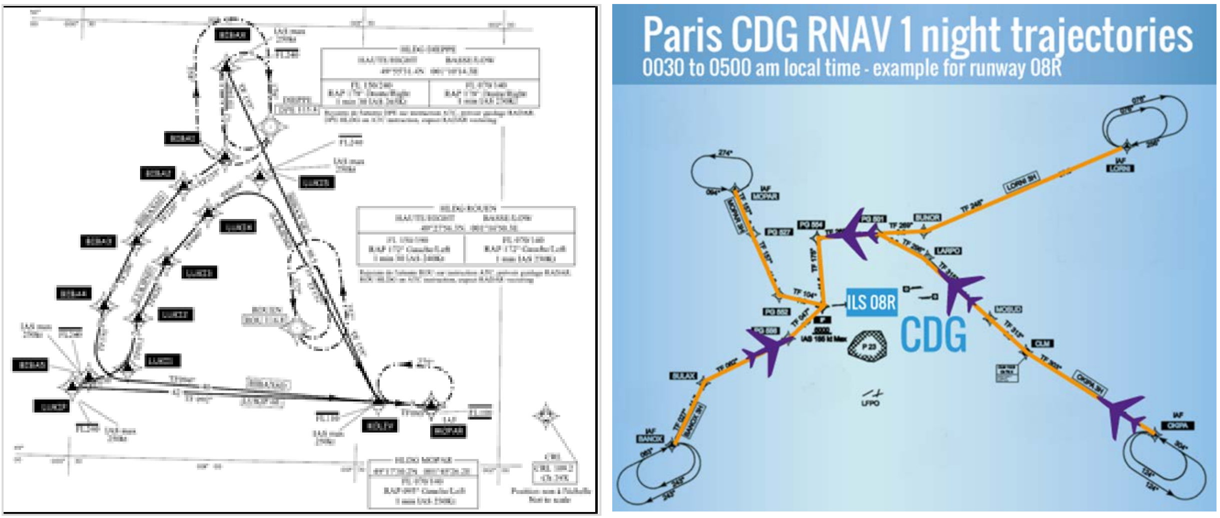

Figure 1. (Left) Point Merge NW Paris CDG since 2013, (Right) A new PBN route network for Paris CDG since Sept. 2016

2.1.3 Approach and landing PBN network

France DGAC has set up a specific PBN organization and program to deploy approaches meeting the PBN RNP APCH navigation specification requirements at all instrument runway ends, as closely as possible to the A37-11 ICAO target schedules. A first set of runways (193 QFU) had been identified within the French continental airspace in 2010, and has been successfully doted of PBN trajectories with at least 2D lateral guidance by 31/12/2016. The main ICAO objective, requiring deployment of PBN 3D lateral + vertical guidance) could however not be fully met at this date. This is mainly due to late availability of PBN vertical guidance in Europe (EGNOS was available in 2011, and the ABAS + BaroVNAV European safety case available in 2012 only). However, by end of 2016, still 150 PBN vertically guided approaches could be deployed, and the remainder with respect to our new target of 204 runway ends is now expected to be completed by 2019. **French west Indies and French Guiana will be completed in 2018.**
France return of experience is that a significant value of PBN for approaches is their relative ease of deployment within an ATM airport system since they are not specific to one technology, but really "performance based" by nature, meaning that several GNSS technologies may be handled transparently by ATC along a single and well-defined approach and landing trajectory. The table below is a reminder of the different technologies supporting PBN for approaches.

PBN technology	Type of guidance	PBN operational minima
GPS ABAS	2D lateral only	LNAV (Lateral NAVigation)
GPS + ABAS Barometric VNAV	3D lateral & vertical Barometric vertical guidance being provided by a computer fed by continuous barometric information, thus requiring accurate and updated local pressure QNH information.	LNAV/VNAV (Lateral NAVigation/Vertical NAVigation)

PBN technology	Type of guidance	PBN operational minima
SBAS	3D lateral & vertical Geometrical lateral and vertical guidance being provided by a SBAS (Satellite Based Augmentation System) such as EGNOS (European Geostationary Navigation Overlay Service).	LPV (Localiser Performance with Vertical guidance)

Figure 2. Different PBN technologies and approach minima

It is however important to note that France return of experience, as shown in figure 3 schematizing Paris Charles de Gaulle PBN implementation, is that these three PBN compatible technologies do not support the same operational capability. SBAS, with EGNOS in Europe, clearly offers one order of magnitude better performance in term of approach minima, and as well safety of approaches, than ABAS technologies.

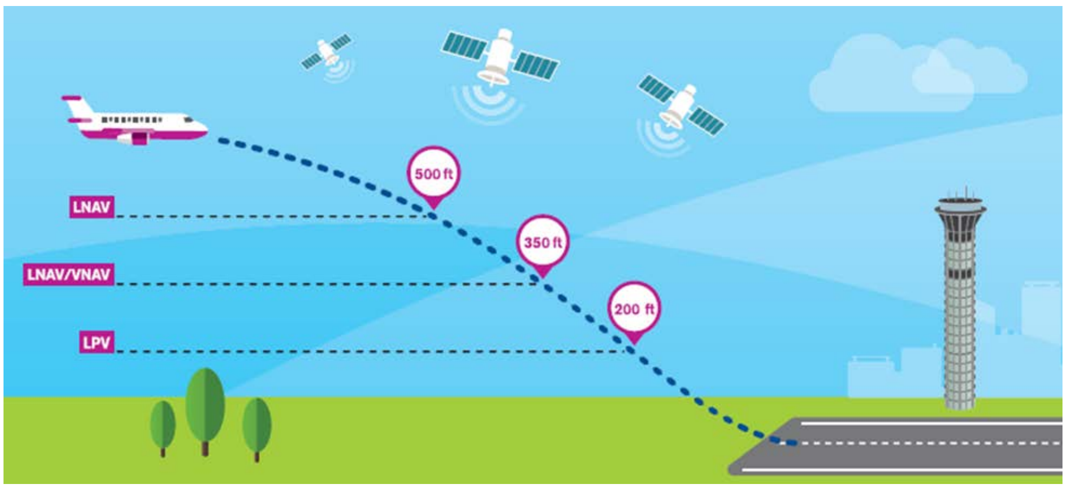

Figure 3. Different PBN technologies minima at Paris Charles de Gaulle RWY 26 L

In this respect, as shown in figure 4, France has now defined a strategy to build a combined network of ILS and PBN approaches supporting a new “Cat I everywhere, everytime” concept. “Everywhere” here refers to the capability of PBN to be deployed over runways without ILS Cat I, and “everytime” refers to situations where the existing ILS is out of service (maintenance, etc…). By mid-2017, about 40 runway ends will have access to PBN Cat I minima, and the other runways of our network will be progressively upgraded to Cat I minima.

The PBN Category I performance target is in our view particularly adapted, since this represents a performance level addressing weather conditions compatible with landing at the destination airport more than 95% of the time in average.

France PBN target:

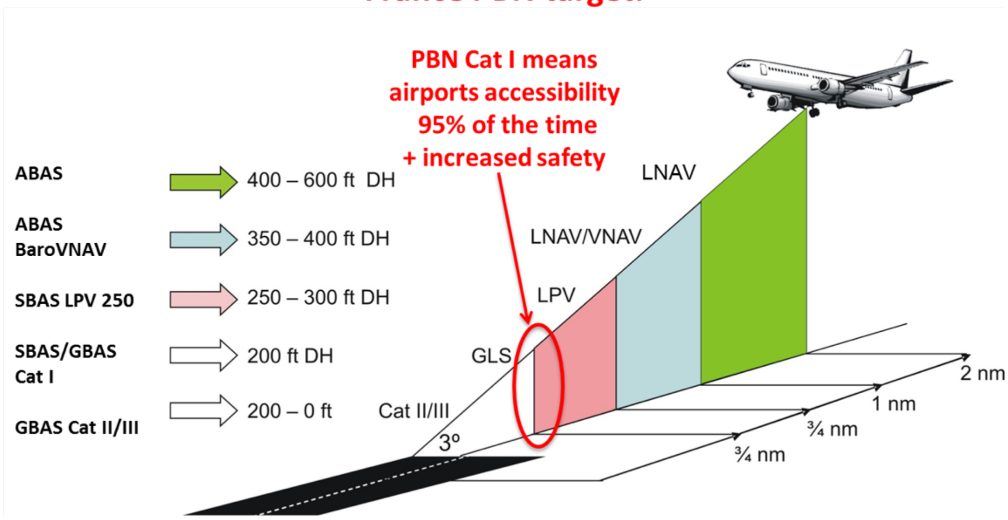

Figure 4. France Approach network PBN target

However, this PBN Cat I capability is not yet accessible to all airspace users, and as already noted, we obviously support ABAS or ABAS + BaroVNAV equipped users with specific minima lines over our approach charts. Some users (e.g. HOP! Air France regional airline) have decided to accelerate their retrofit equipment with SBAS to benefit now of the best PBN minima and therefore benefit from the best possible airport accessibility. Implementation of France PBN approaches network was notably made possible through European co-financing programs by European Union.

3. PBN support to ground navaids rationalisation

3.1 France ILS minimal network

3.1.1 Instrument Landing System has high procurement and maintenance costs as it requires separate localizer, glideslope transmitters and antennas for each runway end. Up to 2016, alongside with maintenance costs, all expenses related to ILS in France were entirely supported by DGAC, including small and medium size airports.

3.1.2 For this reason, addressing ILS DGAC investments over small and medium airfields thanks to PBN Category I implementation was deemed as a first rationalization priority. It was also agreed that the infrastructure economies achieved through this plan would contribute to a wider plan aiming at reducing terminal area air navigation charges.

3.1.3 DGAC France then defined a list of consistent criteria to identify airports where the legacy ILS will no longer be maintained. Airlines and airport operators have been regularly consulted to reach a balanced agreement. The maximum distance between ILS equipped airports supporting diversion in case of GNSS outages, the status of implementation of PBN approaches before the ILS withdrawal, and thorough meteorological studies showing the availability of PBN with respect to ceiling and visibility local conditions have been taken into account in the final decision.

3.1.4 This final decision has identified 49 Category I ILS equipment which will either be removed, or transferred to the airport operator before the end of 2017. 67 ILS will be maintained in the minimal network, including all pre-existing Category II/III ILS. In May 2017, 30 ILS had been definitively stopped, with 6 more expected to be stopped before the end of the year. **ILS are maintained for now in the French West Indies and French Guiana given the heterogeneity of traffic.**

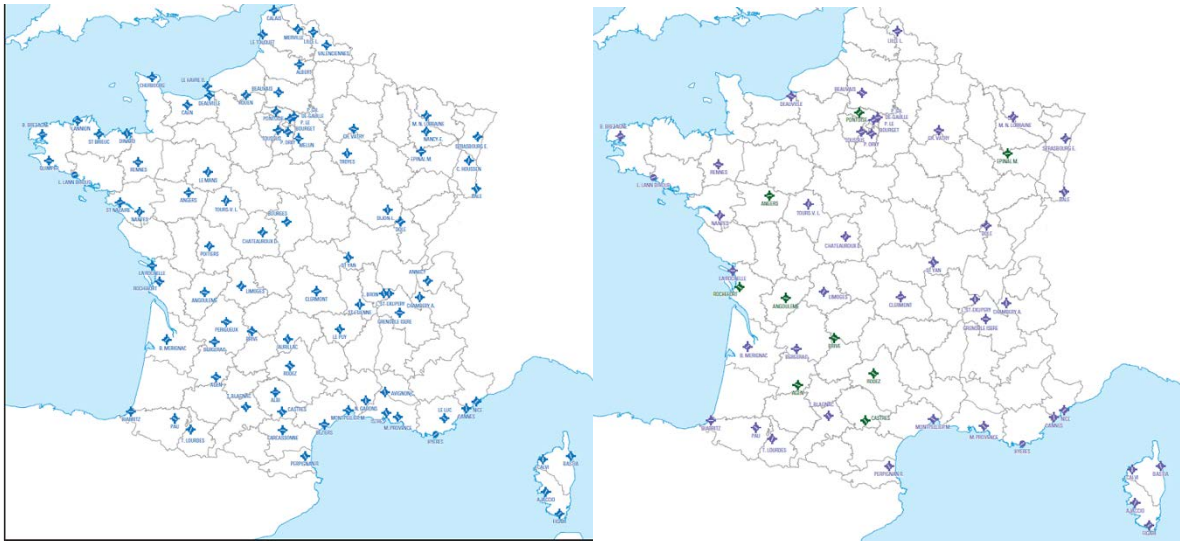

Figure 5.(Left) Airports equipped with an ILS in 2015 (Right) Minimal ILS Network in 2017. In green, ILS transferred from DGAC to the airport operator.

3.2 VOR and NDB

The next step following the design and implementation of the ILS minimal network, was to design minimal VOR and NDB networks. This work is now starting in France aiming in particular to reduce the VOR infrastructure to a minimal network supporting dual-coverage at 3500 ft. and above.

3.3 DME

No DME rationalization is planned at this stage, in particular since DME contributes to a backup network supporting En-Route RNAV 5 and Terminal RNAV 1 PBN operations in case of GNSS outages for aircraft equipped with a multi-mode receiver.

4. France return of experience over some specific issues of PBN implementation

4.1 High density Terminal areas

4.1.1 One of the key concerns for France in high density TMA is to guarantee an optimal capacity at all times. With the introduction of RNP 1 with RF (Radius to Fix) curved legs, alternatively to RNAV 1, as required e.g. by 2024 within the PCP regulation, capacity flaws may occur mainly due to additional radio exchanges and specific management of RF unequipped aircraft. It is therefore difficult to introduce new PBN functions, such as RF, without penalizing the global TMA capacity, unless the equipment rate of aircraft operators' approaches 100%. One other mean to derive benefits though RNP 1 with RF would be to design specific trajectories to be flown during periods of low traffic only. This solution is under discussion with airspace users.

4.1.2 The transition from RNAV 1 to RNP 1 specification raises another issue that needs to be clarified: long term (i.e. more than a few hours) loss of GNSS signal. Through the RNAV 1 specification, a high flexibility for reversion is maintained, thanks to the large number of users equipped with RNAV 1 DME/DME multimode receivers. However, since for most aircraft DME/DME is not a certified RNP 1 solution, interrogations remain regarding the acceptable conditions for using DME/DME along RNP 1 published routes when the outage lasts for a longer period.

4.1.3 Unless these two questions are resolved, France intention is to publish RNP 1 trajectories only when it will be proven to be of operational relevance in terms of safety and performance.

4.2 Progressing toward a better PBN infrastructure and user equipment for approaches

4.2.1 France has implemented all kind of PBN supporting GNSS technologies to support at best the diversity of users' avionics equipment during this initial phase of PBN implementation. However, some significant differences in performance have been noted, between SBAS and ABAS technologies in particular. These differences are well accepted today by ANSPs and airspace users, but may not be acceptable in the future when traffic increases, and correlatively approach performance and safety requirements. Actions have thus to be conducted by the aviation community to identify a path to progressively transition from today situation to the implementation (procedures and avionics) of the best available technologies.

4.2.2 In this respect, limitations of ABAS and BaroVNAV technologies, as noted by France along a number of different implementation project do include:

- ABAS 2D: lack of vertical guidance impacting safety, lack of availability (RAIM availability issues) requiring running predictions at dispatch level and potentially flight delays, capacity limitation for busy airports due to the lesser efficient speed management process of 2D approaches along the final approach, highest PBN minima,
- ABAS and BaroVNAV 3D: lack of availability (RAIM availability issues) requiring prediction at dispatch level, unstabilized approaches due to temperature variations impacting the aircraft (too low/too high), severe potential safety issues due to QNH mis-setting by the ATC or the crew, minima improved with respect to ABAS 2D, but still significantly higher than SBAS Cat I.

4.2.3 Alternatively, none of these drawbacks have been noted by France for the PBN SBAS technology. It is also noted that some airlines, aircraft manufacturers and IFALPA are also well aware of these PBN ABAS limitations and also recommend now defining a global roadmap toward transitioning to a more systematic use of 3D geometrically guided approaches, supporting in particular performance and safety standards closer to ILS (i.e. PBN with SBAS, or GBAS).

5. Action by the conference

5.1 The meeting is invited to:

a. Note the information contained in this paper

b. Discuss the issue that requiring states to publish RNP 1 alternatively to RNAV 1 creates fleet equipage issues and does not address the lack of reversion capability in case of a standing loss of GNSS

c. Acknowledge that there is a need to coordinate roadmaps to transition from 2D and barometrically 3D PBN approaches to a wider user of 3D geometrically guided approaches in the future

d. Discuss any other relevant matters as appropriate

— END —