SPREADING THE USE OF EGNSS

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Summary: This article focuses on spreading the use of European satellite navigation systems in aviation. Development of satellite navigation systems and their applications overcame all obstacles in the last five years and currently is the best and cheapest option in aircraft navigation. The article describes the recent progress in the field of satellite navigation, a new type of approach LPV-200 and its position against ILS approach systems in terms of costs and benefits.

Key words: EGNOS, EGNSS, LPV-200, Cost-benefit analysis.

INTRODUCTION

Satellite navigation is used for civilian purposes for the third decade and also here can be observed the fast never-ending development similar to other areas of engineering and technology. Continuous improvement of satellites, increasing their number in orbits and increasing the number of satellite systems indicate that the satellite navigation will be not only one of the primary means of navigation on Earth in the future, but possibly the only one. This situation is caused mainly by the demand, respectively by the efforts of different geographical areas of the world to ensure 'own' satellite navigation system for its residents.

From history we can observe the development of the American Global Positioning System (GPS) and Russia's effort to be as good as the Americans in the form of implementation of their satellite system version in the form of GLONASS. Due to the efforts of Europe (European Union) to be as independent as possible and reduction of its dependence on world leaders, the European Galileo system are being currently implemented. The only fully functional system, however, is the GPS, as GLONASS is constantly on the edge of the minimum number of satellites to cover the world. Galileo has twelve operational satellites since April 2016, but the full constellation of thirty satellites is still a long way to go.

The constantly increasing use of GNSS can be seen in the graph in Fig. 1 and in Fig 2. The anticipated progress of the future is very positive.

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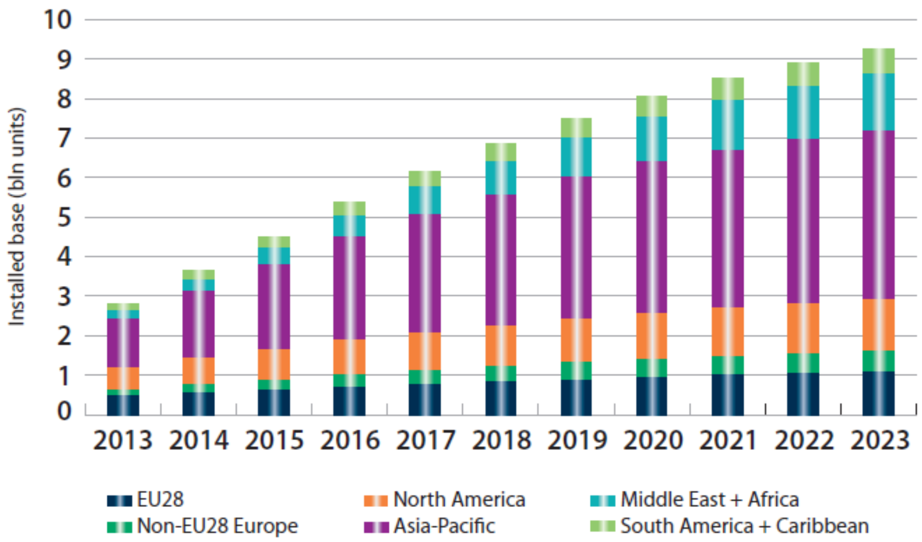
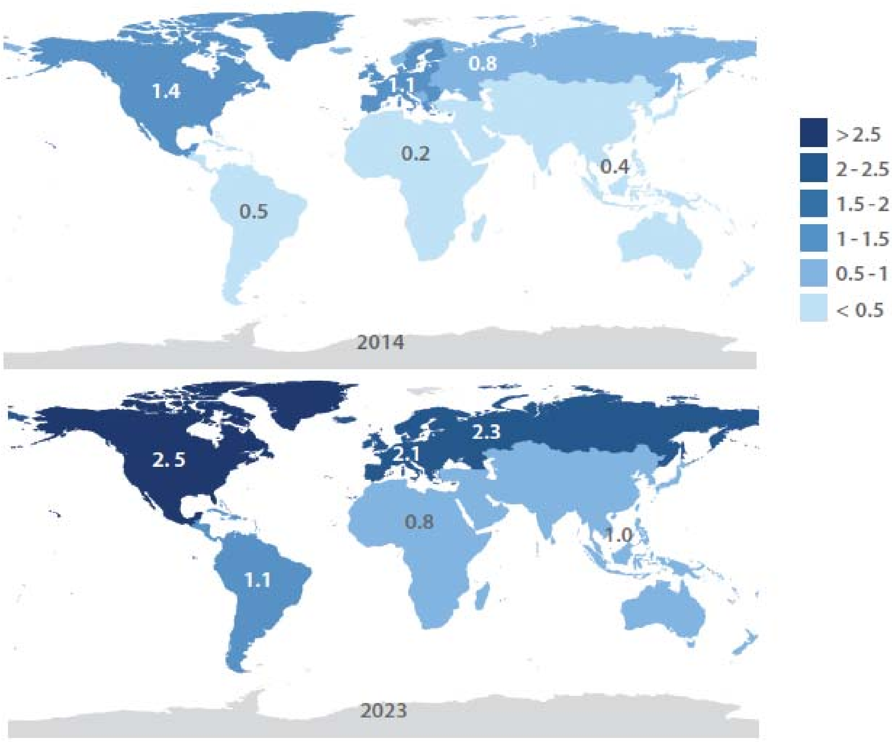


Source: GSA (1)

Fig. 1 – Installed base of GNSS devices by region



Source: GSA (1)

Fig. 2 – GNSS devices per capita: 2014 and 2023

It is necessary to point out the latest developments in Europe and its impact on aviation and consider the real benefits and costs. The first chapter of this article therefore focuses on the technical aspects of the European Global Navigation Satellite System (EGNSS) to show how quickly things are improving. In the next chapter, analysis of costs and benefits are shown in aviation application.

1. EGNSS IN AVIATION

Currently, EGNSS in aviation is represented only by the EGNOS system. The EGNOS or the European Geostationary Overlay Service is a European system officially launched in 2009 that corrects the GPS signal. According to ESA, EGNOS can increase accuracy from 17 meters to 3 meters based on GPS system and ensure the integrity, making GNSS based on GPS also suitable for critical parts of flight such as approach to landing.

Thanks to EGNOS and its Safety of Life Service (SoL) is possible in Europe to implement performance-based navigation (PBN) for the required navigation performance approach to landing (RNP APCH) in four forms, see Table 1.

Tab. 1 – RNP APCH types

PANS-OPS Terminology	PBN Terminology	Chart Minima	Minimum Sensor
NPA	RNP APCH down to	LNAV (MDA)	Basic GNSS[2]
APV Baro-VNAV	RNP APCH down to	LNAV/VNAV (DA)	Basic GNSS + Baro-VNAV
-No criteria available	RNP APCH down to	LP (MDA)	SBAS
APV SBAS	RNP APCH down to	LPV (DA)	SBAS

Source: (2)

In Europe these types are already widespread, except for an RNP APCH down to LP, which is not publish here, and there are no plans to use it. From the right column of Table 1 can be observed that the most accurate approach is RNP APCH down to LPV (Localizer Performance with Vertical guidance) with adequate minima. From the beginning of SoL service, LPV minima was minimally 250 feet (for decision height DH). Here it is important to note that the value of 250 feet was, and still is, very good, but at first glance it does not provide improvement compared to other, even non-precision, approach systems (see Table 2).

Tab. 2 – Non-precision approach systems' minima

Radio navigation Aid	Lowest Minimum Decision Height
LOC	250 ft
VOR/DME	250 ft
VOR	300 ft
NDB/DME	300 ft
NDB	350 ft
RNAV (GNSS)	300 ft
SRE	250 ft

Source: (3)

The advantage of RNP APCH down to LPV is in greater accuracy of horizontal and vertical guidance, which ensures effective and real reduction of minima at most airports compared to other non-precision instrument approach systems and also compared to RNP APCH down to LNAV/VNAV. So far, however, the general minima of 250 feet DH was still restrictive in poor weather conditions at major airports where there are no nearby obstacles increasing Obstacle clearance height (OCH) and consequently DH.

1.1 LPV-200

Solution to relatively higher LPV minima at 250 feet is current newcomer - LPV-200. LPV-200 delivers accurate information on an aircraft's approach to a runway with the use of GNSS positioning technology. The result is lateral and angular vertical guidance without the need for visual contact with the ground until an aircraft is 200 feet above the runway. (6) The value of 200 feet is the same as for ILS Cat I (Instrument Landing System Category I).

1.1.1 Certification

The new EGNOS LPV-200 service level was declared operational on 29 September 2015 by European GNSS Agency (GSA). LPV-200 fulfils the operational parameters for Category I precision approach required by ICAO (see table 3), which are better than APV-I parameters fulfilled before.

Tab. 3 – SoL service performance requirements by ICAO

	Accuracy		Integrity				Continuity	Availability
Typical operation	Horizontal Accuracy 95%	Vertical Accuracy 95%	Integrity	Time-To-Alert (TTA)	Horizontal Alert Limit (HAL)	Vertical Alert Limit (VAL)		
En-route (oceanic/ continental low density)	3.7 km (2.0 NM)	N/A	1 – $1x10^{-7}$/h	5 min	7.4 km (4 NM)	N/A	1 – $1x10^{-4}$/h to 1 – $1x10^{-8}$/h	0.99 to 0.99999
En-route (continental)					3.7 km (2 NM)	N/A		
En-route, Terminal	0.74 km (0.4 NM)	N/A	1 – $1x10^{-7}$/h	15 s	1.85 km (1 NM)	N/A	1 – $1x10^{-4}$/h to 1 – $1x10^{-8}$/h	0.99 to 0.99999
Initial approach, Intermediate approach, Non-precision approach (NPA), Departure	220 m (720 ft)	N/A	2 – $1x10^{-7}$/h	10 s	556 m (0.3 NM)	N/A	2 – $1x10^{-4}$/h to 1 – $1x10^{-8}$/h	0.99 to 0.99999
Approach operations with vertical guidance (APV-I)	16.0 m (52 ft)	20 m (66 ft)	1 – $2x10^{-7}$ in any approach	10 s	40 m (130 ft)	50 m (164 ft)	1 – $8x10^{-6}$ per 15 s	0.99 to 0.99999
Category I precision approach	16.0 m (52 ft)	6.0 m to 4.0 m (20 ft to 13 ft)	2 – $2x10^{-7}$ in any approach	6 s	40 m (130 ft)	35.0 m to 10.0 m (115 ft to 33ft)	1 – $8x10^{-6}$ per 15 s	0.99 to 0.99999

Source: ICAO Annex 10 (4)

With this relatively minor change, the LPV-200 approach is now 100% possible substitute for ILS Cat I, which is its biggest benefit. At the same time LPV-200 also provides other benefits such as:

- „reduced delays, diversions and cancellations thanks to the lower minima, potentially reducing the operational costs for flying to LFPG;
- increased continuity of airport operations in case of ILS outage or maintenance;
- enhanced safety levels, as the LPV-200 procedures can serve effectively as CAT I approach procedures and can also be used as a back-up to ILS-based procedures;
- improved efficiency of operations, lowering fuel consumption and CO2 emissions, and decreasing aviation's environmental impact." (5)

1.1.2 First Implementation

The first LPV-200 approach was published by French Air Navigation Service Provider (DSNA) at Paris Charles de Gaulle Airport (LFPG) on 28 April 2016. After five days, implementation was completed by the first flights of ATR 42-600, Dassault Falcon 2000 and Airbus A350.

APPROCHE AUX INSTRUMENTS — PARIS CHARLES **DE GAULLE**
Instrument approach
CAT A B C D
ALT AD : 392, ***THR : 338 (13 hPa)*** — *FNA* **RNAV** (GNSS) RWY 08L

FREQ : Voir / *See* AD 2 LFPG IAC COM 01

RNP APCH

T° MNM Baro-VNAV : - 20°C. Procédures LNAV NON autorisées pendant les opérations simultanées. Utilisation du FD ou de l'AP fournissant un guidage de trajectoire RNAV requis durant les opérations simultanées. Fonction du FMS permettant d'intercepter l'axe de la piste suite à un guidage radar. *LNAV procedures NOT authorized during simultaneous operations. Use of FD or AP providing RNAV track guidance required during simultaneous operations. FMS function allowing the interception of the runway centerline after radar vectoring.*

EGNOS CH 57477 E 08 A RDH : 57 — VAR 1°W (10)

MNM AD : distances verticales en pieds, RVR et VIS en mètres / *vertical distances in feet, RVR and VIS in metres.* — REF HGT : *ALT THR*

CAT	LPV		OCH LPV	LNAV-VNAV		OCH LNAV VNAV	LNAV		OCH LNAV	MVL / Circling (2) 08L →08R	
	DA (H)	RVR		***DA*** (H)	RVR		***MDA*** (H)	RVR		***MDA*** (H)	VIS
A	***540*** (200)	550	159	***670*** (340)	800	331	***780*** (440)	1300	434	***940*** (600)	3000
B	***540*** (200)		171	***680*** (340)	800	333	***790*** (450)	1400	447	***940*** (600)	3000
C	***540*** (200)		189	***680*** (340)	800	336	***790*** (450)	1400	447	***1040*** (700)	3500
D	***540*** (200)		200	***690*** (350)	900	344	***790*** (450)	1400	447	***1090*** (750)	4000
DL	***550*** (210)		203	-							

DIST RW08L NM	**14**	**13**	**12**	**11**	**10**	**9**
ALT (HGT)	***4853*** (4515)	***4535*** (4197)	***4216*** (3878)	***3898*** (3560)	***3579*** (3241)	***3261*** (2923)
DIST RW08L NM	**8**	**7**	**6**	**5**	**4**	**3**
ALT (HGT)	***2942*** (2604)	***2624*** (2286)	***2306*** (1968)	***1987*** (1649)	***1669*** (1331)	***1350*** (1012)
DIST RW08L NM	**2**					
ALT (HGT)	***1032*** (694)					

Observations / *Remarks* : (1) Mouvements simultanés : voir consignes ADC 06 / *Simultaneous movements : see instructions ADC 06.*
(2) MVL : voir consignes ADC 07 / *Circling : see instructions ADC 07.*
Panne de guidage GNSS durant l'approche / *Loss of GNSS guidance during approach* : voir/*see* ENR 1.5.

FAF - THR 14.5 NM	70 kt 12 min 24	85 kt 10 min 12	100 kt 8 min 41	115 kt 7 min 33	130 kt 6 min 40	160 kt 5 min 25	185 kt 4 min 41
VSP (ft/min)	372	451	531	610	690	849	982

Source: (7)

Fig. 3 – Cut-off from Instrument Approach Chart LPV-200

This first implementation includes two important elements that are the future of flying. The first are the types of aircraft that flew this approach. They are the most advanced air transport aircraft and business jets. An important change can be seen in this: arrival of new generation of airliners, which replaces the old one. This means replacing older types of

Boeings and Airbuses with new ones that are capable to fly according GNSS, even with Satellite based augmentation systems (SBAS, EGNOS in Europe), and can use LPV-200. The second element is financial and is hidden in first one. This trend favours airports currently using ILS category I. These airports can reduce costs, because they no longer need to have the ILS system older airliners are compatible with.

"EGNOS LPV-200 is now the most cost-effective and safest solution for airports requiring CAT I approach procedures," says GSA Executive Director Carlo des Dorides. "The involvement of major aircraft manufacturers confirms that this service is a real added-value for civil aviation, setting the basis for a better rationalisation of NAVAIDs in European airports." (5)

2. COST AND BENEFIT ANALYSIS OF LPV-200

It is necessary to confirm the added value, costs and benefits of LPV-200. Cost-effectiveness is a parameter that has become increasingly important in more and more competitive environment of air transport. Its assessment, however, faces major differences between used approach systems. Due to LPV-200 parameters I focus only on the comparison with well-known ILS approach system.

2.1 Differences between LPV and ILS

There are two fundamental differences between systems based on ground-based radio navigation devices and systems based on GNSS in general.

The first major difference is the history of the systems. Currently, the ILS approach system is considered as a must, which must be at the airport when the airport operations are meant "seriously". This is because of years of proven quality and reliability, but also due to achievable minima (ILS Cat. IIIc up to 0 feet DH). On the other side, LPV is very young. Flying LPV approach is possible in Europe only in the last five years and its usage is not yet as wide as of ILS. The minima of 200 feet for LPV-200 are also an absolute novelty.

A second difference is the control over the approach system. Airport operator (owner of the system) has full control over the ILS system and he alone is responsible for the operation of the system. On the contrary, airport operator has no control over GNSS, i.e. he has no power over the LPV approach capabilities and does not even have instant information about GNSS functionality. Therefore, ILS is preferred choice.

2.1 Benefits and costs of LPV and ILS

Benefits and costs of each approach can be divided according to their recipients. Primarily, they are airport operators and aircraft operators. Secondarily, also pilots, residents living in the vicinity of airports, operators of systems and all society. For clarity, the benefits and costs are shown in Table 4 below.

Tab. 4 – Cost and benefits of LPV-200 and ILS

Costs	**LPV-200**	**For**	**ILS**	**For**
Infrastructure	billions of EUR	European commission (society)	336 000 EUR	Airport Operator
Installation	0 EUR	-	175 000 EUR	Airport Operator
Construction works	0 EUR	-	195 000 EUR	Airport Operator
Implementation/ publication (for RWY end)	20 000 EUR	Airport Operator	20 000 EUR	Airport Operator
Calibration	0 EUR	-	30 000 EUR	Airport Operator
Total for Airport Operator	**20 000 EUR**		**756 000 EUR**	
Total for Society *	billions of EUR		0 EUR	
Operation costs (yearly)	0 EUR	-	79 000 EUR	Airport Operator

Benefits	**LPV-200**	**For**	**ILS**	**For**
Speed	6 months	Airport operator	12 months	Airport operator
GNSS	130 billion EUR/20 years	Society	-	-
Route design flexibility	Yes	Airport operator/ Aircraft operator	No	Airport operator/ Aircraft operator
Simplicity to fly	Yes	Pilots	Yes	Pilots
Noise designed procedures	Yes	Residents living near airports	No	Residents living near airports
Aircraft types	Business jets, better GA, new airliners	Airport operator/ Aircraft operator	Business jets, better GA, all airliners	Airport operator/ Aircraft operator
Requirements	RNP APCH by end 2018	Airport operator	No	-

Source: Author, ICAO, EC (8), (9)

It is evident from the table 4 that the implementation of LPV-200 is better than trying to build an ILS system. But, this is true only for the airport operator, who is willing to accept one disadvantage - the limitations related to older airliners. In the following years, however, this disadvantage will be gradually reduced and deleted. Currently, the greatest benefit (except the financial one) is certainty that the introduction of some type of RNP APCH will be mandatory by the end of 2018. Then, why don't implement LPV-200?

CONCLUSION

Aviation is constantly modernized and development is heading forward very quickly. Today, EGNOS can be used for aviation only slightly longer than five years and already achieves the same accuracy than seventy years old ILS. Due to EU investment in satellite navigation, it is essential that EGNSS systems need to be used. The more they are used, the more the benefit from investments is increased. The current status of aviation and EGNSS favours approaches based on GNSS than on terrestrial radio navigation systems, which is apparent from a comparison of costs and benefits.

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