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Contribution of the EGNSS to aviation

Bc. Tomáš Volena
Ing. Jakub Kraus

Czech Technical University in Prague, Faculty of Transportation Sciences, Department of Air Transport
Horská 3, 128 03 Prague 2, Czech Republic
volentom@fd.cvut.cz, kraus@fd.cvut.cz

Ing. Lucia Melníková, PhD.

Technical University of Košice. Faculty of Aeronautic, Department of Air Traffic Management
Rampová 7, 041 21 Kosice, Slovak Republic
lucia.melnikova@tuke.sk

Abstract This article deals with the EGNSS, which means European part of Global Navigation Satellite System - European Geostationary Navigation Overlay Service and Galileo service. Firstly, it focuses on the merit of these services and the reason of implementation. It defines both systems as for its principals and application in the aviation. Furthermore, it copes with the value and benefits of the EGNSS as far as the finances, ecology and other aspects are concerned.

Key words EGNSS, EGNOS, Galileo, Satellite navigation, RNP, PBN, LPV

1. INTRODUCTION

Satellite navigation is a branch that nowadays experiences rapid growth. The GNSS is no longer a matter of an amateur or a military usage only but it evolves through time. Furthermore, as the global satellite navigation evolves, it extends its aim from the road transport to agriculture, mapping, maritime and the most importantly aviation. Satellite systems offer global accessibility in the 24/7 mode under all meteorological conditions. They used to be on the board of an aircraft as a back-up or an orientation system only, however, thanks to the rapid progress of this industry, they were transformed into one of the most reliable and integral navigation system. On the contrary, this evolution took some time. Firstly, the signal from the GNSS satellites had to be augmented to ensure all the legal requirements and secondly, the signal has to be delivered to the customers. That is guaranteed by the EGNOS system which cooperates with the Navstar GPS. Additionally the Navstar GPS is not the only system that is expected to be used in the future. With satellite navigation expanding, Europe wants to be an active partner in satellite navigation community. Until now, the GNSS users have had to depend on the GPS or Russian Glonass. The European answer to them is Galileo which will give users alternative that is run by civil, not military authorities. Unfortunately, the Galileo system is not yet fully operational.

2. EGNOS SYSTEM

For understanding the EGNOS system it is obligatory to explain the conception of the SBAS. This abbreviation stands for Satellite-Based Augmentation Systems which work as augmentation units that simply make the GNSS signal more precise. The SBAS systems consist of the three main parts:

a) SBAS satellites that transmit signal from the ground segments stations to the SBAS receivers that calculate the position and time information from the GNSS service.
b) Ground infrastructure which calculates the pseudorange between the GNSS satellite and the referential SBAS receiver with a known position and additionally provides corrections for the satellite and transmission errors.
c) SBAS receiver that obtains the correction data from the SBAS satellites and uses them for the position augmentation.

The SBAS systems have more than just the augmentation role. They also offer the providers information about the current condition of the GNSS satellites. Because SBAS satellites are geostationary, different countries use their own SBAS systems. There are WAAS in the USA and Canada, MSAS in Japan, GAGAN in India and EGNOS in Europe.

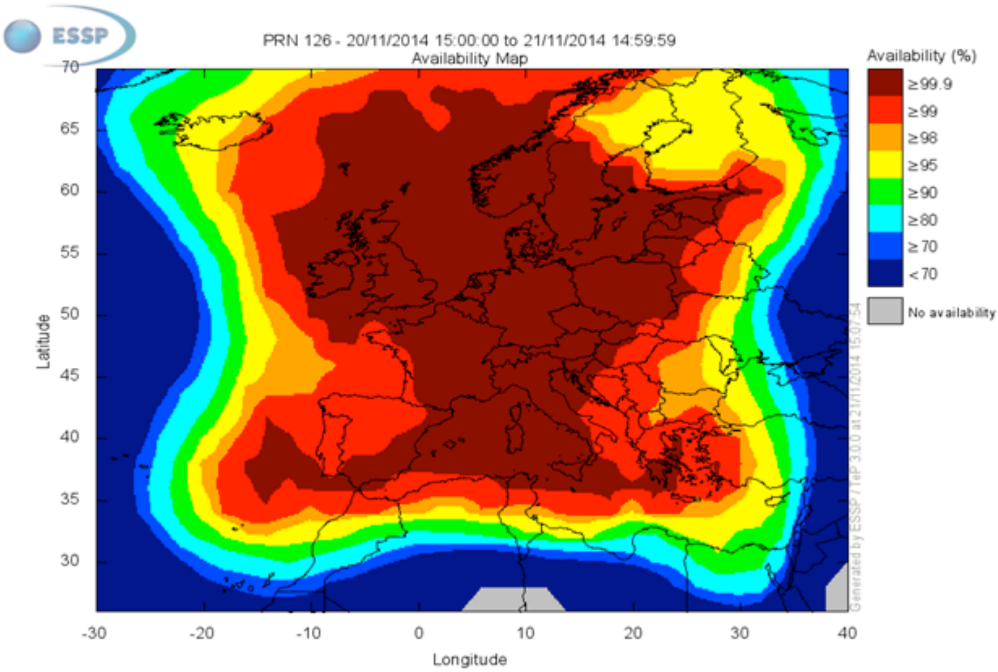

Figure 1. Availability of the EGNOS Inmarsat signal [10]

The EGNOS or the European Geostationary Overlay Service is a European system officially launched in 2009 that corrects the GPS signal. It therefore increases the accuracy from 17 metres up to 3 metres, according to the European GNSS Agency. Consequently, EGNOS makes GPS suitable for safety critical applications such as aviation. EGNOS system even provides verification of the system’s integrity and additionally reports when the system should not be used for navigation purposes. Integrity is a feature that ensures the user is familiar with the signal incorrectness which is crucial for the safety-critical applications.

As far as the infrastructure is concerned, it is composed of the three segments aforementioned. More specifically, the space segment consists of three geostationary satellites – two INMARSAT III above Atlantic and Indian Ocean and one ESA Artemis satellite above Africa. Importantly, the EGNOS satellites broadcast on the same frequency as the GPS that is in the L1 frequency band. The ground segment is composed of stations which are mainly distributed in Europe and are interconnected between themselves through a land network. According to the EGNOS provider – the ESSP, in the late 2014 there are 39 Ranging and Integrity Monitoring Stations (RIMS) that receive the satellite signals and forward the information to the control and processing centres (MCC). There are four MCC centres that receive the information from the RIMS stations and generate messages to improve the accuracy. Moreover, there are 6 stations that access the geostationary satellites that later generate the GPS-like signal. This data is then transmitted to the European users.

Figure 2. EGNOS implementation status. [9]

Finally, the user segment is a set of EGNOS receivers developed for various types of users. Generally, EGNOS offers three services:

i. The Open Service that is provided for free, however, without any guarantee. It is designed for anyone with an EGNOS satellite navigation receiver.
ii. The Safety-of-Life Service which provides the integrity message warning when there is any malfunction of the GPS signal and does that within 6 seconds.
iii. The Commercial Service is the most sophisticated service of all. It provides a terrestrial data through an internet connection. EDAS or the EGNOS Data Access Service disseminates EGNOS navigational data in real time and importantly, without relying on the signals from the EGNOS satellites. Therefore it can be used when the satellites are not visible, blocked or

disturbed by interference. For example, northern areas of the EU may suffer from poor EGNOS availability when the geostationary satellites are hovering above the equator hence not sufficiently visible.

Besides EGNOS usage in a wide range of market segments, one of the most important is in aviation. The systems provide the accuracy needed to help guide pilots both en-route and also for runway approaches. Moreover, larger airplanes may land at regional airports which could not have been previously equipped sufficiently for such aircrafts. The EGNOS dramatically increases the vertical precision which leads to substantial reduction in the decision height. For such procedures only certified EGNOS receiver, an adapted approach procedure and corresponding flight management system functions are needed. It is necessary to mention that no investments and maintenance costs for the ground infrastructure are required. The benefits of such implementation are obvious – the level of safety is increased and decision height can be lowered potentially down to as low as 200ft. Already implemented EGNOS approaches can be seen in the Figure 2 as a green airplane, yellow are planned. Moreover, non-ILS equipped airports become much more accessible providing that appropriate approach procedures and charts are created. Because of the high reliability of these systems and according to Guidance Material for the Implementation of RNP APCH Operations, ICAO Assembly Resolution 36-23 urges the States to implement approaches with vertical guidance to all instrument runway ends by 2016. RNP APCH to LNAV/VNAV and RNP APCH to LPV minima were the two options to fulfil the resolution. It is worth mentioning that also airports benefit from EGNOS. Besides the financial part, airports with a demanding environment can implement near-precision approaches. Airports in mountainous areas usually require complex approach trajectories and airports located in the vicinity of cities are often obliged to avoid the populated areas for safety and noise reduction reasons. LPV approaches could enable doing all that and moreover as the final approach is virtual and not linked to any ground device, it is possible to implement different approaches on a same runway end considering the aircraft category. Such solution results with protection of light aircrafts against wake turbulence from heavier aircraft, higher traffic flow thanks to a reduced separation and noise reduction.

3. GALILEO SYSTEM

Galileo is Europe's own GNSS system providing a highly accurate positioning service under civilian control. The purpose of such implementation is mainly fear of the GPS services will be switched off. Indication of Europe's desire to be independent gives the European Global Navigation Satellite Systems Agency with their statements. According to this source, Galileo should give users a new and reliable alternative, run by civil authorities. Moreover, they mention that a signal failure, whether accidental or intentional, would jeopardise financial and communications activities, security and emergency services.

The system will guarantee availability of the service under all circumstances and thanks to the integrity monitoring by EGNOS, the user will immediately know there is a system failure. In 2011 came the first two of four operational satellites designed to confirm the Galileo concept in space. Two more satellites followed on 2012. However, for fully functional system there is need for more satellites. It is expected by the European Space Agency that the initial operational capability will be reached around 2015. Once this phase will be achieved, the first open service test will be enabled. However, the system will have to be built gradually to be working in the full operational capability. The full service will be launched with 27 operational and 3 spare satellites positioned in the three circular planes. Furthermore, two Galileo control centres have been implemented in Europe to provide the control and the management of the satellites. On 12 March 2013 Galileo's space and ground segment contacted each other for the very first time and the full testing mode had begun.

As far as the services are concerned, it is needed to say that Galileo will be deeply interconnected with the EGNOS system. Once Galileo becomes fully operational, a portfolio of services will be provided based on different needs:

i. The Open Service will be accessible by the general public free of charge, providing improved global positioning.
ii. The Public Regulated Service will be powered by encrypted signals with controlled access for specific users such as governmental bodies.
iii. The Search and Rescue Service will contribute to the international Cospas-Sarsat international system for search and rescue. The satellites will be equipped with a transponder, which is able to transfer the signal from the user to a rescue centre, which will begin with the rescue operation. At the very moment, the user is informed that help is on the way.
iv. The Safety-of-Life Service will continue to work.
v. The Commercial Service will provide a signal mainly for professional users and it can be said the potential applications of satellite navigation in the business are limitless.

Besides Galileo's sophisticated functions that surpass the GPS, it is important to state the technical difference between the systems. Notably the key difference between Galileo and GPS is that the European system is originally designed with integrity and quality monitoring. Moreover, the Galileo satellites will be placed in orbits at a greater inclination to the equatorial plane than GPS which results with a better coverage at high latitudes. Because of this fact, it will be suitable for operation in northern Europe, which is not well covered by the GPS. Additionally, it is claimed that Galileo will have reduced errors than GPS.

The question is whether the Galileo system is needed considering the use of the GPS and the augmentation of the EGNOS. Many experts claim that it will result in real and direct benefits. That is mainly because the satellite navigation will become a fully redundant service for civil aviation users. The total number of satellites will dramatically extend and they will be fully independent.

4. CONTRIBUTION OF THE EGNSS

Considering the fact there will be fully redundant satellite navigation systems, it is expected that the level of safety in aviation will increase rapidly. That is besides other things because of the implementation and evolution of the Performance-based Navigation including RNP APCH.

Thanks to EGNOS, the procedures of RNP APCH have already been implemented in Europe, however, the integration and application could be much more effective with evolving satellite navigation. According to the ICAO RNP APCH Guidance Material, the RNP APCH reduces risk of controlled flight into terrain by providing stabilised approach. Also, the pilot is more aware of the situation through provision of vertical guidance. RNP APCH can support withdrawal of conventional aids therefore saving costs for maintenance and calibration flights. The safety objective alone is sufficient argument to implement RNP APCH using GNSS and EGNOS since most aircraft operators already have RNAV capabilities on board. Furthermore, operational improvements that can be quantified are the ones associated with delay or diversion and may be lowered by reduced operational minima.

On the other hand, it is necessary to mention the costs. They may emerge from the procedure design and implementation costs which can consist of flight tests and chart preparation and off course AIP changes. Additionally, safety assessment has to be done. In case of implementing the RNP APCH at airports with non-instrument runway ends, some upgrades have to be done, e.g. runway lighting. Finally, sufficient ATC training in PBN has to be completed. The costs are obviously on the airborne side too. Aircraft has to be sufficiently equipped and additionally airworthiness and operational approval have to be issued.

Beforehand, ICAO had to define performance requirements for aircraft navigating on an ATS routes and it has been done by Performance-based Navigation. PBN provides the means for flexible routes and terminal procedures through the application of Area Navigation specifications. As the procedures have been evolving, PBN is helping the global aviation reduce aviation congestion, conserve fuel and protect environment.

Contribution of the EGNSS to the environment is radical. Bearing in mind that until present day the PBN with GNSS navigation and EGNOS have increased the efficiency of air transport, the benefits from the EGNSS in the future will be staggering. IATA estimates that shorter PBN routes globally cut CO2 emissions by 13 million tonnes per year by providing a mechanism for optimized profile descents and optimized flight paths. Moreover, redundant GNSS system will ensure consistent, precise path that can be routed to avoid noise sensitive areas. Furthermore, more accessible runways will reduce delays and diversions due to bad weather. EGNOS with Galileo will also allow more precise, shorter approaches, all of which results in reduced fuel consumption and CO2 emission. Later on, ADF and VORs may be withdrawn, potentially resulting in reduced airport user charges.

The overall benefits are quite clear – the redundant system will bring satellite navigation forward to a potential replacement of contemporary navigation aids. Galileo should accelerate the implementation of satellite navigation in aviation, more specifically in terms of approaches with vertical guidance. The crucial fact is that the very short time-to-alert of six seconds will ensure the requirements of civil aviation authorities. Moreover, GPS and Galileo possibly won't be competing against each other but mainly with other civil aviation services such as surveillance systems, ILS and others. On the other hand, civil service of Galileo is usually presented as a comparative advantage. There is no doubt that it is one of the benefits, but also probably the main reason why the system is not yet fully functional.

5. CONCLUSION

The level of safety throughout the time needs to be ensured unconditionally. The rapid development of the GNSS influences aviation and it is necessary to say the effect is highly positive. Nowadays only first part of the EGNSS is in operation and it influenced the situation dramatically. Thanks to EGNOS, RNP APCH have been implemented and overall usage of this system is highly beneficial. However, the role of the GNSS in the future will be much more important. Once the Galileo system will be fully operational, we can expect radical extension of the GNSS in aviation. Many specialists say that satellite navigation is the future of aviation, mainly in the terms of approaches. It is hoped the Galileo system will be operational according to the schedule because there is no doubt that benefits of its cooperation with GPS and EGNOS will be positive.

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