IMPLEMENTATION OF GBAS SYSTEM AT THE VÁCLAV HAVEL AIRPORT

Irena Ambrožová[1], Stanislav Pleninger [2]

Summary: This paper describes possibilities of GBAS installation at the Václav Havel Airport in Prague. It contains possibilities of GBAS utilization at the approach and landing phase of flight, further evaluation of low-visibility conditions at LKPR and especially cost and benefits analysis.

Keywords: satellite systems in aviation, GBAS, low visibility conditions, precision approach, CAT I, CAT II/III.

INTRODUCTION

Global positioning system provides the velocity, positioning and timing service to the user. For civil aviation users, the services are required to satisfy the strict requirements classified by the parameters such as precision, integrity, continuity, availability. The GPS isn't able to meet the above mentioned parameters for such critical applications as an approach and landing during low visibility operations (i.e. CAT II and III). Hence specific augmentation system called GBAS was introduced in order to enable usage satellite systems (nowadays e.g. GPS) for the most critical aviation applications as an approach and landing.

GBAS is composed of a ground station which is able to calculate differential pseudo range corrections and monitor signal in space (SIS). Using corrections and associated integrity data, the user receiver is able to correct its own measurements. Currently, GBAS has been certified for CAT I precision approach, however it can provide performance to meet CAT II/III requirements. It is intent to use it instead of ILS (Instrumental Landing System) or MLS (Microwave Landing System) which are currently the only navigation mean which can provide CAT II/III precision approach. What more GBAS equipment is cheaper that ILS equipment it terms of maintenance, installation and flight inspection. (1)

1. GBAS ANALYSIS AND PERFORMANCES

One of the biggest advantages of GBAS is that with similar performance to ILS only one GBAS station can cover the whole runway system and final approach paths. The coverage of the signal is 23 – 25 NM, however due to ionosphere errors distance between reference station and RWY threshold should be maximum 6 km for CAT I and 5 km for CAT II/III. It means decreasing infrastructure cost in the airport. We can see categories of PA procedures by ICAO standards on following table. (2)

[1] Bc. Irena Ambrožová, Czech Technical University in Prague, Faculty of Transportation Sciences, Department of Transport Telematics, Konviktská 20, 110 00, Tel.: +420604204099, E-mail: irena.ambrozova@gmail.com

[2] Ing. Stanislav Pleninger, Ph.D., Czech Technical University in Prague, Faculty of Transportation sciences, Department of Air Transport, Tel.:+420 224359185, E-mail: pleninger@fd.cvut.cz

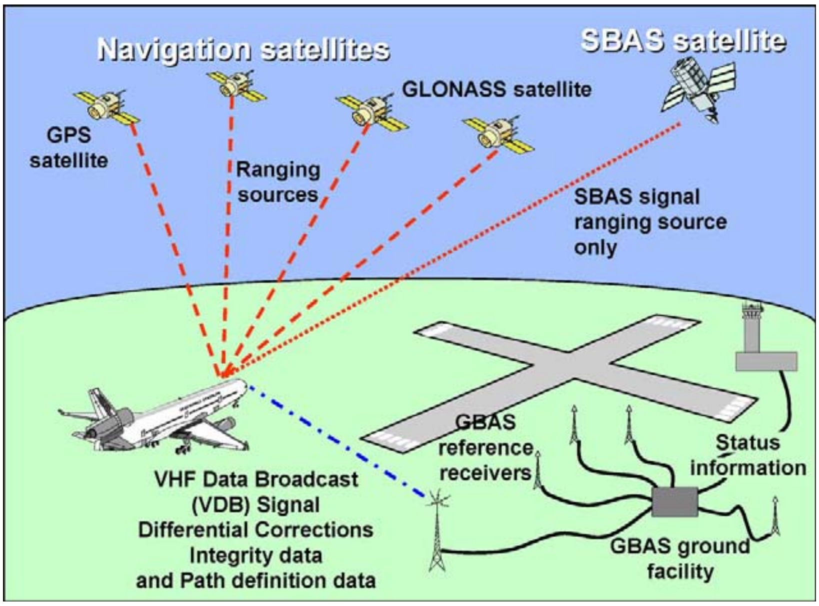
Tab. 1 – ICAO standards of PA categories

Category	Decision height (DH)	Runway visual range (RVR)
CAT I	DH > 200 ft (60 m)	> 550 m (or visibility > 800 m)
CAT II	200 ft (60 m) > DH > 100 ft (30 m)	> 300 m
CAT III A	100 ft (30 m) > DH or no DH	> 175 m
CAT III B	50 ft (15 m) > DH or no DH	175 m > RVR> 50 m
CAT III C	No limits	No limits

Source: (3)

1.1 GBAS SYSTEM DESCRIBTION

For illustration on Figure 1 is typical GBAS configuration which includes three components: ground segment, airbone segment and space (satellite) segment.



Source: (3)

Fig. 1 – GBAS configuration

- **The ground segment** consists of three or four reference receivers. They track the signals from satellites and pass pseudo range measurements and other information to the central processing unit. Processing unit computes estimates of the pseudo range corrections for each satellite. The differential corrections and integrity information are broadcasted via VDB antenna. GBAS also broadcasts information that is used to define a reference path. (3) (4)
- **The airbone segment** receives the satellite signals and ground segment signals. It includes airbone equipment (Multi–Mode receiver) which:
  - Receives navigation signals emitted by GNSS satellites
  - Measures pseudo range from each satellite
  - Provides availability check of the service

  - Determines aircraft position
  - Applies corrections received from ground segment (1) (4)
- **The satellite segment** provides signal to onboard GNSS receiver and to the ground GBAS station. (1) (4)

1.2 NAVIGATION INFORMATION

GBAS navigation message contains data mentioned in following table.

Tab. 2 – GBAS navigation message

Message Type	Message Name
1	Pseudo range corrections
2	GBAS related data
3	Reserved for acquisition data
4	Final approach segment
5	Ranging source availability (optional)
6	Reserved for carrier corrections (CAT II/III)
7	Reserved for military
8	Reserved for test

Source: (4)

For PA procedures are the most important:

- **Message Type 1** – provides the differential correction data (like time of validity, ephemeris decorrelation parameter, pseudo range correction etc.).
- **Message Type 2** – identifies the exact location for which the differential corrections are referenced and computes a tropospherics correction.
- **Message Type 4** – includes information about Final Approach Segment definition for each runway end or approach served by the ground segment. (1) (4)

1.3 GBAS IMPLEMENTATION IN EUROPE

GBAS in CAT I configuration is used at the aerodromes over the world (in USA is GBAS known as WAAS). The first one was installed in 1997 in New York and the first in Europe was at Frankfurt airport in 1998. Nowadays there is no operationally GBAS used in CAT II/III configuration, however there are many of prototypes at aerodromes, and it should be certificated during the next few years. Following figure shows GBAS implementation at aerodromes in Europe. (5)

Source: (5)

Figure 2 – Map of GBAS facilities in Europe

Blue colour symbolizes GBAS facilities used for research and testing (with dot: charts published). It is for example Palermo, Lisbon, Frankfurt, Braunschweig and Toulouse where are placed prototypes for CAT II/III testing. Yellow colour symbolizes aerodromes, where is used or plan to use GBAS S-CAT[3] (with dot: charts published). Green colour symbolizes the airports with active GBAS system CAT I (with dot: charts published). And finally purple colour is for those aerodromes where is GBAS planned in the future. (5)

2. IMPLEMENTATION AT VÁCLAV HAVEL AIRPORT

Situating of runways is apparent from following Figure 3. Nowadays is used RWY 06/24 and 12/30. However it is planned to be build the parallel one 06R/24L by the year 2020 and relocate the traffic from 12/30 there. At 06R/24L should be installed lighting system and all necessary infrastructure for landing precision approach. (6)

[3] S-CAT – it is a cathegory of a local area differential GNSS precision approach system that can provide descent to a CAT I decision height, provided all the other requirements for CAT I. (4)

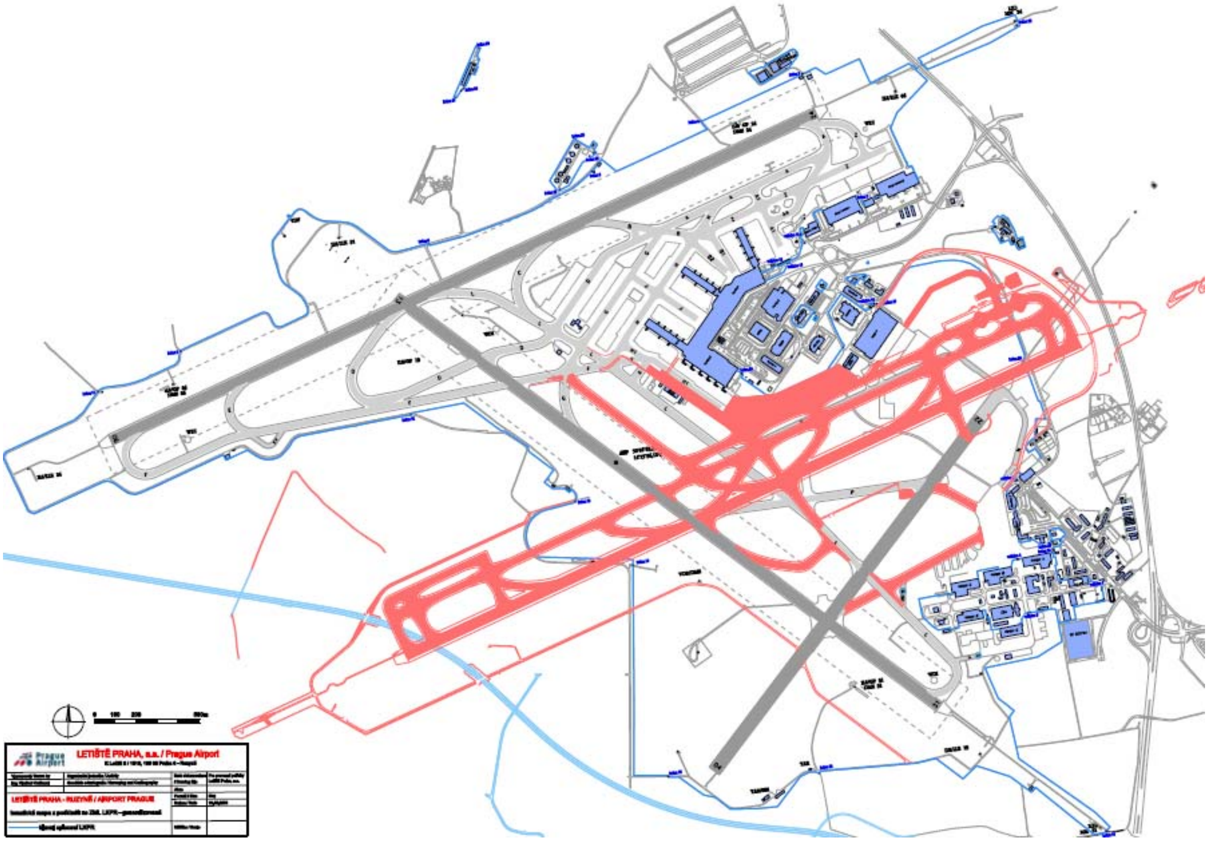


Fig. 3 – Situating of RWY at Prague airport (with RWY 06R/24L)

2.1 RADIONAVIGATION AND LANDING AIDS

Actual published approaches for each RWY are following:

- RWY 06: ILS (CAT I, LOC), NDB-DME, RNAV (GNSS) NPA, APV Baro
- RWY 12: ILS (CAT I, LOC), VOR-DME, RNAV (GNSS) NPA, APV Baro
- RWY 24: ILS (CAT I, II, IIIa, IIIb, LOC) , RNAV (GNSS) NPA, APV Baro
- RWY 30: ILS (CAT I, LOC), VOR-DME, RNAV(GNSS) NPA, APV Baro (6)

The life cycle of ILS installed at RWY 06/30 ends up by the year 2017 and at RWY 06/24 by the year 2022. (6)

2.2 METEOROLOGICAL CONDITIONS

If we think about replacing ILS by GBAS system it is necessary to analyze operational characteristics which are significantly influenced by meteorological conditions. ILS serves as a precision approach system which can provides procedure up to lowest minimums (CAT IIIb at Prague airport). GBAS has even better performances, nevertheless it hasn´t been certified for CAT II/III yet, so it is not able to serve as system usable during LVP [4] It was made a statistics of low-visibility procedures based on meteorological data obtained from Air Navigation Services of the Czech Republic. Based on this statistic was computed the total number of aircraft served during LVP. Table 3 evaluates the total and average time of duration LVP.

Tab. 3 – LVP duration in 2009 - 2012

	year 2012	**year 2011**	**year 2010**	**year 2009**
Total time	195 h 8 min	286 h 33 min	209 h 7 min	156 h 33 min
Average time of LVP	53,08 min	226,22 min	190,11 min	156,55 min

Source: (7)

With regard to the fact that on the RWY 06, 12 and 30 is placed ILS CAT I system and on the RWY 24 ILS CAT II/IIIb system we can calculate the ILS utilization for each category.

The total sum of operations per year is approximately 132 000 when 66 % of all is placed on RWY 24, 11 % on RWY 06, 15 % on RWY 30 and 6 % on RWY 12. The amount of operations during the LVP is influenced by type and qualification of the aircraft and many other aspects. And surely some part of the operations is not able to realize due to cancellation of the flight or divergence of the aircraft, as is typical for ATR with RVR (RWY visibility range) < 300m. (7) In following Table 4 are calculated hour capacities of operations at Prague airport.

Tab. 4 – Hour capacity of operations at LKPR

Hour capacity	Number of arrivals /total number of departures and arrivals
Night operations (except LVP)	12/24
Peak hour operations on RWY 12/30, except LVP	24/38
Peak hour operation on RWY 06/24, except LVP	30/44
LVP on RWY 24 (due to RVR 350 – 600 m)	17/30
LVP on RWY 24 (due to RVR < 350m)	14/30

Source: (7)

The real utilizing is in fact a bit lower, because capacities mentioned bellow are taken during the peak hours. From the values mentioned above we can compute the percentage of low-visibility conditions from the total operational hours at LKPR. In 2012 were LVP 195 h and 8 min, it means 2.26 %. In addition we know the total number of served aircraft –

[4] **LVP-** Low visibility procedures are applied when RWY visual range is lower than 600 m and CLD base lower that 200 ft. It serves also for low-visibility take-offs (LVTO). LVTO is a take-off with an RVR lower than 400 m, but not less than 75 m. (7)

131 564, the duration of LVP and hour capacity LKPR during LVP, so we can calculate the maximum possible number of aircraft served in LVP. It is 5 944 aircraft, which is 4.5 % from total annual traffic on LKPR[5]. Based on this statistics is evident that an availability of some radionavigation system certifiable for LVP operations at LKPR is inevitable.

2.3 GBAS COST BENEFIT ANALYSIS

If we think about installation of GBAS system at LKPR, we have to consider many aspects. The major one is that at RWYs are installed ILS systems with lifetime up to the 2017 and 2022. The other important fact is based on GBAS certification which is nowadays only for CAT I. For CAT II/III it should be soon, but it could take longer time. With regards to these facts two scenarios is possible to consider:

- The first one is to situate GBAS CAT II/III and renew the ILS CAT I as a back-up mean in case of loss of signal or breakdown GBAS. By the year 2017 the lifetime of ILS installed at the RWY 12/30. (8) By this year GBAS should be certificated for CAT II/III and also the onboard equipment should be more expanded and available. So one of the optimal possibilities is to install GBAS CAT II/III in the year 2017 and not renew ILS at RWY 12/30. After that it seems to be the best option not renews the ILS system at RWY 06 and renew only the one at RWY 24R [6] as a back-up system (after the end of life time in 2022).
- In case of problems with certification of GBAS CAT II/III that might be prolonged, we can consider the second scenario. In this situation the best option would be install GBAS CAT I and let or renew the ILS CAT II/III at 24R for LVP operations.

2.3.1 Scenario 1

In the first scenario is desirable let RWY 24 for LVP, because there is installed lighting and other RWY infrastructure for CAT II/III. The following table describes investments necessary for installation of GBAS CAT II/III (and one GBAS system) according the first scenario. Cost on maintenance, spare parts and testing equipment are included in *operation costs*. Also important statement is fact that GBAS is able to serve all RWYs by one installation. To compare with ILS which it is able to serve only one direction of RWY by one system.

[5] Realistic estimate is approximately 3000 operations (aircraft) during LVP, which is about 2.3 % from total traffic on LKPR.

[6] Most of operations (arrivals and departures) are taken place at RWY 24R

Tab. 5 – Total cost for GBAS implementation according scenario 1

GBAS installation costs	*Price* (€)
CAT II/III infrastructure	1 000 000
Installation and commissioning	120 000
Civil works	44 000
(Certification	30 000
Operation costs (2017 - 2027)	430 000
ILS CAT I installation costs	
DME and ILS CAT I infrastructure	336 000
Installation and commissioning	175 000
Civil works	195 000
Calibration	30 000
CAT I operation costs (2022-2027)	395 000
Total costs	2 755 000

Source: (9)

To sum the results: the total cost of GBAS installation according the first scenario would be **2 755 000 €** (approx. **70.8 millions CZK).**

2.3.2 Scenario 2

The Table 6 summarizes total costs of GBAS installation according scenario 2. It is meant in assumption of delay in GBAS CAT II/III certification.

Tab. 6 – Total cost for installation GBAS according scenario 2

GBAS installation costs	Price (€)
CAT I infrastructure	500 000
Installation	120 000
Civil works	44 000
Certification	30 000
Operational costs (2017 - 2027)	430 000
ILS CAT II/III installation costs	
DME and ILS CAT III infrastructure	400 000
Installation and commissioning	175 000
Civil works	195 000
Calibration	30 000
CAT III operational costs (2022-2027)	525 000
Total costs	2 449 000

Source: (9)

To sum up the results: the total costs of GBAS installation according scenario 2 would be **2 449 000 €** (**62, 9 millions CZK).**

2.3.3 GBAS vs. ILS

According the financial statements above is sure that the total price in scenario 1 and 2 is similar. However we are also interested in the difference of total costs in comparison with ILS renewal. The summary of total costs on ILS renewal and operation in 2017 – 2027 for all RWY is computed in Table 7.

Tab. 7 – Total cost for ILS renewal and operation

ILS installation costs at RWY 12 (CAT I)	Price (€)
DME and ILS CAT I infrastructure	336 000
Installation	175 000
Civil works	195 000
Calibration	30 000
CAT I operation costs (2017-2027)	790 000
ILS installation costs at RWY 30 (CAT I)	
DME and ILS CAT I infrastructure	336 000
Installation	175 000
Civil works	195 000
Calibration	30 000
CAT I operation costs (2017-2027)	790 000
ILS installation costs at RWY 6 (CAT I)	
DME and ILS CAT I infrastructure	336 000
Installation	175 000
Civil works	195 000
Calibration	30 000
CAT I operation costs (2022-2027)	395 000
ILS installation costs at RWY 24 (CAT II/III)	
CAT III lighting system and infrastructure	400 000
Installation	175 000
Civil works	195 000
Calibration	30 000
CAT III operation costs (2022-2027)	525 000
Total costs	5 508 000

Source: (9)

The total costs on renewal and operation of ILS system in 2017 – 2027 would be **5 508 000** € (**141.55 millions CZK).** The total costs on GBAS installation could be considered as more efficient to compare it with ILS. In scenario 1 (implementation of GBAS CAT II/III) we can save about **2 753 000 €**. And in assumption of scenario 2 (implementation of GBAS CAT I) we can save about **3 059 000 €**.

CONCLUSION

This paper described the ground-based augmentation system – its architecture, performances and utilization at the landing and precision approach phase of flight. In addition in the article is presented GBAS implementation at Europe and finally the possibilities of its installation at the Václav Havel airport in Prague. There are shown two scenarios with economical analysis and compared to the total costs of ILS system, which is placed at the LKPR right now.

As is noticeable from the results GBAS could be a very attractive navigation system for the civil aviation users. Especially as far as cost benefit GBAS implementation is concerned the advantages are very dependent on specific operational and airport infrastructure aspects.

REFERENCES

(1) NERI, P., L. AZOULAI a J. MULLER. GBAS NSE MODEL FOR CAT II/III AUTOLAND SIMULATIONS. 4-6 May 2010, s. 14, ISBN: 978-1-4244-5036-7 Available at: http://ieeexplore.ieee. org/xpl/login.jsp?tp=&arnumber= 5507222&url= http3A2F2Fieeexplore.ieee.orgFiel52F54929412F55071252F05507222.pdf3Farnumber3 D5507222BEHREND,

(2) Ferdinand a Oliver LEHMANN. CAT II / OTS CAT II OPERATIONS USING EXISTING CAT I GROUND BASED AUGMENTATION SYSTEM. 30th Digital Avionics Conference [online]. 2011, s. 11 [cit. 2013-03-31]. Available at: http://www.eurocontrol.int/eec/public/standard_page/ETN_2010_2_GBAS_Full.html

(3) International Civil Aviation Organization: Annex 6, Aircraft operations, maintenance and general aviation. Ninth Edition– July 2010. [cit. 2013-05-25] Available at: http://www.icao.int/safety/ism/ICAO%20Annexes/Forms/AllItems.aspx

(4) Augmentation system principle and concept: GBAS (augmentation system). ACAC seminar 17-18 Oct 2011, s. 18. [cit. 2013-01-25] Available at: http://siraj.ec.pildo.com/uploads/Rabat/ files/GBAS_course.pdf FLY GLS

(5) GBAS facilities. Fly.gls.net: net - The future of precision approach [online]. 2013 [cit. 2013-03-29]. Available at: https://maps.google.com/maps/ms? msa=0&msid= 217875097500112150552.00049bf0be48258e49d8e&hl=en&ie=UTF8&t=m&ll=11.8673 51,17.578125&spn=152.799123,26.71875&z=1&source=embed

(6) AIP of the CR: Část 3 - Letiště. [online]. 2011 [cit. 2013-03-24]. Available at: http://lis.rlp.cz/ais_data/www_main_control/frm_cz_aip.htm

(7) Conslutation with employee of Aviation Meteorological Services of the Czech Republic – RNDr. Bohumil Techlovský

(8) Consultation with employee of Air Navigation Services of the Czech Republic – Ing. Jakub Hocek

(9) REPORT ON THE EUROCONTROL XLS BUSINESS CASE STUDIES. EUROPEAN AIR TRAFFIC MANAGEMENT PROGRAMME. 2010, pp. 150-205, ISBN 987-1-4233-5370-4