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Agenda Item 3
21- 23 June 2023

International Civil Aviation Organization

THE FIFTH MEETING OF THE ASIA/PACIFIC GBAS/SBAS IMPLEMENTATION TASK FORCE (APAC GBAS/SBAS ITF/5)

(Tokyo, Japan, 21- 23 June 2023)

Agenda Item 3: Updates from States/Administrations about GBAS/SBAS Implementation

Update on GBAS Proof-of-Concept Project

(Presented by Japan and Thailand)

SUMMARY

This paper presents an update on the GBAS Proof-of-Concept (PoC) Project between Japan and Thailand. It focuses on the development of the ionospheric threat model, flight demonstration results, and future actions to be carried out for the GBAS implementation at Suvarnabhumi International Airport in Bangkok, Thailand.

1. INTRODUCTION

1.1 Since Thailand is in the low geomagnetic equatorial region, it is susceptible to ionospheric irregularities such as equatorial plasma bubbles (EPBs) and equatorial ionization anomalies (EIAs). Therefore, assessing their impact is crucial for approving GBAS operations in Thailand. In early 2019, the Ministry of Internal Affairs and Communications (MIC) and the Ministry of Land, Infrastructure, Transport, and Tourism (MLIT) of Japan initiated a joint technical collaboration called the "GBAS Proof-of-Concept (PoC) Project" between Japan and Thailand. The primary objective of this collaboration project is to install GBAS PoC equipment at Suvarnabhumi International Airport and conduct experiments for deploying GBAS in a low geomagnetic latitude area that is affected by ionospheric irregularities. The anticipated outcome of this collaboration project would be mutually beneficial for both parties and would also facilitate the effective implementation of GBAS in the Asia-Pacific region by other member states.

2. PROJECT OVERVIEW

2.1 The GBAS PoC project receives support from the Ministry of Internal Affairs and Communications (MIC) through an industrial promotion program aimed at assisting Japanese industries in addressing social problems and challenges in Asian countries by leveraging Japan's advanced wireless technologies. Under this program, the NEC Corporation has been contracted by the MIC to supply the GBAS PoC equipment and offer technical support for the project. The objective is to aid host countries in becoming acquainted with GBAS technology and to facilitate informed decisions regarding GBAS implementation in the future.

2.2 The original timeframe for this project was scheduled from 2020 to 2023. However, Japan and Thailand have mutually agreed to extend the duration until March 2024 to accommodate additional activities. A summary of the conducted activities is provided in Table 1.

Table 1. Summary of key activities of the GBAS PoC Project

Year	**Key Activities**
2020	- initial ionospheric threat model preparation - construction and installation preparation - equipment preparation
2021	- ionospheric threat model preparation (continue)
2022	- equipment construction and installation - equipment evaluation - flight demonstration preparation - training and technical transfer - flight demonstration and performance evaluation
2023	- flight demonstration and performance evaluation (continue). - performance analysis and determine practical solution for implementation
2024	- performance analysis and determine practical solution for implementation (continue)

3. GBAS POC EQUIPMENT

3.1 Figure 1 illustrates the installation location and configuration of the GBAS PoC system, which includes three reference receivers (RRs), a data processing unit, a VDB (VHF Data Broadcast) transmitter, and an Ionospheric Field Monitor (IFM). Meanwhile, Figure 2 illustrates the construction layout of the reference receivers and VDB situated above the end of runway 19R at Suvarnabhumi International Airport.

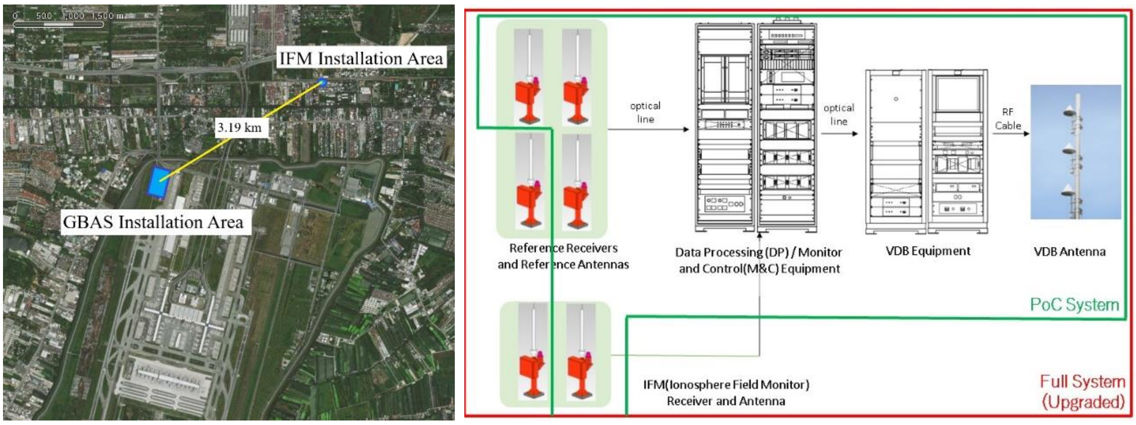

Figure 1. The GBAS PoC installation location (left) and system configuration (right)

Figure 2. Construction layout of the GBAS PoC System at Suvarnabhumi International Airport

3.2 In early 2022, the GBAS PoC equipment was fully constructed and installed at the end of runway 19R at Suvarnabhumi International Airport, as depicted in Figure 3. Furthermore, Figure 4 illustrates the Ionospheric Field Monitor (IFM) that has been installed on the campus of King Mongkut's Institute of Technology Ladkrabang (KMITL) to detect ionospheric disturbances.

Figure 3. GBAS Shelter and VDB antenna (left) and RR antenna (right) installed at Suvarnabhumi International Airport

Figure 4. IFM Antenna and Receiver installed at KMITL

4 DEVELOPMENT OF IONOSPHERIC THREAT MODEL

4.1 To evaluate the impacts of ionospheric irregularities on GBAS, the Aeronautical Radio of Thailand (AEROTHAI) developed the ionospheric threat model with technical support from the Electronic Navigation Research Institute (ENRI) and King Mongkut's Institute of Technology Ladkrabang (KMITL). The collected GPS data was analyzed to estimate the background residual ionospheric uncertainty during both ionospheric quiet and disturbed conditions. Furthermore, the ionospheric threat model development involved estimating the ionospheric delay gradient (slope), front speed (v), front width (w), and direction during the ionospheric disturbed conditions.

4.2 AEROTHAI evaluated the ionosphere characteristics in Bangkok for the years 2012, 2020, 2021, and 2022, representing both high and low solar activities. The evaluation was conducted using the single-frequency carrier-based and code-aided (SF-CBCA) method [1], courtesy of ENRI. GNSS data was collected from three receivers located at different sites: Stamford International University, KMITL, and the Suvarnabhumi International Airport (01L Localizer station), as shown in Figure 5.

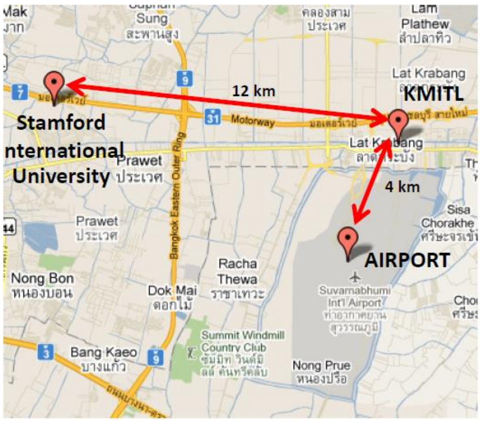

Figure 5. GNSS stations used for ionospheric threat model development

4.3 The SF-CBCA method is employed to estimate the single-difference of ionospheric delay between a pair of GNSS receivers with known relative positions. The method involves estimating float solutions using Kalman filtering and then fixing them using the double-difference of the integer ambiguity of carrier-phase measurements. The results of the method, after validating the ambiguity resolution, are summarized in Figure 6.

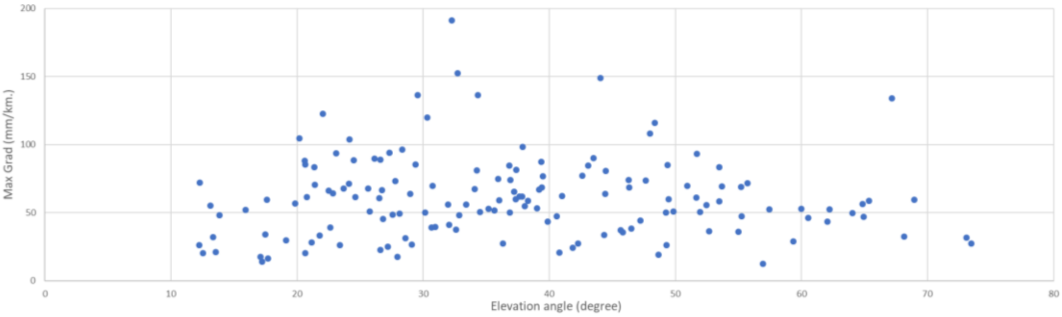

Figure 6. The ionospheric delay gradient observed during the year of 2012, 2020, 2021, and 2022

4.4 Furthermore, the front speed (v), front width (w), and direction were calculated as part of the analysis. After consulting with the ionosphere expert, the parameters for the ionospheric threat model for Bangkok are summarized in Table 2. the system. To ensure that the threat model accurately reflects the nature of ionospheric activities primarily caused by solar activity during each solar cycle, these parameters are expected to be reviewed and updated on an annual basis, as necessary.

Table 2. Ionospheric threat model parameters for Bangkok

Parameters	**Range of values**
Slope (g)	300 mm/km
Width (w)	4-200 km
Front speed (v)	0-300 m/s
Direction	All direction (0-360 Degree)
Depth (D)	15 m (maximum)

5 FLIGHT DEMONSTRATION RESULTS

5.1 To conduct the flight demonstration, AEROTHAI developed eight GLS approach procedures for all four runway ends of Suvarnabhumi International Airport, with technical assistance from the Japan Civil Aviation Bureau (JCAB). Four of these GLS procedures are overlays of ILS procedures, showcasing that a single GBAS system can cover multiple runways ends. The remaining four special GLS procedures emphasize the advantages of GBAS without requiring modifications to runways or hardware configurations. Examples of GLS approach procedures are provided in Figure 7. Two procedures utilize a higher glide path angle (GPA) of 3.2 degrees for runway 19R and 01L, aiming to reduce aircraft noise emissions. The other two procedures involve a displacement of 300 meters from the existing runway threshold for runway 19L and 01R, demonstrating GBAS's capability to provide approach guidance during runway maintenance activities.

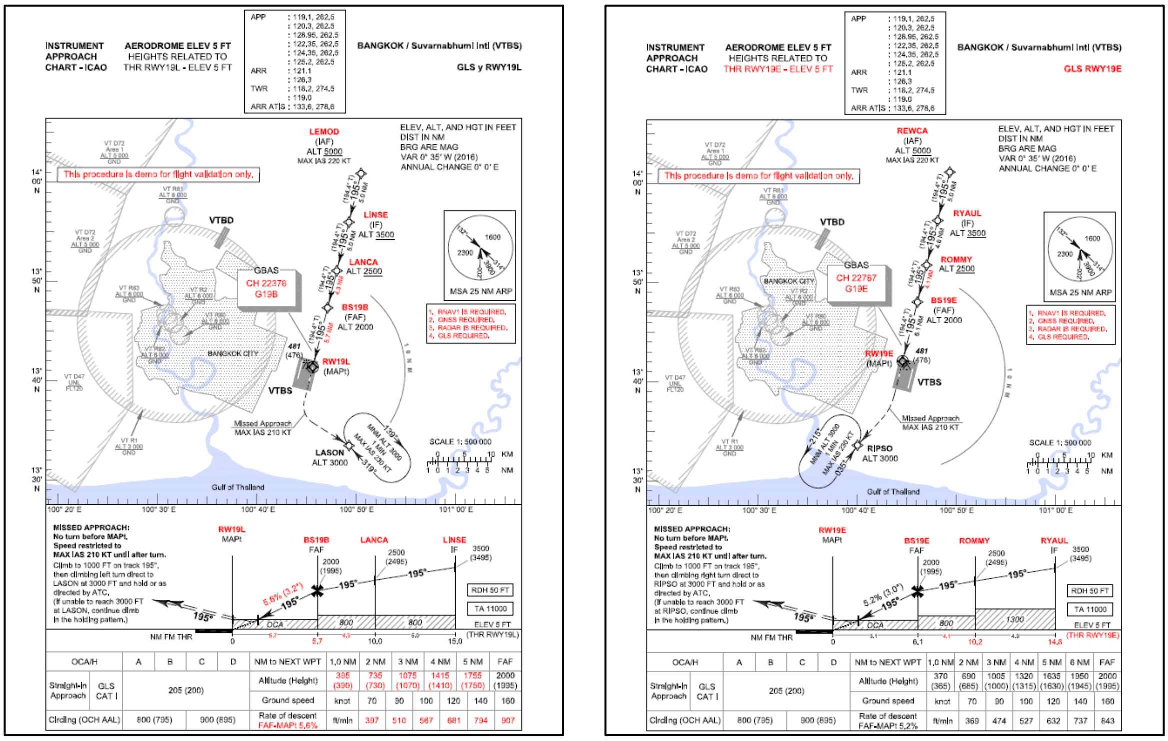

Figure 6. GLS procedure runway 19L with GPA of 3.2 degrees (left) and GLS procedure runway 19R with 300 meters of displaced threshold (right) <Not for operation>

5.2 During the period of November 2022 to January 2023, AEROTHAI conducted several GBAS flight demonstrations using their Beechcraft Super King Air 350 aircraft equipped with the GBAS Flight Inspection System (FIS), as depicted in Figure 8 (left). The aircraft performed various flight patterns, including arc flights, level runs, and normal approaches. Several parameters were evaluated during these demonstrations, including the coverage of the VHF Data Broadcast (VDB), deviation errors between GLS and ILS approaches, and radio signal interferences.

Figure 8. Flight demonstration aircraft "Beechcraft Super King Air 350" (left) and patterns (right)

5.3 The overall results of the demonstration indicated that the GBAS system successfully met all performance requirements. The VDB coverage was found to be sufficient, and the deviation error between GBAS and ILS approaches remained within acceptable limits. Additionally, the GBAS system demonstrated its ability to improve runway throughput and capacity by eliminating the need for critical or sensitive areas of the ILS during runway operations.

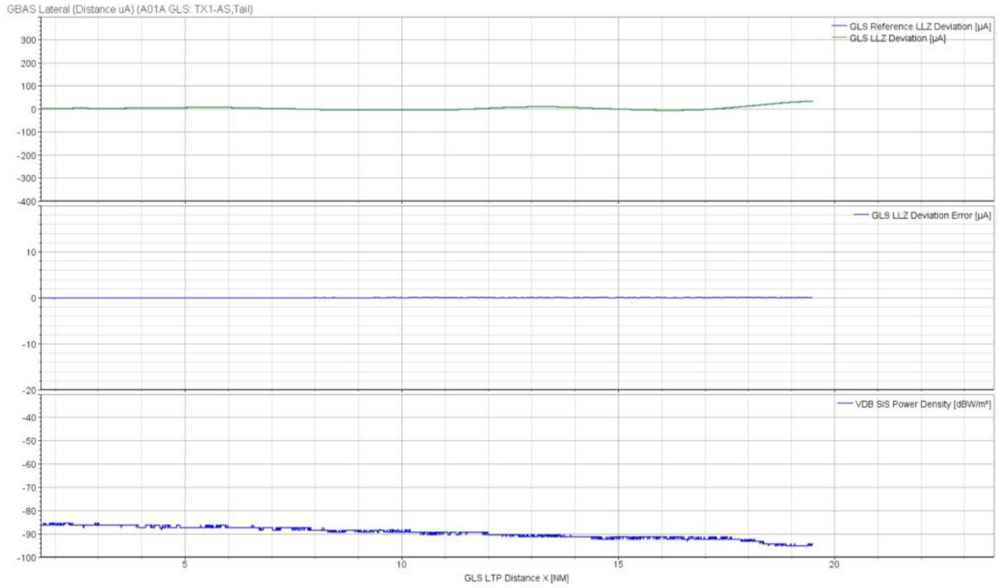

Figure 8. Example demonstration results of GLS lateral deviation (top), GLS deviation error (middle), and VDB power density (bottom)

6 FURTHER ACTIVITIES

6.1 Although the several flight demonstrations successfully demonstrated the ability of GBAS to provide flexible and smooth navigation guidance for CAT-I operations, there are still several considerations that need to be addressed for real operations. These considerations include factors such as ionospheric scintillation, radio frequency interference, and the selection of an appropriate location for the IFM. To ensure the successful implementation of GBAS and meet the operational requirements, a performance analysis will be conducted. Practical solutions will be determined based on the analysis to address these considerations and ensure the system operates safely and effectively.

7. ACTION REQUIRED BY THE MEETING

7.1 The meeting is invited to:

a) note the information contained in this paper; and
b) discuss any relevant matters as appropriate.

8. REFERENCES

[1] WP/5 Ionospheric Delay Gradient analysis with the single-frequency carrier-based and code aided method presented by Japan at ISTF/5, 16-18 February 2015.

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