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**Twenty Sixth Meeting of the Communications/
Navigation and Surveillance Sub-group (CNS SG/26) of
APANPIRG**

Video Tele-Conference, 15 – 19 August 2022

Agenda Item 6: Navigation

6.4 Other navigation related issues

RESEARCH AND DEVELOPMENT ACTIVITIES RELATED TO GBAS IN JAPAN

(Presented by Japan)

SUMMARY

This information paper reports on the status of research and development related to GBAS in Japan. There are two major subjects, development of GBAS, including DFMC GBAS and GAST D, for challenging ionospheric environment and advanced operations enabled by GBAS.

1. INTRODUCTION

1.1 GBAS is a navigation system that can provide precision approach services and advanced operations beyond what can be provided by the conventional ILS. However, the ionospheric activity is one of the challenges that prevent high performance of GBAS in regions such as the magnetic low latitudes.

1.2 Electronic Navigation Research Institute (ENRI) has been working on enhancement of the GBAS performance in the magnetic low latitude region by improving ionospheric threat models and integrity monitors for the single-frequency GBAS (GAST C and D) which have been standardized in the ICAO Annex 10.

1.3 The ICAO is working on standardization of the dual-frequency and multi-constellation (DFMC) GBAS as an ultimate mitigation of the threats induced by the ionosphere, because the ionospheric delay can be evaluated by using the two frequencies of the GNSS signals. ENRI is contributing to the standardization activities by the ICAO by its own researches since 2015.

1.4 Advanced operations enabled by GBAS are of great interests to maximize the benefit of GBAS implementation. ENRI has been working on developing and demonstrating operations enabled by the currently standardized GBAS systems.

1.5 This information paper reports on the status of research and development related to GBAS in Japan.

2. DISCUSSION

GBAS for challenging ionospheric environment

2.1 The DFMC GBAS is being standardized by the ICAO and is in the phase of developing the concept and defining the architecture. It is deemed as an ultimate solution to provide best performance of GBAS in the ionospheric challenging environment. As the ionospheric activities are high in a large part of the APAC region including Japan, DFMC GBAS which can mitigate the threats by the ionosphere will provide significant improvement in the GBAS performance in this region. Currently, there are two proposals for the DFMC GBAS architecture. One is so-called “SESAR GAST F” developed and proposed through the European SESAR activities. The other is called GAST X which foresees future extensions of applications beyond the category-III approach and landing operation.

2.2 ENRI has been conducting researches since 2015 to contribute to the DFMC GBAS concept development activities by ICAO through this research. The main research topics includes the development of mock-ups of the ground and airborne subsystems of DFMC GBAS, validation and comparison of the two proposed architectures by using the mock-ups, and scintillation effects on DFMC GBAS. The DFMC GBAS testbed consists of the ground and airborne mock-ups. The ground mock-up was first installed at the Sendai Airport, Japan, and then relocated to the New Ishigaki Airport in 2019 by replacing the GAST D ground experimental prototype used in the GAST D SARP’s validation activities. The airborne mock-up was developed based on the GAST D airborne experimental system.

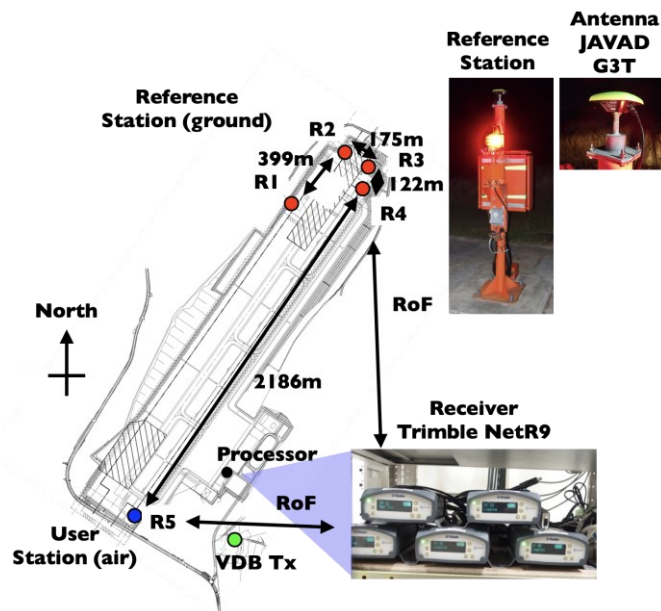


Figure 1. Layout of components of the DFMC GBAS ground mock-up at New Ishigaki Airport.

2.3 The DFMC GBAS ground mock-up consists of five ground GNSS stations. Each station consists of a JAVAD GrAnt G3 antenna and a Trimble NetR9 receiver. The receivers are placed in the equipment room together with the data processor. The receiver and antenna pair is connected with an optical fibre with EO/OE converters on each side. The layout of the reference stations is the same as the GAST D ground experimental prototype. Four reference stations are located around the end of RWY 22 and used primarily to generate GBAS augmentation information. Another one is located around the end of RWY 04 (Fig. 1) and used primarily as a pseudo-user. The VDB transmitter is located in the communication/radar station just outside the New Ishigaki Airport

2.4 The DFMC GBAS ground mock-up software is designed to be able to test different architectures. It can generate Message Types (MTs) 42 and 50 proposed in the SESAR GAST F. MT-23 proposed in the GAST X can also be generated.

2.5 The hardware of the DFMC GBAS airborne mock-up is the same as the GAST D airborne experimental subsystem. The GNSS receiver is the JAVAD Delta G3T. The VDB receiver is the Telerad RE-9009A. They are installed on the Beechcraft B300 King Air “Yotsuba” (Fig. 2). The software of the DFMC GBAS airborne mock-up was developed based on the GAST D airborne experimental subsystem software. It can be operated in the GAST C, D and SESAR GAST F modes. It will be upgraded to be able to be operated in the GAST X mode.



Figure 2. The experimental aircraft of ENRI, Beechcraft B300 King Air “Yotsuba”.

2.6 The DFMC GBAS testbed at the New Ishigaki Airport is supported by multiple ionospheric observation instruments (Fig. 3). An all-sky airglow imager (ASI) which is located at about 15 km west of the airport can detect optical emissions from the atoms and molecules of the atmosphere. Emissions at 630.0 and 777.4 nm can be observed by the ASI to observe the ionospheric electron density distribution at about 250 and 350 km, respectively. Four ionospheric scintillation receivers are installed in the Ishigaki Island. One of the scintillation receivers is co-located with the ASI. Other three receivers are located at about 11 km southeast of the airport with mutual separation of several hundred meters by which ionospheric irregularity movement as well as the ionospheric delay gradient. Additional scintillation receiver is planned to be installed at the New Ishigaki Airport by sharing one of the ground reference station antennas.

2.7 The first data collection campaign was conducted around the New Ishigaki Airport in February 2020. Because all the flights were made in the daytime and the geomagnetic activity was low, the ionospheric conditions during all the flights were quiet. To obtain data under disturbed ionospheric conditions, a flight data collection campaign including flights in the nighttime was conducted. The Plasma bubble which is the primary cause of steep ionospheric gradients in the low latitude region often occur in the period from the sunset to the midnight in the equinox seasons in Ishigaki. Therefore, the second flight data collection campaign was conducted from 8 to 10 March 2022.

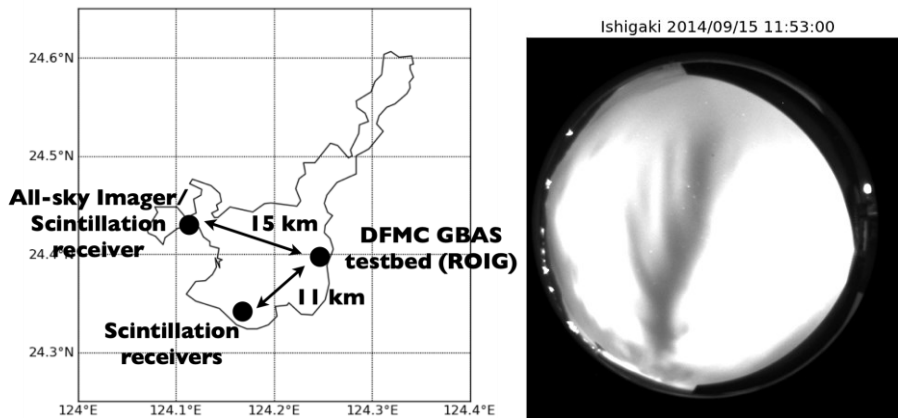


Figure 3. DFMC GBAS testbed and supporting instruments for ionospheric observation and an example of the plasma bubble images taken by the all-sky imager.

2.8 Because the DFMC GBAS concept and architecture has not been finalized yet, the DFMC GBAS ground mock-up was operated without online GBAS message generation and only to collect GNSS data. Thus, the airborne mock-up was also operated only to collect GNSS data in the airborne condition.

2.9 Two flights, one in the daytime and another in the nighttime, were made every day. Five approaches were made during each flight, and data from 30 approaches in total were collected. Fig. 4 shows the flight trajectories of the flights in the daytime and nighttime on 8 March 2022. They are almost the same on the other days. The approach direction was limited to the RWY-04 in the daytime which was the runway direction in operation. In the nighttime, we could use both the runway directions. Although all the flights were made without technical problems and data were all successfully obtained, ionospheric conditions were quiet throughout the campaign. Fig. 5 shows the scintillation activities (S4 index) during the nighttime flight on 8 March 2022. It was almost the same on the other days.

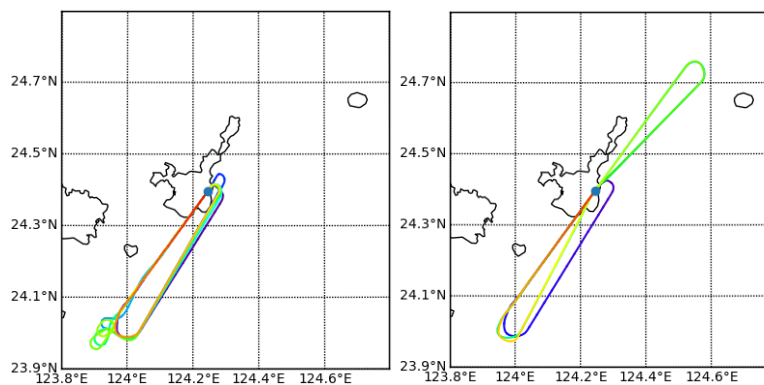


Figure 4. Trajectories of the flights on 8 March 2022 in the daytime (left) and nighttime (right). The color of the trajectory indicates the progress of flight from the departure (blue) to the end (red).

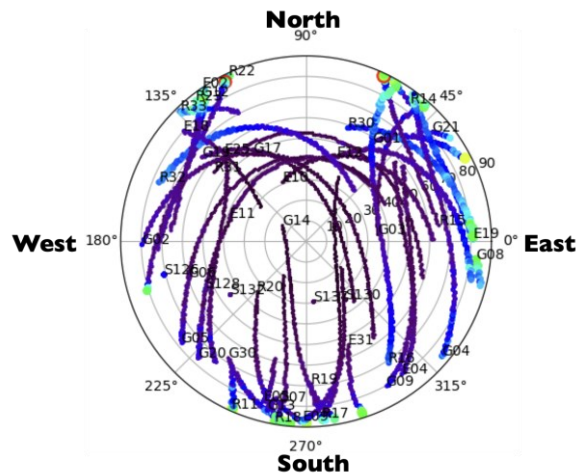


Figure 4. S4 indices during the nighttime flight at the ASI site on 8 March 2022. The width and color of the satellite trace indicate the S4 index from 0 (black) to 1.0 (red).

2.10 Although we could not obtain flight data under disturbed ionospheric conditions, the obtained data are still useful as basic data under the nominal ionospheric conditions in the airborne dynamic environment.

2.11 To obtain data under disturbed ionospheric conditions, additional flight data collection campaigns are planned in October 2022 and March 2023. The campaign in October 2022 is planned for two weeks to increase the probability to encounter disturbed ionospheric conditions. Design of the campaign in March 2023 is subject to the results of the October 2022 campaign. The results will be shared with the GWG and will offered for discussion in the IGM and DFMC GBAS Concept ad hoc groups.

2.12 GAST-D performance enhancement in challenging ionospheric conditions such as the low latitude region is of great interest of Japan. ENRI has been contributing to the GWG IGM ad hoc activities. Main focuses are scintillation effects on the GAST-D integrity monitors and better ionospheric threat definition. Ionospheric gradient data collection is being conducted in collaboration with research institutes and organizations in Indonesia, Thailand and Vietnam.

Advanced operations enabled by GBAS

2.13 Electronic Navigation Research Institute (ENRI) has been working on advanced operations by GBAS. Flight demonstration of RNP to GLS APCH were conducted at Hiroshima airport (HIJ) in April 2021 with a portable GBAS equipment. Path length and fuel consumption were reduced as compared with the conventional approach. Flight demonstration of GLS steep glide slope and offset approach at Takamatsu airport (TAK) were conducted in November 2021 (Fig. 5). Airlines received a good impression on the demonstrated approach procedure which would enhance accesses to the airport.

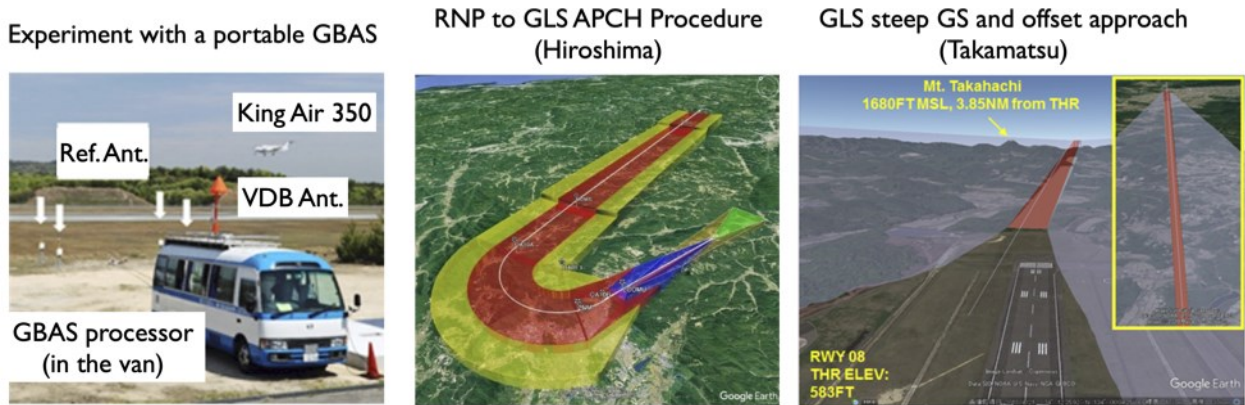


Figure 5. RNP to GLS APCH flight demonstration.

2.14 A new project of ENRI was launched from April 2022 to study advanced operations enabled by GBAS. The objectives include improved surface operations in the low visibility condition, effective runway operations and reduced environmental load by using GBAS-specific function, and GBAS CRM (collision risk model) development for future procedure design to support introduction of precision approaches to a runway where it is difficult to set ILS approaches. The project consists of the following four research subjects:

- Development of fundamental operational concepts for increased glide path approaches and secondary runway aiming point operations applying to specific airports in Japan utilizing GBAS,
- Development of an operational concept and a testbed of pilot support tool for runway exit and taxi guidance using GBAS functions,
- Development of the CRM and improved OAS (Obstacle Assessment Surface) for GBAS, and
- Evaluation of reduced runway occupation time with GAST D where ILS equivalent CSA is not required in congested airports such as RJAA by using “GRACE” (a fast time simulator of airport surface traffic) developed by ENRI.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

- a) Note the information contained in this paper; and
- b) Discuss any relevant matters as appropriate.
