[EN-A-031] Interoperability of ENRI GAST-D Prototype with Different Airborne Software Implementations

(EIWAC 2017)

+S. Saito*, M. Stanisak**, T. Yoshihara*, T. Feuerle**, A. Lipp***

*Navigation Systems Department
Electronic Navigation Research Institute (ENRI)
Tokyo, Japan
[susaito |yosihara]@enri.go.jp

** Institute of Flight Guidance
TU Braunschweig
Braunschweig, Germany
[t.feuerle |m.stanisak]@tu-braunschweig.de

*** EUROCONTROL Experimental Center
Bretigny-sur-Orge, France
andreas.lipp@eurocontrol.int

Abstract: GBAS interoperability trials conducted in Ishigaki, Japan in June 2016. Interoperability of different implementation of GBAS airborne equipment/software including TU Braunschweig software (TriPos), ENRI software, Pegasus, and Thales MMR prototype were tested against GAST-D ground experimental prototype developed by ENRI and manufactured by NEC. Although some differences were observed in protection levels, which is considered to be due to satellite selection strategies, position solutions and course deviations were in good agreement between different implementations and interoperability was successfully demonstrated.

Keywords: Ground-Based Augmentation System (GBAS), GBAS Approach Service Type-D (GAST-D), Interoperability, Low latitude ionosphere

1. INTRODUCTION

he Ground-based augmentation systems (GBAS) is now globally used for Category-I approach operations. For Category-II and III operations with GBAS, which is called GBAS Approach Service Type-D (GAST-D), new international standards (SARPs) [1] have been finalized by the Navigation Systems Panel (NSP) of International Civil Aviation Organization (ICAO) in December 2016 and are in the process of publication in November 2018.

To contribute to the operational validations of the GAST-D SARPs, Electronic Navigation Research Institute (ENRI) has developed a prototype of GAST-D ground subsystem and installed it at New Ishigaki Airport, Japan [2]. It was designed based on the development baseline SARPs for GAST-D [3], which was defined for operational validation and different from the final version of GAST-D SARPs. Since the integrity requirements are assured not only by a ground subsystem but also by an airborne subsystem, ENRI also has developed a GAST-D experimental airborne system, and conducted flight trials successfully in different ionospheric conditions [4].

Interoperability between different combinations of ground and airborne subsystems is one of the important aspects of the operational validation of GAST-D SARPs, because it ensures that different ground and airborne manufacturers interpret the SARPs in the same way. Interoperability between a ground facility mockup of Multi-Constellation/Multi-Frequency (MC/MF) GBAS, which is a further generation GBAS and includes GAST-D capability, developed by TU Braunschweig (TUBS), and different airborne software/receivers including ENRI's one has been successfully demonstrated in trials conducted at Toulouse Airport, France in May 2016 in the frame of SESAR 15.3.7 [5,6].

To demonstrate interoperability between the ENRI's GAST-D ground prototype and airborne software/receivers, another interoperability trial was conducted in June 2016 at Ishigaki, Japan in the same frame as the interoperability trials conducted at Toulouse. This paper presents results of this interoperability trial.

2. EXPERIMENTAL SETUP

The Interoperability trials between ENRI's GAST-D ground prototype and airborne software/receivers were conducted from 21 to 24 June 2016 at Ishigaki, Japan. Measurements were made only in daytime due to limited access to the test site. The airborne software/receivers included a Multi-Mode Receiver (MMR) GAST-D capable prototype developed by Thales, TUBS airborne software (TriPos), and ENRI's airborne experimental system (ENRI-Airbone). Raw data recorded by a GNSS receiver and a VDB receiver were later analyzed offline by the Pegasus tool developed by EUROCONTROL.

All the airborne subsystems were connected to a stationary fixed GNSS antenna on the ground. The GNSS antenna (Trimble Choke-ring antenna) was placed at the Japan Civil Aviation Bureau's aeronautical communications transmitting site near the New Ishigaki Airport. It is about 2 km south-west from the GBAS reference point of the GAST-D ground prototype.

Since it was outside the PAR (precision approach region) of the two approaches of the runway of the airport which are usually served by GBAS final approach segments (FASs) in GBAS message type-4, an additional virtual approach was set up so that the airborne users are inside the PAR of this approach. Figure 1 shows the geometry of virtual approach path, PAR associated with the path, and user GNSS antenna for measurement. Since the measurements were made in daytime and geomagnetic conditions were quiet throughout the period of the trial, there were no severe ionospheric disturbances such as plasma bubbles during the trial.

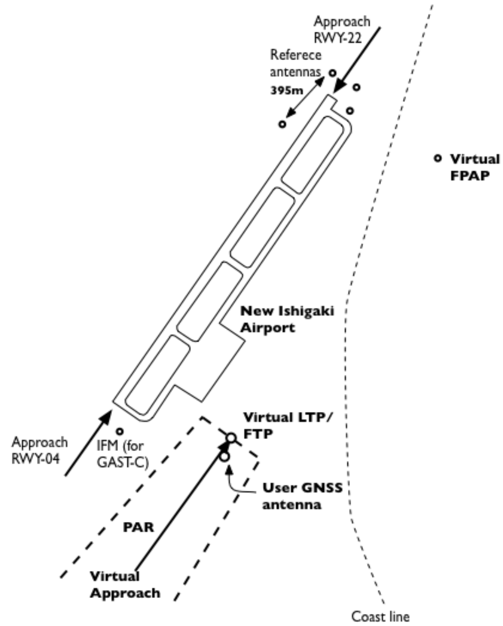

Figure 1. Geometry of measurements at New Ishigaki Airport.

Table 1. Parameters of airborne data analysis.

Parameter	Meaning	Value
AAD	Aircraft Accuracy Designator	B
$CN_{0,min}$	Minimum Carrier-to-Noise density	33 dBHz
θ_{min}	Minimum satellite elevation angle	5º
σD_V	Standard deviation of D_V	0.3 m
σD_L	Standard deviation of D_L	0.3 m
maxSvert	Largest allowed value of the local vertical component of the projection matrix	3.5
maxSlat	Largest allowed value of the local lateral component of the projection matrix	3.5
maxSvert2	Maximum sum of the two maximum absolute values of the local vertical component of the projection matrix	4.5
maxVAL	Largest allowed vertical alert limit	10
maxLAL	Largest allowed lateral alert limit	40

3. ANALYSIS

In this analysis, TriPos, ENRI-Airborne, and Pegasus were used to analyze the same GNSS data (recorded by a Javad

Delta receiver) and VDB data (recorded by a Telerad receiver). To have equal analysis conditions as much as possible, all these GAST-D airborne processing tools used an identical set of parameters as shown in Table 1.

According to the latest standards for GBAS airborne subsystem (DO-253D) [7], maxSvert2 in Table 1 is related to E_{IG}. However, it was explicitly given, because ENRI's GAST-D ground experimental subsystem was designed according to the development baseline SARPs [2] before the E_{IG} parameter was introduced.

As a reference, the position of the user GNSS antenna was determined by a kinematic analysis with an accuracy of about 1 cm.

4. RESULTS AND DISCUSSION

4.1 Deviation outputs

Figure 2 compares the vertical and lateral guidance outputs (DDM values) derived by the three different software tools. Besides some minor differences, the results are in good agreement with each other. This means that all the receiver software tools processed GBAS corrections as intended and obtained very similar GBAS solutions. The experimental GAST-D MMR by Thales also output consistent results, though the data are not shown here.

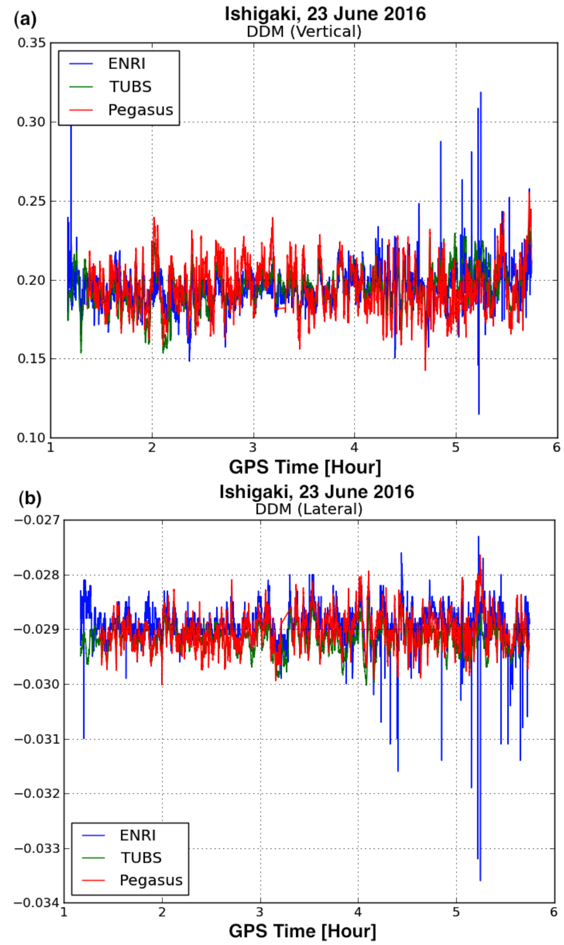

Figure 2. (a) Vertical and (b) lateral DDM values, respectively derived by ENRI-Airborne, TriPos, and Pegasus software for the data on 23 June 2016.

4.2 Position solutions with different smoothing time constants

As one of GAST-D specific outputs, Figure 3 compares the vertical components of position solution differences with two different smoothing time constants (100 and 30 seconds, D_V). D_V values derived by the three receiver software tools were in good agreement.

4.3 Protection levels

Figure 4 compares the vertical protection levels (VPL) derived by the three receiver software tools. In contrast to the vertical and lateral DDM values, there are noticeable differences, though the trends are similar. In addition to bias-type differences in VPL, ENRI-Airborne output spikes in VPL. Some differences in VPL are expected, because, different from position solutions and hence DDM values, VPL depends on the GAST-D airborne parameters, satellite selection strategy including re-admittance, algorithm and thresholds of integrity monitors that may exclude satellites. In addition, ENRI's ground and airborne experimental subsystems support SBAS GEO as a ranging source, while the other tools do not support this. Indeed, MSAS GEO (MTSAT-2) was tracked and used throughout the trials.

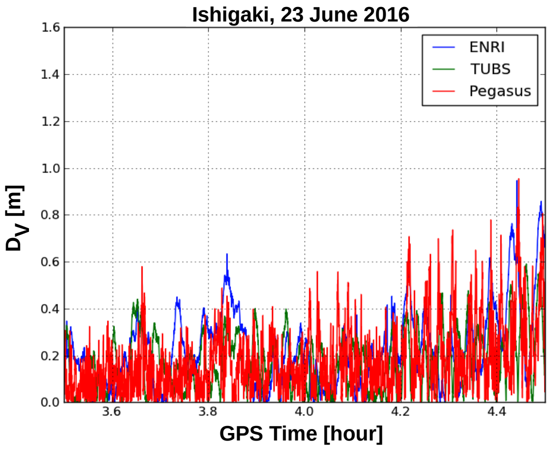

Figure 3. D_V values generated by derived by ENRI-Airborne, TriPos, and Pegasus software for the data from 03:30 to 04:30 GPST on 23 June 2016.

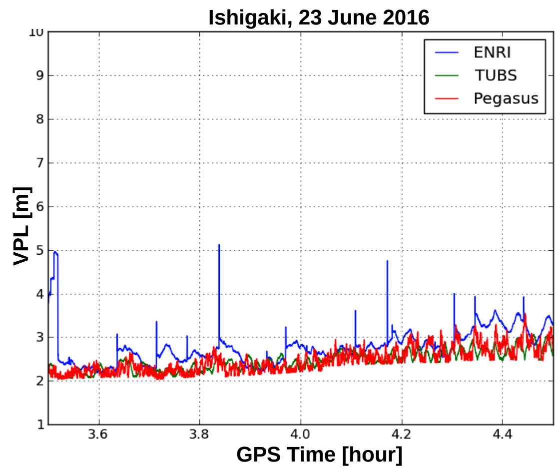

Figure 4.VPL values generated by derived by ENRI-Airborne, TriPos, and Pegasus software for the data from 03:30 to 04:30 GPST on 23 June 2016.

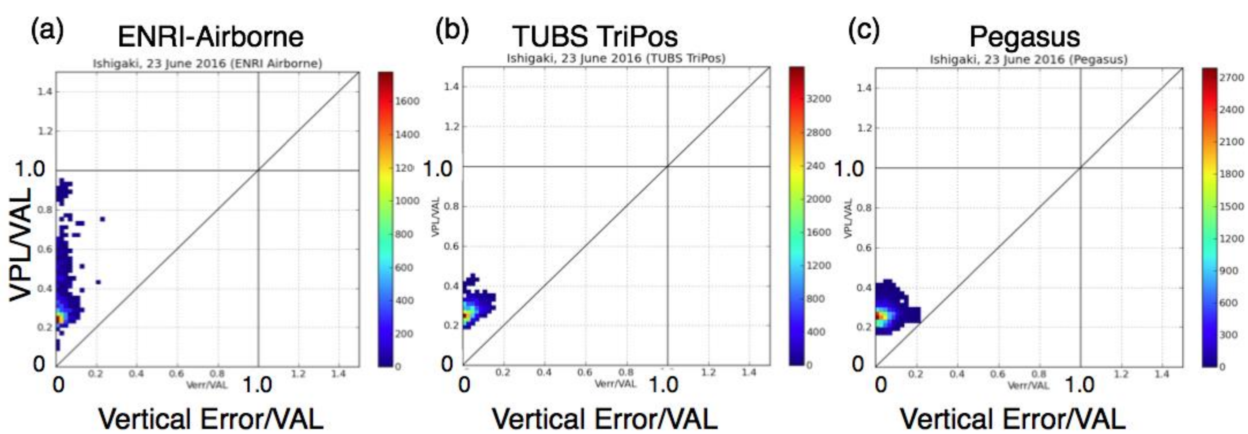

Table 2. Interoperability demostrated in this trial.

Airborne / Ground	ENRI Airborne Experimental system	TUBS TriPos Software	Pegasus Software	Thales MMR Prototype
ENRI GAST-D (manufactured by NEC)	Ground tested at New Ishigaki Airport	Ground tested at New Ishigaki Airport	Ground tested at New Ishigaki Airport	Ground tested at New Ishigaki Airport

4.4 Integrity and availability

Figure 5 shows the normalized vertical integrity diagrams (“Stanford Chart”) derived by the three receiver software tools. TriPos showed the smallest distribution with no integrity failure and no availability loss. Pegasus showed a similar distribution as TriPos with slightly wider distribution. Pegasus had no integrity failure and availability loss, too. ENRI-Airborne showed vertically elongated distribution of data points, which correspond to the spiky VPL. However, the core part of the distribution is similar to TriPos and Pegasus. Agreeing with other results, ENRI-Airborne had no integrity failure and availability loss, too.

5. CONCLUDING REMARKS

Good overall agreements between different implementations were obtained. Deviations and position solution differences with different smoothing time constants (D_V) were in very good agreement. Thales MMR prototype also showed consistent results. VPL values showed some differences, which is considered to be due to different implementations of satellite selection strategy, integrity monitor design, and usage of SBAS GEOs. However, all tools resulted in very good overall integrity and availability. The interoperability of different receiver implementations (ENRI-Airborne, TriPos, Pegasus, and Thales MMR prototype) against ENRI's GAST-D ground experimental subsystem was successfully demonstrated as summarized in Table 2.

6. ACKNOWLEDGMENTS

This work presented in this paper has been funded by EUROCONTROL in the fame of contracts between EUROCONTROL and TU Braunschweig. The experiment in Ishigaki, Japan was technically supported by Japan Civil Aviation Bureau.

7. REFERENCES

[1] ICAO NSP Flimsy 17, "Proposed Amendment to International Standards and Recommended Practices, Aeronautical Telecommunications, Annex 10 to the Convention on International Civil Aviation. Volume I (Radio Navigation Aids)". Montreal, Canada, November-December, 2016.

[2] ICAO, GBAS CAT II/III Development Baseline SARPs, 2010.

[3] T. Yoshihara, S. Saito, A. Kezuka, S. Fukushima, and S. Saitoh, Development of a CAT-III GBAS (GAST-D) ground subsystem prototype and its performance evaluation with a long term-data set, Proceedings of the 5th International Workshop on ATM/CNS (EIWAC2017), November 2017.

[4] S. Saito, T. Yoshihara, A. Kezuka, S. Saitoh, S. Fukushima, and Y. Otsuka, GAST-D Flight Experiment Results with Disturbed and Quiet Ionospheric Conditions, Proc. ION GNSS+ 2015, 1494–1499, 2015.

[5] T. Feuele, M. Stanisak. S. Saito, T. Yoshihara, GBAS Interoperability Trials and Multi-Constellation/Multi-Frequency Ground Mockup Evaluation, Proceedings of the SESAR Innovation Days (2016) EUROCONTROL. ISSN 0770-1268.

[6] T. Feuele, M. Stanisak. S. Saito, T. Yoshihara, GBAS Interoperability and Multi-Constellation/Multi-Frequency Trials, Proceedings of the 5th International Workshop on ATM/CNS (EIWAC2017), November 2017.

[7] RTCA/DO-253D, Minimum operational performance standards for GPS local area augmentation system airborne equipment, July 13, 2017.

7. COPYRIGHT