International Civil Aviation Organization

NINETEENTH MEETING OF THE COMMUNICATIONS/NAVIGATION AND SURVEILLANCE SUB-GROUP (CNS SG/19) OF APANPIRG

Bangkok, Thailand, 20 – 24 July 2015

Agenda Item 5.3 **Review outcome of Fifth Meeting of Ionospheric Studies Task Force (ISTF/5)**

OUTCOMES OF ISTF/5

(Presented by Secretariat)

SUMMARY

This paper presents the outcomes of the 5th Ionospheric Study Task Force meeting held in Ishigaki, Okinawa, Japan from 16 to 18 February 2015.

1. INTRODUCTION

1.1 The Fifth Meeting of Ionospheric Studies Task Force (ISTF/5) was held in Ishigaki, Okinawa, Japan from 16 to 18 February 2015.

1.2 The meeting was attended by 21 participants from 6 States (China, India, Japan, Malaysia, Thailand, USA), 1 Regional Organization (Eurocontrol) and 5 Industry organizations (Boeing, UK NATS, Honeywell, Indra Navia, Thales).

1.3 The session of the Meeting on 16 February afternoon (webconference) was attended by 24 Participants from 8 States (Australia, China, India, Japan, Malaysia, Philippines, Thailand, USA), 1 Regional Organization (Eurocontrol) and 4 Observers from Industry. A list of participants is provided at Attachment 1.

1.4 The report of the meeting is available here: http://www.icao.int/APAC/Meetings/Pages/2015-ISTF5.aspx.

2. DISCUSSION

Progress of Task 1 - Data Collection

2.1 The meeting was informed about the current status **Task 1 - Data Collection** based on AATR analysis of ISTF data (status as of February 2015):

Contribution by	Data Period	Data Format	Analysis Status
India	Mar., Jun., Sep., Dec., 2004 Mar., Jun., Sep., Dec., 2008 Mar., Jun., Sep., Dec., 2012	GAGAN-TEC	AATR generation being done by India

Contribution by	Data Period	Data Format	Analysis Status
Japan	TBD	RINEX/GTEX	To be transferred to ISTF server
Hong Kong	Land Department; Oct. 2000 – Dec. 2009 01 Oct 2012 HKIA: Jul. 2010 – Aug. 2013	 NovAtel Binary RINEX RINEX	 Being converted to RINEX - AATR generation in progress
Philippines	20081011 20100405 20100803 20100804 20110528 20110605 20110805 20110806 20110926 20111024 20111025 20120309 20120312 20120315 20120424 20120616 20120709 20120715 20120716 20121001 20121008 20121009 20130317 20130601 20130629 20131002	GTEX0.1	GTEX to AATR conversion tool under development
Singapore	13-27 Mar. 2013 01 Jun. 2013 02 Oct. 2013 16-30 Sep. 2013 22-29 Oct. 2014	RINEX	AATR being generated
Thailand	VTBS: 2011-2013 VTCC: 2012-2013 VTPP: 2013 VTSB: 2009-2013 VTSS: 2010-2013	NovAtel Binary	Being converted to RINEX
APEC GIT	Jul. 2006 – Jan. 2007	APEC GIT specific binary	To be decoded by MATLAB program provided by APEC GIT

Progress of Task 2 - Iono Analysis

Along-Arc TEC Rate (India)

2.2 India explained that the AATR (Along-Arc TEC Rate) parameter identifies the regional irregularity and would be useful for data mining by all associated ISTF member states. India in collaboration with Japan and Australia explained the process adopted for testing and verification of AATR generation tools developed independently by Japan and India and recommended ISTF to examine the methodology for testing and verification and the results of AATR tool for its use in regional Ionospheric work.

2.3 India has generated the AATR from the GAGAN-TEC data for the year 2004, 2008 and 2012 and has analysed the data. The extreme dates have been identified for each year and for each receiver of GAGAN-TEC network and are provided as attachment- Appendix A with the paper. Since the extreme conditions are rare in nature, the 99.7th percentile of AATR is also estimated.

2.4 The ISTF/5 meeting agreed that the AATR parameter can be used to locate ionospheric events.

Single-frequency carrier-based and code-aided method (ENRI)

2.5 ENRI developed a method to estimate ionospheric delay differences between two GNSS receivers based on single-frequency carrier-phase and code measurements, which is called "single-frequency carrier-based and code-aided (SF-CPCA) method. Performance of the SC-CPCA method was tested with the data from the GBAS reference receivers installed at the New Ishigaki Airport. The ratio of epochs when fixed solutions were obtained to all the epochs (fix rates) were compared for different position errors artificially added to the well-surveyed positions. It was found that relative position accuracy of 1.5 cm is required to obtain fix rates greater than 95 %.

LTIAM (USA)

2.6 LTIAM uses dual frequency TEC and has an inter-frequency bias, this bias being estimated, while ENRI's method is based on estimates using one single frequency. This method can be free from bias.

2.7 The meeting considered both analysis methodologies as candidate methods to derive GBAS ionospheric threat model.

GBAS Iono Monitoring Assessment (Eurocontrol)

2.8 Eurocontrol reported about their programme GBAS Iono Monitoring Assessment that is composed of Data selection, RINEX processing, automatic gradient screening and selection, Validation and Gradient validation. LTIAM was significantly modified with additional steps of processing introduced. LTIAM tool has been used by Eurocontrol for SBAS and GBAS since mid-2012. 2 years of data were processed from 7 European sites, and monitoring will be performed until mid-2016, based on the current program scope. A list of potentially iono gradient threats (station pair, PRN, date, maximum gradient, elevation angle), gradient speed of selected gradients and eventually the iono mitigation models are the expected outcomes. A high number of potential iono gradients were identified, losses of lock were excluded and further work was be needed to select the cases to investigate as not all could be processed manually. Eurocontrol explained that so far very few iono gradients were identified in the Canaries Islands.

2.9 A long-term ionospheric anomaly monitoring (LTIAM) was needed by USA to build an Ionospheric threat model, monitor ionospheric anomalies over the system life cycle, verify CAT I threat model, and trigger updates if needed. The LTIAM tool was borne.

2.10 The version 2.1 was made available to IGWG participating members in 2012. The other current LTIAM users: are USA and Eurocontrol. The same version of the tool and supporting documents are made available to the ISTF group members once an approval from FAA is obtained: LTIAM user manual, LTIAM Algorithm Description Doc v2.1, LTIAM-2.1 (zip file)

Task 5 - Iono Models

SBAS threat model (ENRI)

2.11 A brief explanation of the ionosphere threat model developed for WAAS/MSAS to enhance development of threat models for Equatorial Regions was introduced. Each SBAS provider needs to develop ionosphere threat model applicable within its service volume based on observation data in past and/or some ionosphere disturbance models. Augmentation systems need to generate ionospheric corrections: fitting into the message structure defined by SARPS; accurate enough to improve position accuracy; and meeting integrity requirements.

2.12 Japan's experience is that the major concern for vertical guidance is ionospheric anomalies. En-route thru NPA modes is available at the whole Fukuoka FIR. APV-I is not always available: 95% at the center of Japan and less than 50% at Okinawa islands (Including Ishigaki Island) because of large protection levels due to the large uncertainty of ionospheric errors: the ionospheric term (GIVE, grid ionosphere vertical error) is the dominant component of the Vertical Protection Level. The availability of vertical guidance of MSAS is therefore lowered by the ionospheric term.

2.13 For SBAS, ionosphere propagation delay must always be overbounded by GIVE information broadcast along with vertical delay.

2.14 The objective set by the TOR of ISTF is the development of Regional Ionospheric Threat Models for SBAS if the need is identified. The meeting confirmed that the need is identified. The Task Force needs to develop SBAS ionosphere models including spatial and temporal threat representations acceptable for participating States/Regions.

2.15 With regard to the terms of reference to "develop SBAS ionosphere models including spatial and temporal threat representations acceptable for participating States/Regions" and due to the different distributions of ground networks and other factors, the model cannot be common for SBAS. The common part could be about the methodology. The same methodology using data deprivation can be applied for all SBAS threat model. A guidance material is needed for the safety case for using SBAS services in the APAC region: how to mitigate operational hazards related to the ionospheric threats.

2.16 The meeting identified therefore 6 steps to complete the Task 5 for SBAS:

1. Identify the operational hazards related to the ionospheric threats for SBAS;

2. Identify factors influencing the mitigation strategy (ground stations distribution, iono model used, etc.);

3. Identify common threats (independent of any particular iono model) such as temporal and spatial threats;

4. Identify requirements for the threat model (such as: level of overbounding of ionospheric errors);

5. Develop a methodology to generate threat mitigation models;

6. Optionally, develop a tool for generating the threat model; and

2.17 Steps 1 and 2 should start immediately. Following actions were raised:

GBAS threat model (ENRI)

2.18 This paper introduced briefly the ionosphere threat model for GBAS (Ground-based Augmentation System). There are two kinds of ionospheric effects on GBAS. The first is ionospheric delay spatial gradient, which sometimes produces significant ranging errors. As the second, scintillation effect reduces available ranging source through loss of lock in signal tracking. It could reduce GBAS availability. GBAS messages are designed to mitigate effects of ionospheric spatial gradient under nominal conditions. However, it is required to detect and exclude anomalous ranging sources with unacceptable error under abnormal ionospheric conditions.

2.19 Threat model describes characteristics of the ionosphere from a view point of risks and defines the range of parameters that should be taken into account in designing a GBAS. It is needed to develop ionosphere threat model(s) considering dominant ionospheric phenomena in each region (SED, plasma bubbles, nominal conditions).

- Nominal condition: GBAS broadcast parameter of evaluation for remained ionospheric error (σ iono);

- Abnormal condition: Detect and exclude affected ranging sources; and

- Ionospheric phenomena: SED and Plasma bubble

2.20 The meeting discussed that there would probably be 2 sets of parameters for the APAC region for GBAS. A magnetic latitude would be used to segregate the areas of application of the models. The States would use this criterion to determine which model to use.

2.21 Prediction activities are not in the scope of ISTF, but the probability of gradients will be estimated.

2.22 The meeting identified 5 steps to complete the Task 5 for GBAS:

Using the draft GAST D SARPS guidance as a reference,

1. Identify the operational hazards related to the ionospheric threats for GBAS;

2. Identify factors influencing the mitigation strategy for GBAS in addition to parameters referenced in the GBAS related SARPS guidance material (such as occurrence probability, number of simultaneously influenced satellites, etc.)

3. Summarizing the iono characteristics of the APAC region (SED, plasma bubbles, optionally nominal ionosphere) for 2 sets of parameters in the APAC region;

4. Recommend/develop tool(s) for generating the threat model; and

5. Develop a methodology to generate the threat model.

The meeting agreed that Dr. Yoshihara, Task Lead/Task-5 for GBAS would be responsible for conducting the 5 steps.

GBAS Brazilian Ionospheric Threat Model Project

2.23 Ionospheric activity in equatorial regions (within 25 degrees latitude of the geomagnetic equator) is known to be significantly more variable and more intense than what is encountered in mid-latitude regions such as CONUS. The goal was to develop a new model for Brazil.

2.24 The threat points were identified with the LTIAM tool. A second phase of validation was however needed to those that are actual ionospheric events. The comprehensive analysis supports that multiple satellite-station pairs were impacted by the same EPB in different times and locations. Extreme ionospheric gradient candidate of interest were finally validated to be real. Gradients above 500 mm/km should be validated using the proposed methodology while developing an ionospheric anomaly threat model for GBAS operation in the Brazilian region.

Chennai GPS Iono Data Analysis

2.25 The meeting was informed about the Chennai GPS Iono Data Analysis, showing gradients up to 311 mm/km.

2.26 The meeting established the following draft decision:

Draft Decision 5/1 - Need for ionospheric threat models in the APAC region

That, considering that extreme ionospheric gradients were observed in the APAC region through data collection, and in Brazil likewise, the need for GBAS threat model is confirmed**.** Considering the various factors such as variable ground stations network layouts and service levels, guidance for establishing a SBAS iono safety case model is needed**.**

f/ Task 6 - Space Weather

Space Weather Report about discussions in the MET group (SP/06, Japan)

2.27 An update on Task 6 -Space Weather was made by Japan. ISTF/4 discussed that the influence of equatorial event should be more emphasized in the draft ConOps. Consequently, during IAVWOPSG/8 in February 2014, IFALPA and Japan on behalf of the Asia-Pacific Ionospheric Studies Task Force provided the group with additional comments and information that were duly noted. During the ICAO/Met divisional meeting held in July 2014 the number of centres that would provide space weather information services serving international air navigation was discussed. Global centres could inform about solar radiation storms and solar flares, as well as for geomagnetic storms and ionospheric disturbances at the predictive stage and be augmented by an optimal number of regional centres for geomagnetic storms and ionospheric disturbances at the observation stage. There was an agreement that the optimal organization along with the roles, requirements and capabilities should be determined only after having clarified the service requirements and capabilities.

Joint session with ICAO NSP CSG

- *ISTF opines that there should be mitigation of iono effects for SBAS and GBAS, what are CSG views concerning GBAS system?*

2.28 CSG views are that this effort was undertaken 15 years ago with GAST-C, and it is felt necessary to mitigate iono effects. The question is rather how, and what additional mitigation beyond basic standard, based on regional threat characterization, should be implemented.

2.29 It was discussed that it would be more efficient to have models adapted to low/mid/high latitudes. There should be no or few impact on avionics.

- *How manufacturers see the need for and the feasibility to implement iono mitigation models*

2.30 In-service experience data, stored by recording capabilities on the ground would contribute efficiently to the safety cases. A guidance material for that purpose would be helpful.

2.31 From the manufacturers' perspective, a threat model of GBAS is needed. The threat model could be incorporated in the guidance material for GAST. It should be compatible with the GAST-D interface as much as possible.

2.32 Different models would be created for SBAS and GBAS. However a common methodology (for data to be collected and analyzed) would be helpful and harmonization through ICAO regions could be needed at a later stage.

2.33 Vigilance activities and keeping the models valid would need a longer term commitment. It was suggested that the prediction of ionospheric gradients/losses of lock could be part of the user requirements for the future space weather services. An initial coordination with IAVWOPSG could take place under Task 6 of ISTF.

3. ACTION BY THE MEETING

3.1 The meeting is invited to:

a) note the information contained in this paper;

b) discuss and adopt the draft decision in para 2.26; and

c) discuss any relevant matters as appropriate.

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