INTERNATIONAL CIVIL AVIATION ORGANIZATION
ASIA AND PACIFIC OFFICE

REPORT OF

SIXTH MEETING OF IONOSPHERIC STUDIES TASK FORCE (ISTF/6)

Bangkok, Thailand

(19 - 21 January 2016)

The views expressed in this Report should be taken as those of the Meetings and not the Organization.

Approved by the Meeting
and published by the ICAO Asia and Pacific Office, Bangkok

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PART I – HISTORY OF THE MEETING

1. Introduction

1.1 The Sixth Meeting of Ionospheric Studies Task Force (ISTF/6) was held at the ICAO Asia and Pacific Office, Bangkok from 19 to 21 January 2016.

2. Attendance

2.1 The meeting was attended by 28 participants from 10 States/Administrations (Australia, Cambodia, China, India, Indonesia, Japan, Philippines, Singapore, Thailand, and USA), 3 International Organizations from NEC, KAIST, and MITRE. List of participants are provided at **Attachment 1** to this Report.

3. Opening of the Meeting

3.1 On behalf of Mr. Arun Mishra, the ICAO Deputy Regional Director, Mr. Yoshiki Imawaka, ICAO Deputy Regional Director of the ICAO Asia and Pacific Office, welcomed the participants to the meeting.

3.2 Mr. Yoshiki Imawaka recalled the importance of ISTF deliverables for the aviation community, insofar as the models being finalized would help to protect PBN procedures from anomalous ionospheric conditions. There was also an important objective to transfer the work done from research/development to every day's operations, which could not happen without the industry. 2016 is an important year for PBN as it is the final year for States/Administrations to comply with assembly resolution A37-11, specifically in the approach segment where APV approach (Baro-VNAV and GNSS-augmented) should be implemented at all instrument runway ends. GBAS will become a priority as we will be entering ASBU Block 1 in 2018 and should be implemented everywhere it is economically beneficial. 2016 is also an important year as it should see the starting of adoption of GAST-D specifications, gradually making of GBAS a system enabling all categories of operations at airports. The major reason for ISTF to deliver with no delay was the GBAS operations and trials ongoing in APAC States, including Australia, China, India and Japan. Lastly, Mr. Imawaka stressed that the potential contribution of this Task Force to the map of space weather services could help to mitigate space weather effects on CNS systems, which would have to be further coordinated with the Meteorology Panel (METP) and WG-MISD.

4. Officers and Secretariat

4.1 The ISTF meeting was chaired by Dr. Susumu Saito, Chairman of the Task Force. Mr. Frédéric LECAT, Regional Officer, ICAO APAC Office was the Secretary of the meeting.

5. Working Arrangements, Language and Documentation

5.1 The ISTF met as a single body. The working language for the meeting was English inclusive of all documentation and this Report. The lists of Working/ Information Papers and Presentations are provided at **Attachment 2** to this Report.

5.2 Three participants attended remotely using webconference with the meeting.

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Agenda Item 1: Adoption of agenda

1.1 The agenda was reviewed and adopted with no change by the meeting as follows:

Agenda Item 1: Adoption of Agenda

Agenda Item 2: Review of outcome of relevant Meetings/Conferences

Agenda Item 3: Review of status of States' activities and ISTF webconferences

Agenda Item 4: Review of deliveries of Tasks and related Action Items

- Task 1 - Data Collection
- Task 2 - Iono Analysis
- Task 3 - TEC Generation
- Task 4 - Scintillation Data
- Task 5 - Iono Models
- Task 6 - Space Weather

Agenda Item 5: Work plan and next meetings toward completion of tasks, and assessment of possibility to disband the Task Force

Agenda Item 6: Any other business

Agenda Item 2: Review of outcome of relevant meetings/conferences

WP/6 - Outcome of the NSP/2 Meeting

2.1 ISTF Chair introduced the outcome of the 2nd meeting of the Navigation Systems Panel (NSP/2) related to ISTF work which was held from 1 to 11 December 2015 in Montreal. In the GBAS working group (GWG) (previously Category-II/III subgroup, or CSG) the validation of the ionospheric gradient monitoring (IGM) was one of the two issues left before the validation of the draft SARPs of GBAS service type-D (GAST-D) that would be finalized for approval of NSP in 2016 for applicability date of November 2018.

2.2 The major issue of IGM was that the tropospheric delay gradient may be a noise to degrade the delectability of the IGM. This was not found until the operational validation of the draft SARPs of the GAST-D was conducted in the world after technical validation was completed. The incorporation of plasma bubbles phenomena which were shown to have large ionospheric gradients exceeding the threat space was also discussed. An ad hoc group on IGM presented possible approaches to address these issues. GWG was of the view that these issues could be addressed, although the validation may require some more time.

2.3 The meeting discussed that IGM does not impact the Category I, but only Category-II/III and that the incorporation of plasma bubbles threat mitigation would be adequately inserted into the guidance material of the GAST-D SARPS.

APANPIRG/26 outcomes

2.4 The meeting was informed that the Twenty Sixth Meeting of the Asia/Pacific Air Navigation Planning and Implementation Regional Group (APANPIRG/26) was held at ICAO APAC Office, Bangkok, Thailand from 7 to 10 September 2015. The meeting was attended by 141 participants from 26 Member States, 2 Special Administrative Regions of China and 5 International Organizations (CANSO, IATA, IBAC, ICCAIA and IFALPA). APANPIRG/26 reviewed the outcomes of the Nineteenth Meeting of the Communications, Navigation and Surveillance Sub-group (CNS SG/19) of APANPIRG held at the ICAO Regional Office, Bangkok, Thailand, from 20 – 24 July 2015 (WP/9). The meeting noted with appreciation the work done and achievements by the SG and those contributory bodies reporting to APANPIRG through the SG. In line with ISTF proposal, APANPIRG agreed to the following conclusions:

Conclusion APANPIRG/26/37 – Need for ionospheric models in the APAC Region

That, considering that extreme ionospheric gradients were observed in parts of APAC Region through data collection, the need for GBAS threat model is confirmed.

Conclusion APANPIRG/26/38 – Standard for exchange and sharing of GNSS data in the APAC Region

That, considering the need for sharing GNSS data to study the ionospheric effects on navigation systems, the SCINTEX and GTEX Formats are adopted as ICAO APAC standard for exchange of GNSS data and these formats be posted on the ICAO APAC Regional Website.

IP/2 - Review of outcome of Relevant Meetings/Conferences Secretariat

2.5 Five webconferences (ISTF#4, #5, #6, #7 and #8) were held over 6 months since ISTF/5 respectively on 19 June, 2 July, 26 August, 24 September and 4 December 2015. The main points addressed were respectively:

- the GBAS threat mitigation strategy;
- the SBAS safety case guidance material, ICAO WG-MISD (MET information and Services Development), collaboration between APANPIRG CNS and MET subgroups, publication and intellectual property of the ionospheric threat models and ISTF Work plan for 2015-2016;
- the status of AATR analysis for data on the ISTF data and use of LTIAM tool;
- the preparation of a document describing high level operational needs of Space Weather to mitigate the effects of space weather on the regional CNS systems and operations and progress of analysis of ionospheric data were discussed; and
- the progress of the document describing high level operational needs of Space Weather to mitigate the effects of space weather on the regional CNS systems and operations and progress of analysis of ionospheric data were discussed.

Agenda Item 3: Review of status of States' activities and ISTF webconferences

WP/2 - Development of a Ground-based Augmentation System (GBAS) Ionospheric Threat Model (GITM) for Singapore

3.1 Singapore presented a summary of an upcoming Joint Research Project between Civil Aviation Authority of Singapore and The MITRE Corporation. The objective is to develop a GBAS Ionospheric Threat Model (GITM) for Singapore using actual ionospheric delay data collected and aiming at characterizing anomalous ionospheric delay gradients. The results obtained from the data processing would be used to generate a dedicated GITM for Singapore. While no schedule was defined yet, the intention was to implement GBAS procedures at all runway ends at Changi airport.

3.2 Singapore wished to compare the GITM with other validated threat models from other locations to provide additional confidence that the model adequately captures the full range of ionospheric behaviors that could affect the GBAS service. The meeting discussed that most data in ISTF were processed with the LTIAM tool, which therefore would not ensure any independence of tools. It was discussed that if time allowed, Singapore would contribute to the work of the Task Force by processing its own data to validate the ionospheric regional threat model. Symmetrically, Singapore may need data from neighbors and guidance from experienced States, in which case the ISTF framework would be helpful. It was also agreed that exchanging information of dates of ionospheric disturbances between contributing states would be helpful.

ACTION ITEM 6/1: F. Lecat to add a dedicated topic on the ICAO ISTF portal for exchanging information of dates of ionospheric disturbances between contributing states

IP/5 - Status Update of GNSS Activities in India – India

3.3 India reported about the current status of GNSS (SBAS and GBAS) activities in India. Indian airspace and airports are now GAGAN (GPS Aided Geo Augmentation Navigation) capable. India explained that the experience gained during the implementation of GAGAN by Airports Authority of India (AAI) can be fully shared with all the states wherein GAGAN service volume is contiguous with Indian service volume, with the inclusion of a few reference stations using GAGAN GEOs and the capabilities of monitoring signal-in-space, GNSS augmented services can be extended.

3.4 As far as SBAS is concerned, GAGAN was recently certified for Approach with Vertical Guidance service (APV1) over Indian landmass and LPV approaches are being developed for a number of selected runways within India. However, the GAGAN service volume is susceptible to the ionospheric variations that are very predominant and affect the GPS as well as GEO signals. In order to meet the set objective of APV1 over the Indian land mass, India has developed an appropriate region specific ionosphere model for GAGAN.

3.5 Regarding GBAS, installation of GBAS at Chennai was completed, however issues related to the high ionospheric gradient in equatorial region and therefore requirement of developing ionospheric threat model for low latitude region remained the major concern related to performance of the system. The FAA approved version of Block-2 software had been incorporated into the system in December 2015. India explained that the System was expected to be certified by Director General of Civil Aviation (DGCA) by June 2016 for daytime operations only.

IP/6 - Overview of India's contribution in Ionospheric Studies Task Force – India

3.6 India summarized the contributions made by India in achieving the objectives of Ionospheric Studies Task Force (ISTF). India remained committed to providing continued support to ISTF activities and other GNSS activities under ICAO in Asia Pacific region. In particular, India reminded that out of total 37 stations nominated by APAC States as data sources of ionospheric scintillation measurements, 23 are from India. Their locations start from magnetic equator to low mid-latitude region. Data shared by India include equinox, summer and winter months during low solar activity (2008), medium solar activity (2004) and high solar activity (2012) periods.

IP/3+SP/1 Introduction of Recent Japanese SWX Activity, PSTEP Project NICT – Japan

3.7 Japan introduced its Project for Solar-Terrestrial Environment Prediction (PSTEP), aiming mainly at delivering four products for space weather users, namely:

- a radio propagation simulator;
- a tailor-made space weather system for satellite anomaly;
- a radiation monitoring system for aviation and human space activities; and
- a ground induction current (GIC) monitoring system

3.8 The meeting discussed that the Radio Propagation Simulator could bring an interesting contribution to deliver the potential space weather service improvements expected to detect, forecast and/or mitigate the effects of ionospheric anomalous conditions on CNS systems in APAC region.

IP/7 - Activities and status of ionosphere studies in GNSS implementation in China

3.9 China reported that GRIMS (Ground Regional Integrity Monitoring System) established in 2004 to monitor GPS satellites' integrity was recently upgraded from receiving GPS only signals to receiving both GPS and BDS signals. The number of sites would be increased from 8 currently to more than 30 in order to provide denser and wider coverage and extract detailed characterizations of ionosphere over China area, with the average baseline length decreasing to about 200 km.

3.10 China further reported that a commercial Ground Based Augmentation System (GBAS) and a GBAS prototype had been installed in Shanghai Pudong Airport and Tianjin Airport respectively. The ionosphere model for GBAS would be developed by using data from GRIMS and IGS.

SP/2 - Status of ionospheric studies for GNSS, SBAS and GBAS in Indonesia

3.11 LAPAN, the National Institute of Aeronautics and Space of Indonesia, reported about their Monitoring of GNSS and SBAS disturbances and had initiated Simulation Studies about GBAS. LAPAN envisaged using ISTF tools to deepen their analysis. However, LAPAN could have access to a limited set of data only. The meeting noted that such data should be delivered to LAPAN in the interest of the safety of aviation to enable the definition of a suitable mitigation model.

Agenda Item 4: Review of deliveries of Tasks and related Action Items

a) Task 1 - Data Collection

Nil

b) Task 2 - Iono Analysis

WP/8 + SP/3, SP/4 and SP/5 - Current status of data analysis by KAIST and ENRI Japan

4.1 Japan presented the current status of data analysis jointly conducted by KAIST and ENRI, which resulted in a table of dates with severe magnetic disturbance based on data from Hong Kong and Thailand as a first step. The data sets include dual-frequency observation data from a good number of stations in RINEX format which is suitable for LTIAM analysis. It was further agreed to analyze the data for 20 days of magnetic disturbances.

4.2 The 20 days were divided into 2 sets of 10 days which would be analyzed by KAIST and ENRI, respectively. This is because the LTIAM tool is designed to work effectively for a number of stations, and it was considered that dividing data by dates for all the available stations would be more effective than dividing stations for all the dates of interest. Depending on the time necessary for the analysis, further analysis would be conducted for days in Equinox seasons where plasma bubble activity is generally high.

4.3 The meeting discussed that the maximum gradient of around 470mm/km was consistent with Indian results and was considered validated.

WP/9 Ionospheric Gradient Analysis for GBAS using Time Step Method – India

4.4 India presented the technique developed to estimate the ionospheric delay gradients for the GBAS threat model along with detailed analysis and results. The Time Step method was considered useful in absence of multiple receivers at short baseline since a single receiver is sufficient in that case to estimate the ionospheric gradient. This technique has been employed for GAGAN TEC receivers as they are separated by long baselines of around 500 km.

4.5 The computation of ionospheric gradients was completed for all the days of years 2004 to 2013 (10 years) for almost all the stations of GAGAN-TEC network. Based on manual screening of the gradients at Bangalore station, a total of 138 days were identified as having significant ionospheric activity with extreme gradients. A large number of threat points exceeding the CONUS model gradient threshold of 425 mm/km were observed at Bangalore.

4.6 The time step method was considered a suitable and effective method by the meeting. However, it was pointed out that there is a previous study [J. Lee et al., proceedings of ION PLANS 2006] comparing results of the time step method and station pair method to show that the time step method tend to give larger gradients than the station pair method, and this would have to be kept in mind in using results with both methods.

4.7 A large gradient of almost 1000 mm/km was identified but the meeting discussed that further validation would be necessary.

ACTION ITEM 6/2: India/Japan (Dr. Yoshihara): to validate the particular gradient at Bangalore

WP/10 - Preliminary results on Ionospheric Gradients using LTIAM Tool and the Way Forward – India

4.8 India further presented the preliminary results of ionospheric delay gradients derived from the Long Term Ionospheric Anomaly Monitoring (LTIAM) tool, and regarding Chennai.

4.9 Data from two IGS International GNSS Station sites in Bangalore with a baseline of 6.2 km and one Station from GAGAN-TEC network were processed. Similarly, there is one IGS station at Hyderabad and Lucknow and one each from GAGAN-TEC network.

4.10 Results were extensively discussed by the meeting. One gradient on 14 April 2014 of 350 mm/km was validated, while the other gradients would need more validation work. The validated gradient of 350 mm/km was comparable with the gradient derived by Honeywell which is of 300 mm/km for the same day. The meeting discussed that the gradients should be derived using different methods (LTIAM, time step method, etc) and further correlated.

ACTION ITEM 6/3: India/KAIST (Dr. Jiyun Lee): to further analyze the gradients at Chennai

4.11 The meeting agreed that the inclusion of IGS (International GNSS Stations) into the network data to develop the GBAS threat model would be needed.

c) Task 3 - TEC Generation

Nil

d) Task 4 - Scintillation Data

Nil

e) Task 5 - Iono Models

WP/3 - Ionosphere Threat Model for SBAS - Japan

4.12 Japan presented Ionosphere Threat Model for SBAS previously presented at webconferences held after ISTF/5. Operational hazards related to the ionospheric threats and factors influencing the mitigation strategy were identified.

4.13 Japan reminded the meeting that the Ionosphere Threat Model is used to meet integrity requirements. Each existing SBAS has its own ionosphere threat model to generate ionospheric correction information meeting integrity requirements. Each threat model should fit to its own service region. From this consideration ISTF/5 decided that a unique SBAS threat model could not be made, but rather ISTF should provide guidance to build suitable threat mitigation models and the associated safety case.

4.14 Regarding SBAS Ionospheric Correction and Integrity Parameters, vertical ionospheric delay information at IGPs (Ionospheric Grid Point) is broadcast to users by SBAS. It includes integrity parameters called GIVE (grid ionosphere vertical error) representing uncertainty involved in the associated ionospheric correction. GIVE has to be computed with consideration of spatial and temporal threats, which means that local and/or short-term irregularities are not sampled by any ground station. SBAS must protect users against such irregularities.

4.15 The SBAS ionospheric threat models may be created based on the historical severe ionospheric storm data. For this purpose, the creation of threat models requires archive of GNSS data for a whole solar cycle (11 years), or at least during the latest peak of solar activity. It was reminded that a way to create the spatial threat model available for SBAS is 'data deprivation'.

4.16 In accordance with the discussions held at previous webconferences and to build the guidance on a SBAS safety case related to ionospheric activity, WP/3 listed operational Hazards, and the factors influencing the mitigation strategy. The list was reviewed and would serve as an input to the guidance document.

4.17 In response to an action raised previously, the structure of Guidance Material was proposed by Japan and discussed by the meeting. After some amendments the table of contents at **Appendix A** was agreed by the meeting. However the meeting considered that a review by all participants would be beneficial.

ACTION ITEM 6/4: (05 Feb. 2016, all): to review the table of contents of SBAS Guidance Material by 05 Feb. 2016 and propose amendments if needed to Dr. Sakai

4.18 The detailed schedule proposed by Japan in WP/3 was also discussed and slightly amended.

<u>ACTION ITEM 6/5:</u> **<u>(Japan, Dr. Sakai): to deliver the SBAS Guidance Material in accordance with following milestones</u>:**

- End of March, 2016: Prepare and circulate a draft to ISTF members.
- End of April, 2016: Expect feedback by this date from:
  - Regulators
  - ANSP
  - Industry
- Mid of May, 2016: Complete the draft Guidance Material.
- End June 2016: Feedback on the final draft

4.19 Considering that the work plan was sound and realistic, the meeting agreed on the following draft Conclusion for consideration by CNS SG:

Draft Conclusion xx/xx - Guidance for SBAS safety case related to anomalous ionospheric conditions

That, the guidance for SBAS safety case related to anomalous ionospheric conditions be adopted and published on the ICAO APAC website.

WP/11 Ionosphere Threat Model for GBAS Japan

4.20 Japan presented the ionospheric impacts on GBAS and necessity of appropriate threat model for safety analysis to implement GBAS in each region the guidance to develop the ionosphere threat model for GBAS.

4.21 The meeting was reminded that a civil aviation expectation is that user's ionospheric delay is almost removed under nominal condition. However, range error due to ionospheric delay increases if there is a large spatial gradient between ground substation and user through "carrier smoothing processing", where carrier-smoothed pseudorange is calculated using carrier changes to reduce random noise of code measurement. This process increases an ionospheric range error because ionosphere delays code pseudorange whereas it advances carrier phase. Because absolute magnitudes of the both are almost the same, ionospheric error almost becomes twice in carrier-smoothed code under steady state against a smoothing time constant of 100 seconds. Another ionospheric effect is scintillation. It is caused by ionospheric irregularities with ionospheric disturbances and it produces rapid changes in received signal intensity and carrier phase measurement. Consequently, loss of lock might be frequently occurred during scintillation events and GBAS availability might be also significantly degraded.

4.22 Japan further presented the ionosphere conditions – normal and anomalous - relevant to GBAS safety analysis. GBAS protects users under "nominal" ionosphere condition by differential correction messages and an evaluation parameter for ionospheric error ($\square_{iono}$), which is derived from a broadcast parameter of $\square_{vig}$ (sigma vertical ionospheric gradient). However, it is required to consider "anomalous ionosphere condition" in system safety design of GBAS ground subsystem, which is not bounded by $\square_{iono}$. Namely, anomalous ionospheric condition is defined as situation with larger positioning errors than protection levels, which indicate upper bounds of user's positioning error for horizontal and vertical directions derived from evaluation parameters for error sources in GBAS messages. To mitigate this ionospheric threat on GBAS, it is necessary to detect and exclude affected ranging sources at GBAS ground stations. Therefore, it is important to evaluate both nominal and anomalous conditions for system safety design against ionospheric effects.

4.23 It then emphasized important parameters to describe the ionospheric threat model, and principles for the development and maintenance of ionosphere threat model, and long term validation of ionospheric threat model.

4.24 The meeting discussed and agreed to the principles proposed and amended slightly the table of contents, as per **Appendix B** to this Report.

ACTION ITEM 6/6: (05 Feb. 2016, all): to review the table of contents of GBAS Guidance Material by 05 Feb. 2016 and propose amendments if needed to Dr. Yoshihara

4.25 The same schedule as for SBAS was adopted by the meeting.

ACTION ITEM 6/7: (Japan, Dr. Yoshihara): to deliver the GBAS Guidance Material in accordance with following milestones:

- End of March, 2016: Prepare and circulate a draft to ISTF members.
- End of April, 2016: Expect feedback by this date from:
  - Regulators
  - ANSP
  - Industry
- Mid of May, 2016: Complete the draft Guidance Material.
- End June 2016: Feedback on the final draft

4.26 Considering that the work plan was sound and realistic, the meeting agreed on the following draft Conclusion for consideration by CNS SG:

Draft Conclusion xx/xx - Guidance on GBAS ionospheric Threat Model

That, the guidance on GBAS Threat Model for the ionosphere be adopted and published on the ICAO APAC website

4.27 Following discussions during ISTF webconferences, the meeting agreed that the best way forward to publish the iono model would be through international technical journal. Therefore the meeting agreed to the following draft Conclusion for consideration by CNS SG:

Draft Conclusion xx/xx - Adoption of GBAS Ionospheric Threat Model and publication in Technical journal(s)

That, the APAC GBAS Ionospheric Threat Model be adopted, remain the intellectual property of ICAO and be published in the public domain in selected Technical journals with the list of author/contributors as per **Appendix C.**

f) Task 6 - Space Weather

IP/4 - ICAO WG-MISD (MET Information and Service Development) NICT – Japan

4.28 Japan presented the status and future plan of ICAO/WG-MISD which discusses space weather services in ICAO. The meeting was informed that WG-MISD (Working Group - Meteorological Information and Services Development) was established in April 2015 by the METP. Space weather is one of the items similar to volcanic ash and radioactive material released into the atmosphere to be discussed in WG-MISD. The objectives of the space weather work stream in WG-MISD are as follows:

- Revised Space Weather Concept of Operations (ConOps) for endorsement by the METP (May 2016);

- Space Weather information performance requirements for endorsement by the METP (June 2016); and

- Proposals for Amendment of ICAO Annex 3 with respect to space weather information (September 2016).

4.29 Japan explained that it is necessary that airspace users and information providers of space weather services discuss for establishing suitable space weather services in the civil aviation. Especially, it is necessary to take into account regional information or requirements. For example, while the main focus in the present status of ConOps is on polar route (solar proton event or ionospheric disturbance in the polar region), there was a potential risk arising from equatorial phenomena such as the day-to-day variability of Equatorial Anomaly and/or equatorial plasma bubbles.

WP/4 - Potential operational improvements through space weather services to help mitigate the effects of space weather on the regional CNS systems and operations Secretariat

4.30 In response to the terms of reference of ISTF to "investigate the effects of space weather on CNS systems in the APAC Region", Secretariat presented the draft of high level operational improvements that might be expected from Space Weather services to mitigate the effects of space weather on the regional CNS systems and operations. The document was developed by ISTF.

4.31 After discussion during ISTF webconference #7 held on 24 September, 2015, it was agreed that a two-step approach would be taken:

- The first step is to identify operational needs irrespective of their feasibility, as this feasibility should be addressed through the work of the METP/WG-MISD; and

- The second step is to examine their feasibility and whether the corresponding space weather solutions are global (and should be considered for inclusion at the global level accordingly) or regional only.

4.32 The document developed is the outcome of the first step and includes 10 requirements in the areas of communications, navigation and surveillance. It was reviewed by the meeting and the outcome is placed in **Appendix D**. Main comments were as follows:

- Effects of ionosphere on CNS systems was not fully characterized; examples should be given, and if possible frequency and severity of such events. Australia confirmed that this would be in line with the work conducted by WG-MISD currently on some initial effects (VHF, HF). A survey might even be needed; and

- Significance of NAV-2 was for APAC also, and not only global.

4.33 Considering that the development of provisions for information on space weather to international air navigation is being addressed by the METP, and that regional planning and implementation of required space weather services would then be supported by APANPIRG, specifically through the MET/SG, CNS/SG and ATM/SG, the following way forward was adopted by the meeting:

- Complement the document as far as possible with examples of occurrences of ionospheric effects and if possible frequency and severity of such events;

- Refer the document up to the METP through Japan and Australia who are members of METP and ISTF, with the recommendation to conduct a survey on the effects at the global level, or identify occurrences from an accident investigation databases if/where available; and

- MET/SG, CNS/SG and ATM/SG to continue to keep abreast of space weather developments, and in particular of the METP's development of provisions for information on space weather to international air navigation.

4.34 The next meeting of WG-MISD is scheduled for 21 - 22 April2016.

ACTION ITEM 6/8: **(all, end March 2016): to review draft of high level operational improvements and propose examples of occurrences of iono effects and if possible frequency and severity of such events to Dr. Ishii and F. Lecat**

ACTION ITEM 6/9: **Dr. Saito, Dr Ishii, Dr. Terkildsen, F. Lecat, P. Dunda (end March 2016): to write a WP to METP/WG-MISD about the updated draft of high level operational improvements**

Agenda Item 5: Work plan and next meetings toward completion of tasks, and assessment of possibility to disband the Task Force

WP/7 - ISTF Work Plan for Final Report to CNS SG and APANPIRG - Chairman of ISTF

5.1 ISTF Chair presented the proposed work plan to address the TOR of ISTF. The critical path was identified as being data analysis and iono models. Before reviewing the work plan, the meeting discussed the possible parameters of the iono model as follows:

- Anomalous
  - Parameters
    - Gradient
    - Width
    - Depth
    - Velocity
  - # of impacted satellites
  - Occurrence probability of events
- Nominal
  - σ_{vig}

5.2 Subsequently, the meeting agreed to the following work sharing and objectives for data analysis:

- Parameters for analysis: gradient, width, depth, and velocity of the anomalous ionosphere
- Target date for analysis = Mid-June 2016
- Data analysis
  - India: Data from India
  - Australia: Data from Australia
  - ENRI+KAIST: data from

    - HKC and Thailand
    - APEC GIT
    - Philippines
    - Singapore
  - Indonesia: data from Indonesia (if time allows)
  - Singapore: data from Singapore (if time allows)
- Target date for Drafting of technical article = End of June 2016

5.3 Regarding the publication of the model, the meeting agreed on the following:

- Drafting: Japan, India, Australia, KAIST, ICAO
- Circulation of draft to ISTF participants
- Data used:
  - Australia,
  - HKC,
  - India,
  - Indonesia (if time allows),
  - Philippines,
  - Singapore,
  - Thailand,
  - APEC GIT (if time allows)

5.4. Consequently the meetings would be tentatively organized as follows, 11am-1230pm Bangkok time:

- ISTF Webconference #9, 3 March 2016, drafting of Summary of discussions: Dr. Saito

  - follow up on analysis and models
  - Review of updated doc about Space weather service improvements

- ISTF Webconference #10, 5 April 2016, drafting of Summary of discussions: Dr. Surendra

  - follow up on analysis and models
  - Discuss comments on GBAS and SBAS documents from Regulators, ANSP and industry

- ISTF Webconference #11, 2 May 2016, drafting of Summary of discussions: Dr. Yoshihara

  - follow up on analysis and models

- ISTF Webconference #12, 2 June 2016, drafting of Summary of discussions: F. Lecat
  - Review of final analysis results and GBAS iono model
  - Discuss comments on GBAS and SBAS documents (2nd iteration)

- ISTF Webconference #13, 1 July 2016, drafting of Summary of discussions: Dr. Saito
  - Prepare CNS SG

- ISTF Webconference #14 End August 2016, drafting of Summary of discussions: Dr. Surendra
  - review technical draft publication,
  - update APANPIRG/27
  - Submit a paper in a technical journal

- August 2016 - December 2016 Peer-reviewing process and publication in technical journals,

Assessment of the possibility to disband the Task Force

5.5 The Terms of Reference were reviewed and completion assessed as follows:

- 1) Take the responsibility for identification of the available GNSS data source;
  Completed

- 2) Make recommendation on sharing scenario for Ionospheric data collected;
  Completed

- 3) Make recommendations on selecting ionospheric data sources and sharing scenario for the collected data;
  Completed

- 4) Steer process for evaluation of the data analysis;
  Completed by June 2016

- 5) Study the need for development of Regional Ionospheric Threat Models for GBAS and SBAS;
  Completed

- 6) Development of Regional Ionospheric Threat Models for GBAS and SBAS if the need is identified;
  Completed by June 2016
  SBAS threat model was considered not feasible and replaced by guidance on safety case

- 7) Establish rules for use of shared data and the result of study for non-commercial purpose;
  Completed

- 8) Investigate the effects of space weather on CNS systems in the APAC Region.
  Completed by End March 2016 and referred up to METP/WG-MISD

5.6 The meeting finds it beneficial to submit a working paper to CNS SG which links the items of TOR and corresponding outcomes.

ACTION ITEM 6/10: Dr. Saito/F. Lecat (end June 2016): to write a WP to CNS SG with links between items of TOR and corresponding deliverables of ISTF

5.7 As a result, the meeting estimated that the dissolution could take place in 2016 and agreed to the following draft decision for consideration by CNS SG:

Draft Decision xx/xx – Dissolution of Ionospheric Study Task Force

Considering that all tasks mentioned in the terms of reference are completed, and that in the case where the peer-review process of the technical publications is not successfully completed, CNS SG would handle the follow-up work,

That, the Ionospheric Studies Task Force be dissolved.

WP/5 - Review of ISTF Action List - Secretariat

5.8 The action list was reviewed and all actions open before ISTF/6 were closed. The updated action list is provided at **Appendix E**.

Agenda Item 6: Any other business

6.1 The Chair warmly thanked all participants and ICAO for their continuous support, and noted that this meeting was the last face to face meeting for ISTF. Participants thanked Dr. Saito for his 5 years long dedication to ISTF and more generally for his great contribution to PBN implementation worldwide. The meeting concluded that a heavy work plan was still ahead in 2016, but all were confident that the group would achieve as expected.

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DRAFT TABLE OF CONTENTS FOR GUIDANCE ON GBAS THREAT MODEL

1. Introduction

a) GBAS and its fundamental principles
b) Scope: GBAS threat model to mitigate anomalous ionospheric conditions
c) Ionospheric effects on GBAS

2. Ionosphere conditions to consider for GBAS safety analysis

a) Overview of relationship between GBAS safety assessment and ionospheric conditions
b) Nominal conditions bounded by PL (protection level)
c) Anomalous conditions and ionospheric disturbances to consider

    i. Storm enhanced density
    ii. Plasma bubble
    iii. Other

d) Ionospheric threat model for GBAS safety analysis
e) Role: evaluations of requirement and performance including integrity monitoring
f) Ionospheric front model (Wedge model) and its important parameters

    i. Ranging errors induced by ionospheric anomaly
    ii. Positioning errors in the final implementation

g) Other important descriptions

    i. Localities, dominant season/time, occurrence rate and number of impacted satellites

3. Development of the threat model

a) Observational approach

    i. Tools like LTIAM
    ii. Time Step method
    iii. Other

b) Simulation approach
    i. 3D

c) Validation

4. Post-implementation activities

a) Monitoring of ionospheric activity
b) Maintenance of threat model

5. Annexes

a) CONUS model
b) Safety analysis for GBAS prototyping in Osaka
c) other

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DRAFT TABLE OF CONTENS OF GUIDANCE FOR SBAS SAFETY CASE RELATED TO ANOMALOUS IONOSPHERIC CONDITIONS

1. **Introduction**
2.
   a) GNSS overview
   b) Scope: Guidance for SBAS safety case related to anomalous ionospheric conditions

3. **Threat mitigation strategy against anomalous ionospheric conditions**

   a) High level principles

      i. Improvement of availability and continuity of the system
      ii. The smaller the threat space, the better the performance
      iii. Meeting the integrity requirements is an essential characteristic of threat models
      iv. Schemes for Iono Monitoring and for protecting airspace users

   b) Ionospheric correction by SBAS

      i. Broadcast information
      ii. Protocol of ionospheric correction and protection levels computation
      iii. Generation of ionospheric correction information inside SBAS

   c) Necessity of the threat model

      i. Overbounding uncertainty; Spatial and temporal threats

   d) Creation of the threat model

      i. Function of observability of ionosphere and ionosphere model used
      ii. Necessity to archive data for a certain period: for how long?

   e) Post-implementation activities

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LIST OF CONTRIBUTORS TO THE TECHNICAL ARTICLE ON GBAS IONOSPHERIC MODEL

(Subject to change based on drafting of actual technical paper and information about data sources)

Authors: Dr. Saito, Dr. Yoshihara, Dr. Sunda, Dr. Terkildsen, Dr. Lee, ICAO APANPIRG Ionospheric Studies Task Force

Acknowledgments: Data sources from the following Organizations, by alphabetical order:

- Asia-Pacific Economic Cooperation, GNSS Implementation Team;
- Australia;
- Hong Kong China;
- India;
- Indonesia, National Institute of Aeronautics and Space in Indonesia;
- Philippines, National Mapping and Resource Information Authority (NAMRIA);
- Singapore; and
- Thailand

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OPERATIONAL NEEDS OF SPACE WEATHER SERVICES FOR CNS SYSTEMS

(Version 4 – 20 January 2016)

1. Introduction

Space weather can be defined as the conditions on the sun and in the solar wind, magnetosphere, ionosphere, and thermosphere that can influence the performance and reliability of space-borne and ground-based technological systems and can endanger human life or health of aviation flight crews and passengers [1]. This should be consistent with relevant discussion/outcomes on the definition for space weather from the METP/WG-MISD.

A Space Weather Concept of Operations [2] is being revised by the WG-MISD for endorsement by the METP.
In response to the **terms of reference of ISTF to "investigate the effects of space weather on CNS systems in the APAC Region",** this paper summarizes the operational requirements for space weather information in support of CNS systems as foreseen in the APAC region. They could constitute a good input to the discussions of the METP/WG-MISD.

This paper focuses on the operational benefits which could be reaped from space weather information services. Therefore, what is expected from space weather services may not be feasible at the current stage of space weather knowledge.

For those operational improvements whose benefit would be confirmed on a global scale, appropriate coordination with the METP will be undertaken for potential incorporation into the Concept of Operations for International Space Weather Information in Support of Aviation [2].

2. Operational improvements for space weather services

2.1 Communications

Effect: Space Weather phenomena can affect propagation of radio waves used for aeronautical communications. Following COM systems may be influenced:

[i] HF communications may be disturbed by solar X-ray flare. Increased solar X-ray enhances the ionospheric density in the D-region to absorb HF radio waves (Dellinger phenomenon), and long-distance HF communications may be disrupted.

Examples/occurrences with their severity and frequency: to be developed (from AIG reports, ATS incident reports, operational experience, etc)

Operational improvement SW-COM-1:	
a) Monitor the predicted impact of HF propagation conditions on high frequency aeronautical mobile communications (controller / pilot) over the next 24 hours in volumes of airspace (ATS) and along trajectories of the subscribed users (ATS units and airspace users) b) Warn concerned users when the predicted impact is very likely to affect the communications such that the Mean opinion score (MOS) equals 3 (fair quality) and publish the description of affected volume of airspace (ATS) and trajectories c) Alert concerned users when the predicted impact is very likely to affect the communications such that the MOS equals 2 or less (poor or bad) and publish the description of affected volume of airspace (ATS) and trajectories	
☒Global ☒APAC	☒ Safety ☐ Efficiency/Capacity ☐ Environment

Notes:

- *impact should be easily understandable by ATS/ATFM units and air operators and be characterized using the Mean opinion score (MOS) as per ITU-T recommendation P.800. MOS rates the quality of the voice signal in one of the following categories: excellent (5), good (4), fair (3), poor (2) and bad (1)*
- *volume of airspace (ATS) and trajectory descriptions should use FIXM (see http://fixm.aero/)*
- *description and presentation of impacts should be based on AIXM/IWXXM*
- *the forecast window of 24 hours was taken considering a 6 to 12 hours before takeoff for appropriate preparation of flights and ATFM/ATS units, a cruise of 12 hours and an additional margin of 6 hours*

HF communications through the polar region may be disrupted by sudden enhancement of high-energy particle precipitations in the polar cap region to enhance HF radio absorption (polar cap absorption: PCA).

Operational improvement SW-COM-2:	
a) Monitor the predicted impact of high-energy particle precipitations in the polar cap region on high frequency aeronautical mobile communications (controller / pilot) through the polar region over the next 24 hours in volumes of airspace (ATS) and along trajectories of the subscribed users (ATS units and airspace users) b) Warn concerned users when the predicted impact is very likely to affect the communications such that the MOS equals 3 (fair quality) and publish the description of affected volume of airspace (ATS) and trajectories c) Alert concerned users when the predicted impact is very likely to affect the communications such that the MOS equals 2 or less (poor or bad) and publish the description of affected volume of airspace (ATS) and trajectories	
☒Global ☒APAC	☒ Safety ☐ Efficiency/Capacity ☐ Environment

Notes:

- *impact should be easily understandable by ATS/ATFM units and air operators and could be characterized using the Mean opinion score (MOS) as per ITU-T recommendation P.800*
- *volume of airspace (ATS) and trajectory descriptions should use FIXM (see http://fixm.aero/)*
- *description and presentation of impacts should be based on AIXM/IWXXM*

These are global phenomena.

[ii] **Effect:** VHF communications may suffer from interferences by anomalous radio propagation associated with the sporadic E layer. The sporadic E-layer reflects VHF radio waves to cause long-distance propagation to reach beyond the radio horizon.

Examples/occurrences with their severity and frequency: to be developed (from AIG reports, ATS incident reports, operational experience, etc)

Monitoring and predicting the Es layer conditions are desirable.

Operational improvement SW-COM-3:	
a) Monitor the predicted impact of interferences by anomalous radio propagation associated with the sporadic E layer on very high frequency aeronautical mobile communications (controller / pilot) over the next 24 hours in volumes of airspace (ATS) and along trajectories of the subscribed users (ATS units and airspace users). b) Warn concerned users when the predicted impact is very likely to affect the communications such that the MOS equals 3 (fair quality) and publish the description of affected volume of airspace (ATS) and trajectories c) Alert concerned users when the predicted impact is very likely to affect the communications such that the MOS equals 2 or less (poor or bad) and publish the description of affected volume of airspace (ATS) and trajectories	
☒Global ☒APAC	☒ Safety ☐ Efficiency/Capacity ☐ Environment

Notes:

- *impact should be easily understandable by ATS/ATFM units and air operators and characterized using the Mean opinion score (MOS) as per ITU-T recommendation P.800*
- *volume of airspace (ATS) and trajectory descriptions should use FIXM (see http://fixm.aero/)*
- *description and presentation of impacts should be based on AIXM/IWXXM*

Sporadic E layer is a localized phenomenon.

[iii] **Effect:** L-band satellite communications may be disturbed by scintillations by irregularities in the ionosphere. In the low latitude region, small-scale irregularities in the ionosphere associated with plasma bubbles may cause scintillations in L-band satellite communication radio waves to cause degrading communications or lock-off of satellite signals.

Examples/occurrences with their severity and frequency: to be developed (from AIG reports, ATS incident reports, operational experience, etc)

As per [4] aviation users of the satellite segment in L-Band are Inmarsat, MTSAT and Iridium systems.

For Inmarsat and Iridium the potential impact regards ACARS, FANS and ATN communications, Electronic Flight Bag (EFB) data streaming and in the future the flight tracking systems.

Operational improvement SW-COM-4:	
a) Monitor the impact of scintillations (plasma bubbles) in L-band satellite communication radio waves on data communication performance for: a. ACARS, FANS and ATN communications; b. Electronic Flight Bag (EFB) data streaming and; c. Flight tracking systems. b) Warn concerned users, including communication service providers, when the predicted impact will very likely degrade the performance of CPDLC, ADS-C, EFB or Flight tracking service and publish the description of affected volume of airspace (ATS) and trajectories. c) Alert concerned users when the predicted impact is very likely to cause the loss of CPDLC, ADS-C, EFB or Flight tracking service and publish the description of affected volume of airspace (ATS) and trajectories	
☒Global ☒APAC	☒ Safety ☒ Efficiency/Capacity ☐ Environment

Plasma bubble is a localized phenomenon.

2.2 Navigation

Space Weather phenomena can affect propagation of radio waves used for aeronautical navigations. Following systems may be influenced:

[i] **Effects:** Effects of space weather phenomena are summarized in [3] as parts of GBSS vulnerability. Followings are among them

(a) Ionospheric propagation delay in GNSS signals is proportional to the ionospheric total electron contents (TECs). Different classes of ionospheric TEC disturbances can be error sources in GNSS. Phenomena that accompany TEC disturbances include the day-to-day variation of equatorial ionization anomaly, positive ionospheric storms associated with magnetic storms, and plasma bubbles.

(b) Ionospheric scintillation is caused by small-scale irregularities in the ionosphere. The effects are similar to those on the L-band satellite communications. In the low latitude region, it is associated with plasma bubbles.

(c) Solar radio burst is a sudden enhancement in the radio flux radiated by the sun. Enhancement in the solar radio flux in the GNSS signal bands degrades signal-to-noise ratio of GNSS signals to degrade the accuracy, and in the worst case cause lock-off of signals.

Monitoring and Predicting plasma bubbles are desirable for (a) and (b). Monitoring and predicting magnetic storms and resulted TEC variations are desirable for (a). Monitoring and predicting solar radio burst are desirable for (c).

Examples/occurrences with their severity and frequency: to be developed

<table>
<tr><td colspan="2">Operational improvement SW-NAV-1:</td></tr>
<tr><td colspan="2">a) Monitor and predict the variation of TECs (ionospheric delays) and their disturbances over the next 24 hours in volumes of airspace (ATS), aerodromes and along trajectories of the subscribed users (ATS units, airport operators and airspace users).
b) Warn concerned users, including RAIM prediction service suppliers, when the predicted impact will increase the a priori probability of ionospheric disturbances and publish the description of affected volume of airspace (ATS), aerodromes and trajectories.</td></tr>
<tr><td>☒Global ☒APAC</td><td>☒ Safety ☒ Efficiency/Capacity ☐ Environment</td></tr>
</table>

Note: Current augmentation systems (SBAS, GBAS) assume a priori probability of ionospheric disturbances as 1 (always there), which is very conservative. Such prediction would reasonably decrease the a priori probability and result in enhancing availability of GNSS -based systems.

Operational improvement SW-NAV-2:	
a) Monitor and predict the impact of scintillations by plasma bubbles on GNSS signals over the next 24 hours in volumes of airspace (ATS), aerodromes and along trajectories of the subscribed users (ATS units, airport operators and airspace users). b) Warn concerned users, including RAIM prediction service suppliers, when the predicted impact will increase the a priori probability of ionospheric disturbances and publish the description of affected volume of airspace (ATS), aerodromes and trajectories.	
☒Global ☒APAC	☒ Safety ☐ Efficiency/Capacity ☐ Environment

Note: Since scintillations have direct impact on available satellites, this improvement could be a part of RAIM prediction.

Operational improvement SW-NAV-3:	
a) Monitor and predict the impact of solar radio bursts on GNSS signals over the next 24 hours in volumes of airspace (ATS), aerodromes and along trajectories of the subscribed users (ATS units, airport operators and airspace users). b) Warn concerned users, including RAIM prediction service suppliers, when the predicted impact will increase the a priori probability of ionospheric disturbances and publish the description of affected volume of airspace (ATS), aerodromes and trajectories.	
☒Global ☐APAC	☒ Safety ☐ Efficiency/Capacity ☐ Environment

[ii] **Effect:** VHF ground radio navigation aids may suffer from interferences by anomalous radio propagation associated with the sporadic E layer. The sporadic E-layer reflects VHF radio waves to cause long-distance propagation to reach beyond the radio horizon. Monitoring and predicting the Es layer conditions are desirable.

Examples/occurrences with their severity and frequency: to be developed (from AIG reports, ATS incident reports, operational experience, etc)

Sporadic E layer is a localized phenomenon.

Operational improvement SW-NAV-4:	
a) Monitor and predict the impact of sporadic Es layer conditions on actual navigation performance in volumes of airspace (ATS), aerodromes and along trajectories of the subscribed users (ATS units, airport operators and airspace users). b) Warn concerned users, including RAIM prediction service suppliers, when the predicted impact will increase the a priori probability of ionospheric disturbances and publish the description of affected volume of airspace (ATS), aerodromes and trajectories.	
☒Global ☒APAC	☒ Safety ☒ Efficiency/Capacity ☒ Environment

Note: Solar radio bursts are global phenomena, though it is strongest at sub-solar points on the Earth.

2.3 Surveillance

Effect: Surveillance systems which utilize GNSS such as ADS-B and ADS-C may be impacted by space weather phenomena as a consequence of space weather impact on GNSS.

Examples/occurrences with their severity and frequency: to be developed (from AIG reports, ATS incident reports, operational experience, etc)

Operational improvement SW-SUR-1:	
a) Monitor and predict the effects on ADS-B of space weather impact on GNSS in volumes of airspace (ATS) and along trajectories of the subscribed users (ATS units and airspace users). b) Warn concerned users when the positions reported will not meet the performance criteria and publish the description of affected volume of airspace (ATS) and trajectories. c) Alert concerned users when the predicted impact is very likely to cause the loss of ADS-B service and publish the description of affected volume of airspace (ATS) and trajectories.	
☒Global ☒APAC	☒ Safety ☒ Efficiency/Capacity ☐ Environment

Notes:

- *Ionospheric TEC variations and scintillations may degrade the position accuracy of GNSS-based position solutions which are piped to ADS-B outputs. Whether such impacts really exist has to be confirmed.*
- *As a first approach there would be no need for the ATS units/ATM systems to discriminate ionospheric effects from other effects affecting NUC or NIC,NAC, SIL. What is of interest is whether the positions reported do meet or not the performance criteria.*

Operational improvement SW-SUR-2:	
a) Monitor and predict the effects on ADS-C of space weather impact on GNSS in volumes of airspace (ATS) and along trajectories of the subscribed users (ATS units and airspace users). b) Warn concerned users, including communication service providers, when the predicted impact will very likely degrade the performance of ADS-C and publish the description of affected volume of airspace (ATS) and trajectories. c) Alert concerned users when the predicted impact is very likely to cause the loss of ADS-C service and publish the description of affected volume of airspace (ATS) and trajectories.	
☒Global ☒APAC	☒ Safety ☒ Efficiency/Capacity ☐ Environment

Notes:

- *Ionospheric TEC variations and scintillations may degrade the position accuracy of GNSS- based position solutions which are piped to ADS-C outputs. Whether such impacts really exist has to be confirmed.*
- *As a first approach there would be no need for the ATS units/ATM systems to discriminate ionospheric effects from other effects affecting FOM. What is of interest is whether the positions reported do meet or not the performance criteria.*

3. References

[1] WMO Space Programme SP-5, the Potential Role of WMO in Space Weather, April 2008.

[2] Concept of Operations for International Space Weather Information in Support of Aviation, Draft version 3.0, 6 December 2013.

[3] WP/21, Global navigation satellite system (GNSS) implementation issues, AN-Conf/12, November 2012.

[4] ICAO Doc 9718 AN/957 Handbook on Radio Frequency Spectrum Requirements for Civil Aviation Volume I

Action Item	Action	Owner	Contributors	Target date	Status	Result	Comment
ACTION ITEM 2/1	To develop a guidance material on collection of scintillation data at strategic locations. Preliminary draft of the guidance material should be available by November 2012 and the finalized guidance material, incorporating all the recommended changes, should be available by December 2012	Task 1 Leader		Dec-12	Closed	Guidance material	Based on Hong Kong Satellite Positioning Reference Station Network and adopted as the guidance material and sample MOU for States
ACTION ITEM 2/2	Secretary to communicate with the APEC GIT Co-chairs regarding the data sharing template. Target date for receiving information from APEC GIT is end of December 2012.	ICAO Secretary		Dec-12	Closed	Information from APEC received	
ACTION ITEM 2/3	to coordinate with IGWG Iono Group to acquire LTIAM Tool. Target date is by the end of December 2012.	Task Lead, Task – 2		Dec-12	Closed		7 feb. 14: approval from FAA is pending Sep. 14 ROK contacted FAA again, with no result.
ACTION ITEM 2/4:	categorize the ionospheric delay measurements and scintillation measurements into geographical region to confirm an even spread of all the observation sites in the region. Target date for the Action Item was agreed as January 2013.	Task 1 Leader		Jan-13	Closed	WP ISTF 3	
ACTION ITEM 2/5	to prepare a mechanism to identify the terms of use of data as proposed by the data source and incorporate that in the data processing. Target date for this Action Item is January 2013.	Task 1 Leader		Jan-13	Closed	Data server interface was implemented	
ACTION ITEM 2/6a	a) Setting up of Server – Japan (January 2013)	Japan		Jan-13	Closed	Server at ENRI up and running	Data server sponsored by ENRI should need to be ready to receive/compile the data. Period of analysis could start from discussing which key parameters could be used for identifying such periods. States like India and Japan, which have already carried out some level of analysis, are requested to suggest these periods/parameters based on their experience. Data formats need to be reviewed and updated for their applicability for the purpose of analysis:
ACTION ITEM 2/6b	b) Finalizing data format – Japan (January 2013)	Japan		Jan-13	Closed		Refer to action item 3/1
ACTION ITEM 2/6c	c) Key parameters to categorize data – Republic of Korea – (January 2013)	Republic of Korea		Jan-13	Closed	ISTF/3 IP/7 was presented by ROK	Closed in ISTF/3
ACTION ITEM 3/1	Japan to coordinate with the Chairman of ITU-R WP-3L for the formats of scintillation data with the same name “SCINTEX” to have a unified format.	Task 1 Leader and Dr. Tsugawa			Closed		Closed 6 Feb. 14. Refer to Action 4/3
ACTION ITEM 3/2	to coordinate with FAA for obtaining permission to use the LTIAM tool by ISTF.	- Task Lead, Task-2 and Prof. Lee, ROK			Closed		Duplicated action
ACTION ITEM3/3	to set up the data server for data sharing according to the outcome of ISTF/3 and prepare a manual for the use of the data server including keeping logs for accessing the restricted data	Task 1 Leader			Closed	setup of the ISTF data server for data sharing and exchange by Japan	
ACTION ITEM 3/4	to identify the past periods of interest for data Analysis	Task 2 Leader			Closed	dates of interest documented into a file with MS-excel format	Closed 6 Feb. 14
ACTION ITEM 3/5	- Secretary to issue a letter to India (Airport Authority of India) requesting the use of GAGAN-TEC data.	ICAO Secretary			Closed	Letter received	
ACTION ITEM 4/1	to check whether and under which conditions Septentrio data could be shared within ISTF	Australia		31-Aug-14	Closed	Project stopped.	
ACTION ITEM 4/2	To develop guidelines about how to generate data in GTEX	Task 1 Leader		31-Oct-14	Closed	16 Feb.15 User Guide of RNX2GTEX for Linux/Unix (ver 1.1.3) User Guide of RNX2GTEX for Windows (ver 2.1)	Delayed, due to rotation of Dr. Tsukawa. GTEX format: end of Oct .14 Significant amount of data are available in Raw/RINEX data
ACTION ITEM 4/3	To finalize SCINTEX format with ITU by email	Dr. Tsukawa, Japan		30-Jun-14	Closed		In progress through emails and F2F - Final agreement to take place, depending on ESA side Document completed and sent to IGS meeting - Mamoru Ishii to send F.Lecat
ACTION ITEM 4/4	To provide the dates relevant for data Analysis relating to equatorial ionospheric anomalies	all participants		31-Mar-14	Closed	16Feb15 Data were collected from Philippines, India, Singapore and Hong Kong china. During the meeting data from Thailand were handed over to ENRI. Australia has provided the ftp information, but has not yet been transferred onto the ISTF data server	Closed for India on 24 June 14, which has proposed an approach based on 2delta/2sigma data mining for selecting the dates of interest. Dates are proposed in Excel spreadsheet. 16-Sep.-14: However thanks to AATR method, data analysis can proceed.
ACTION ITEM 4/5	identify which tools to use for data conversion to the common format RINEX.	Task 3 Leader	Australia, India, Japan	7-Mar-14	Closed	Tools selected: TEQC, RTKLIB, which should cover 99% of the needs	
ACTION ITEM 4/6	For LTIAM and ENRI's tools, identify how manual verification will be conducted	Task 3 Leader	Australia, India, Japan	31-Jul-15	Closed		In progress - 16 Sep. 14 - postponed to 31 Oct. 14 19 Jun. 15: LTIAM access is now granted 19 Jun.15: target date postponed to 31 Jul 15
ACTION ITEM 4/7	identify the need for ROTI to be included as one of the parameters for scintillation analysis	Task 3 Leader	Australia, India, Japan	31-Mar-14	Closed	ROTI can be included as one of the survey parameters	Republic of Korea may join the contributors

Action Item	Action	Owner	Contributors	Target date	Status	Result	Comment
ACTION ITEM 4/8	ISTF Participants to send comments about Space weather draft Conops document to Secretary and Secretary to coordinate with IAVWOPSG.	all participants	Secretariat ICAO	14-Feb-14	Closed	Japan introduced to IAVWOPSG the importance of local ionospheric events for navigation, and will attend ICAO MET Div meeting in July 14, with an IP.	The IP will be shared with ISTF participants
ACTION ITEM 4/9	to confirm if/when there will be a joint session with NSP CSG about ISTF outcomes and way forward to implement mitgiation models in the GBAS system	Dr. Saito		15-Oct-14	Closed	Yes joint session on 17Feb.15	
ACTION ITEM 4/10	to coordinate data transfer from Singapore to the ISTF server	Dr. Saito		15-Oct-14	Closed	Data delivered by Singapore	
ACTION ITEM 4/11	collect available information on ionospheric threat definition on SBAS and GBAS systems about EGNOS with ESA	Dr. Surendra Sunda		12-Dec-14	Closed	No paper about EGNOS available in the public domain	
ACTION ITEM 4/12	collect available information on ionospheric threat definition on SBAS and GBAS systems about WAAS and MSAS	Dr. Saito		12-Dec-14	Closed	3 or 4 papers identified and shared during webconference #3	
ACTION ITEM 5/1	to prepare guidance material for GTEX format	Dr. Mamoru Ishii		10-Jun-15	Closed	Guidance material for GTEX format delivered 19 June 15	
ACTION ITEM 5/2	to modify AATR tool to handle cycle slips and irregular data	Dr. Saito		13-Mar-15	Closed		Not distributed yet
ACTION ITEM 5/3	to identify operational hazards related to the ionospheric threats	Dr. Sakai		12-Jun-15	Closed	The spatial variation of ionospheric delay is dominant and the temporal variation is not as significant as the spatial one. The meeting requested to include some typical values for range error for spatial and temporal variation.	
ACTION ITEM 5/4	to identify factors influencing the mitigation strategy (ground stations distribution, iono model used, etc)	Dr. Sakai		12-Jun-15	Closed	Factors identified: Observation density, fidelity of ionospheric model, availability of archived data, and system specific implementation of ionospheric correction are identified as the factors of importance	
ACTION ITEM 5/5	Develop the structure of guidance material for SBAS	Dr. Sakai		12-Jun-15	Closed	Structure of guidance material for SBAS delivered 19 Jun 15: A draft table of contents is presented. After discussion, it was requested to include APAC regional consideration and typical values of influencing factors for SBAS mitigation strategy	
ACTION ITEM 5/6	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	Dr. Yoshihara, Task Lead/Task-5 for GBAS		12-Jun-15	Closed	Structure delivered 19 Jun 15	
ACTION ITEM 5/7	to distribute upgraded AATR tool (now handling cycle slips and irregular data)	Dr. Saito		26-Jun-15	Closed		
ACTION ITEM 5/8	to develop high-level requirements for space weather services for CNS in APAC region	Ms. Susan E. O'Rourke (MET SG chair), Mr. Lo Weng Kee (CNS SG Chair), Dr. Saito, Dr. Ishii, Mr. Peter Dunda (MET RO) and Mr. Lecat (CNS RO).		30-Dec-15	Closed		
ACTION ITEM 5/9	to find out suitable journals for technical publications	Dr. Saito and Prof. Lee		30-Dec-15	Closed		the GBAS threat model and SBAS guidance material should be in public domain
ACTION ITEM 5/10	Since AATR data analysis of GAGAN-TEC data has been done by Dr. Sunda, to analyze just a part of GAGAN-TEC data to cross-check the Dr. Sunda's results	Dr. Saito		30-Dec-15	Closed		
ACTION ITEM 5/11	to urgently sends an email to Jiyun to modify LTIAM so that LTIAM reads RINEX data from local disk	Dr. Sunda		30-Dec-15	Closed		
ACTION ITEM 6/1	to add a dedicated topic on the ICAO ISTF portal for exchanging information of dates of ionospheric disturbances between contributing states	F.Lecat			Open		

Action Item	Action	Owner	Contributors	Target date	Status	Result	Comment
ACTION ITEM 6/2	To validate the particular gradient at Bangalore	India/Japan (Dr. Yoshihara)		30-Mar-16	Open		
ACTION ITEM 6/3	To further analyze the gradients at Chennai	India/KAIST (Dr. Jiyun Lee):		30-Mar-16	Open		
ACTION ITEM 6/4	to review the table of contents of SBAS Guidance Material by 05 Feb. 2016 and propose amendment if needed to Dr. Sakai	all participants		5-Feb-16	Open		
ACTION ITEM 6/5	to deliver the SBAS Guidance Material in accordance with following milestones	Dr.Sakai		30-Jun-16	Open		
ACTION ITEM 6/6	to review the table of contents of GBAS Guidance Material by 05 Feb. 2016 and propose amendment if needed to Dr. Yoshihara	all participants		5-Feb-16	Open		
ACTION ITEM 6/7	to deliver the GBAS Guidance Material in accordance with following milestones	Dr. Yoshihara		30-Jun-16	Open		
ACTION ITEM 6/8	to review the draft of high level operational improvements and propose examples of occurrences of iono effects and if possible frequency and severity of such events to Dr. Ishii and F.Lecat	all participants		30-Mar-16	Open		
ACTION ITEM 6/9	to write a WP to METP/WG-MISD with updated draft of high level operational improvements	Dr. Saito, Dr Ishii, Dr. Terkildsen, F.Lecat, P. Dunda		30-Mar-16	Open		
ACTION ITEM 6/10	to write a WP to CNS SG with links between items of TOR and corresponding deliverables of ISTF	Dr. Saito/F.Lecat		30-Jun-16	Open		

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SIXTH MEETING OF THE IONOSPHERIC STUDIES TASK FORCE (ISTF/6)

(19 – 21 January 2016, Bangkok, Thailand)

Attachment 1 to the Report

LIST OF PARTICIPANTS

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International Civil Aviation Organization

THE SIXTH MEETING OF IONOSPHERIC STUDIES TASK FORCE (ISTF/6)

Bangkok, Thailand, 19 – 21 January 2016

LIST OF WORKING/INFORMATION PAPERS AND PRESENTATIONS

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WP/1	-	Provisional Agenda	Secretariat
WP/2	3	Development of a Ground-based Augmentation System (GBAS) Ionospheric Threat Model (GITM) for Singapore	Singapore
WP/3	3 (e)	Ionosphere Threat Model for SBAS	Takeyasu Sakai, ENRI
WP/4	4 (f)	Operational Improvements in Space Weather services to Mitigate the Effects of Space Weather on the Regional CNS Systems and Operations	Secretariat
WP/5	5	Review of ISTF Action List	Secretariat
WP/6	2	Outcome of the NSP/2 Meeting	Chairman of ISTF
WP/7	5	ISTF Work Plan for Final Report to CNS SG and APANPIRG	Chairman of ISTF
WP/8	4 (b)	Current Status of Data Analysis by KAIST and ENRI	Japan
WP/9	4 (e)	Ionospheric Gradient Analysis for GBAS Using Time Step Method	India
WP/10	4 (e)	Preliminary Results on Ionospheric Gradients using LTIAM Tool and the Way Forward	India
WP/11	4 (e)	Ionosphere Threat Model for GBAS	Takayuki Yoshihara and Susumu Saito, ENRI

WP/IP PPT No.	Agenda Item	Subject	Presented by
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IP/2	2	Review of outcome of Relevant Meetings/Conferences	Secretariat
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IP/4	4 (f)	ICAO WG-MISD (MET Information and Service Development)	NICT - Japan
IP/5	3	Status Update of GNSS Activities in India	India
IP/6	3	Overview of India's Contribution in Ionospheric Studies Task Force	India
IP/7	3	Ionosphere Related Activities in GNSS Implementation in China	China
		PRESENTATIONS	
SP/1		Introduction of Recent Japanese SWX Activity, PSTEP Project	Japan
SP/2		Status of Ionospheric Studies for GNSS, SBAS and GBAS in Indonesia	Indonesia
SP/3		LTIAM Data Processing Results for ISTF Regional GBAS Threat Model (Storm Days)	ENRI – KAIST
SP/4		LTIAM Data Processing Results for ISTF Regional GBAS Threat Model (Scintillating Days)	ENRI - KAIST
SP/5		TM Data Scintillating Days	ENRI - KAIST

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