International Civil Aviation Organization

EIGHTEENTH MEETING OF THE COMMUNICATIONS/NAVIGATION AND SURVEILLANCE SUG-GROUP (CNS SG/18) OF APANPIRG

Asia and Pacific Regional Sub-Office, Beijing, China
(21 – 25 July 2014)

Agenda Item 6: Navigation

3) Review outcome of the Third /Fourth Meetings of Ionospheric Studies Task Force

REVIEW OF THE THIRD AND FOURTH MEETINGS OF IONOSPHERIC STUDIES TASK FORCE (ISTF/3 and 4) –

(Presented by the Secretariat)

SUMMARY

Third /Fourth Meetings of ISTF (ISTF/3 and 4) were held respectively in Seoul from 15 to 17 October 201 and in Delhi from 05 to 07 February 2014. A first webconference was held on 24 June. This paper discusses their outcome and invites CNS SG to review the status of completion of the Action Items identified.

1. INTRODUCTION

1.1 The Third Meeting of Ionospheric Studies Task Force (ISTF/3) was held in Seoul, Republic of Korea from 15 to 17 October 2013. The meeting was hosted by the Ministry of Land, Infrastructure and Transport (MOLIT). The documentation can be found at http://www.icao.int/APAC/Meetings/Pages/2013-ISTF3.aspx

1.2 The Fourth Meeting of Ionospheric Studies Task Force (ISTF/4) was held in New Delhi, India from 05 to 07 February 2014. The first day was a joint session for the 4th ICAO Ionospheric Study Task Force (ISTF) Meeting and the 26th Interoperability Working Group (IWG) Meeting. On 06 and 07 February, ISTF met on a dedicated session. The documentation can be found at http://www.icao.int/APAC/Meetings/Pages/2014-ISTF4.aspx.

1.3 A webconference attended by 6 participants was held on 24 June 14.

1.4 The Chapter 2 focuses on ISTF/4 meeting and first webconference as they delivered the latest outputs.

2. DISCUSSION

Review of outcome of relevant meetings/conferences by ISTF/4

2.1 The ISTF related outcomes of NSP WGW 14, APEC GIT 18 meetings and AOSWA-2 workshop held respectively in November 2013, July 2013 and November 2013 were presented to the ISTF/4 meeting.

2.2 President of the Air Navigation Commission (ANC) explained to the NSP WGW 14 meeting that a proposal for the reorganization of panels is under development, and will likely affect the NSP. Changes under consideration that might affect NSP include moving all spectrum work in one location, perhaps into a new dedicated panel, and restarting the PBN work. A total of nine Job Cards were assigned to NSP. The Secretary confirmed that the work on a number of items that are not covered by Job Cards such as the development of SARPs for Galileo and BeiDou would continue even though they are not covered by Job Cards. Papers reviewed by the meeting covered topics that included updates to the GLONASS SARPs, initial SARPs material for the BeiDou and Galileo core constellations, updates to the SBAS SARPs, and a few other topics. The meeting reviewed the status of GBAS implementations, and considered the maintenance of existing GBAS CAT I SARPs and the validation of the SARPs material on GBAS CATII/III.

IP/5 - AOSWA -2

2.3 The 2nd AOSWA Workshop on Space Environment Impacts and Space Weather Forecast Models was held in November 2013 in Kunming, China. The purpose of the workshop was to promote the regional linkage and information sharing of operation and research on space environment by bringing together members of the Asian-Oceania scientific community as well as other international organizations concerned with space weather. It also provided an opportunity to discuss recent achievements in observational, theoretical, modeling, forecasting, and application addressing the research areas of space weather and environment. The workshop included 5 different sessions:

- Space Weather Research and Exploration
- Space Weather Forecasting and Modeling
- Space Weather Research to Operations
- Space Weather Research on Solar Activities
- Space Weather Research on Ionosphere and Thermosphere

The report is available in the AOSWA Link Vol. 3
http://aoswa.nict.go.jp/news/pdf/aoswalink_issue3.pdf.

Review of status of States' activities by ISTF/4

2.4 An extensive update of the different constellations was made during ISTF/4 as follows.

GPS/WAAS

2.5 FAA informed the meeting that the transition to dual signal was planned for 2020 - 2023. There were 4000 LP/LPV procedures existing in FAA. As the U.S. continues to modernize GPS, new capabilities and signals were being developed and employed including L2C, L5, and L1C. The 4th signal, L1C, is designed with international partners for interoperability and will be

broadcast with GPS III in 2015. The U.S. expected 24 GPS III satellites to be in operation by 2026. The U.S. Air Force Command began testing the new civil signals (L2C and L5) in the latter half of June, 2013. The control segment is also being updated to enable new capabilities for the new signals.

EGNOS

2.6 The meeting was informed that EGNOS technology is facing obsolescence, around 50 % of the issues were solved with the current system version V2.3.2, and new RIMS were deployed in Agadir and Abu Simbel. PROSBAS activity, based on EC funding, was considering DFMC. The operational availability of EGNOS was improved in v2.2 with changes to ionospheric processing. Cooperation between ESA and ASECNA has started about ionospheric studies. The performance should be improved (LPV-200) and multi-frequency/multi-capacity integrated in future versions.

GALILEO

2.7 The Funding of Galileo for full deployment and exploitation was secured. A new GNSS regulation issued in December 2013 requests to cover all EU States.

MSAS

2.8 The meeting was recalled by JCAB that air navigation services offered ranged from en route to NPA RNP 0.3, relying on 8 reference stations.
Main users included regional air carriers, government, fire-fighting and medical sector. Studies about LPV-200 are in progress.

SDCM

2.9 The Russian Space agency updated the meeting on GBAS and SBAS with the project LCCS-A-2000 to combine the use of GBAS stations as additional RIMS SBAS, presenting the advantage inter alia of the proximity to the crew of landing decision point. Today all airspace is covered by GBAS stations. A number of GBAS stations would be used to support SBAS-based procedures. Communication infrastructure should be provided by at least two different service providers. Changes into the Federal aviation rules were introduced concerning the use of GBAS.

K-SBAS

2.10 Republic of Korea made an update on its SBAS program. K-SBAS APV-1 safety-of-life service is planned from 2022 based on L1. CAT-I experimental system based on L1/L5 is planned to be tested until 2021.

BeiDou

2.11 In the future BeiDou would support multifrequency and multi augmentation systems. From 2019 the system would be modernized, transitioning to B1C and B2a.

GAGAN

2.12 Deployment of monitoring stations outside of India is being studied and is believed to benefit to India and its neighbors as well. GAGAN signal is planned to be used outside of the civil aviation community, for railway (fog pass, collision avoidance, etc.), ship positioning, etc. Different manufacturers provide now GAGAN receivers.

SBAS Ionospheric Working Group

2.13 The first meeting was held in 1999. The objective is to facilitate interaction of ionospheric scientists supporting SBAS, harmonize threats and threat models. Two white papers were IONO Research issues for SBAS, 2003, taken into account by the Navigation System Panel, and Effect of iono scintillation on GNSS, 2010. MOPS are being updated. It was recalled that the solar cycle 24 presents weaker disturbance than solar cycles 21, 22 and 23. Formal cooperation was about to take place with Stanford university.

EGNOS ionosphere related activities

2.14 The cooperation and exchange of data have recently started with ASECNA. EGEP/EGNOS iono activities consist in assisting industry for their algorithms and conduct qualification of EGNOS v3. Reference models for performance assessment and qualification were built and 5 scenarios oriented on integrity, availability, or sensitivity testing were developed. The approach followed was data-driven and not dependent upon the complex and dynamic parameters characterizing ionosphere and atmosphere. For the purpose of Scintillation performance analysis, ESA decoupled the receiver effects from the system effects and is being working on scintillation requirements. A network of 5 monitoring stations, SAGAIE, was deployed in Africa.

Performance of SBAS System and Challenges in maintaining Uplink station in the Equatorial Region for the SBAS - GAGAN Experience

2.15 Airport Authorities of India (AAI) presented the results of the analysis done to study the effect of scintillation on the continuity of service of the GAGAN system during its operational tests and evaluation for APV 1 service, and HPL and VPL went over the APV 1 limits. The challenges of integrating uplink station with GEO stationary satellite and maintaining the uplink station in the equatorial region were highlighted. Scintillation affects the downlink and not the uplink.

2.16 The conclusions of the study conducted during the Geo integration of the GAGAN navigation payload with the uplink station were discussed:

- The scintillation effect is predominant in the equatorial region and is post dusk phenomena;
- The continuity of service is affected by the scintillation and other ionospheric effects; and
- The performance of uplink station is also prone to scintillation effects.

Correlation of Scintillation and Loss of Lock for GNSS systems

2.17 India highlighted the purpose of their study to continuously examine the scintillation data over the Indian region and gain a preliminary understanding of the relationship between loss of lock of the receiver and scintillations. This phenomenon of loosing lock at a lower value of S4 index and not loosing lock even when S4 index is comparatively higher in similar conditions raises the question of the sufficiency of S4 index alone to understand the loss of lock phenomenon due to scintillations.

2.18 The meeting agreed that the relationship between the S4 index and loss of lock would need to be further analysed. It was noted that 5 years ago EGNOS used the loss of lock statistics, but were related to a particular RAIM receiver, hence the need for decoupling the receiver side that had then been pursued.

Update on the current status of ionospheric and space weather research and development in Australia

2.19 Australia presented the current status of ionospheric and space weather research and d evelopment. A real time map of a proxy index for ionospheric scintillation derived from high rate GNSS data was added to the suite of space weather products for satellite communication and navigation. It complemented the existing S4 scintillation map derived from Ionospheric Scintillation Monitors (ISM) while providing a denser spatial sampling, and used all available high rate CORS GNSS data streams from the region of interest. The real time map is available at: http://www.ips.gov.au/Satellite/1/2/2.

2.20 A recent research suggested that reasonable accuracy can be achieved in prediction of the quiet time occurrence of EPB with the use of a physics-based coupled ionosphere-thermosphere model, for which the most important driver of daily variability is the geomagnetic activity level (e.g. Kp) which can in turn be modeled with good accuracy from in-situ solar wind observations.

2.21 The GNSS Research Centre Curtin University and Geoscience Australia, under the umbrella of the Cooperative Research Centre for Spatial Information (CRCSI) have commenced at research programme aimed at improved monitoring and modelling of ionospheric scintillation in the southern equatorial anomaly region, including the installation of 9 additional ISMs throughout the region. The ISMS are Septentrio PolaRxS.

Brief status updates (round-table)

2.22 The Philippines indicated that it was in the process to classify the data collected. Concerning data collection, 17 active stations were collecting data. No data was available yet for scintillation analysis since all stations are configured to log at 1Hz. The meeting was informed that out of 6 planned new stations in 2013, 3 were ready for installation.

2.23 In connection with agreement for data utilization, the MOA between NAMRIA and CAAP was approved for use of data, and MOA for sharing data with ISTF was expected to be completed in Q2 2014.

Data Collection (Task 1)

Update on the data server and its usage

2.24 As a reply to **ACTION ITEM3/3 (**Task Lead, Task-1 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 in cluding keeping logs for accessing the restricted data), Japan presented the setup of the ISTF data server for data sharing and exchange installed at ENRI, Japan and introduces how to access the server. Comments received from NICT were that the website was easy to access.

2.25 A question was raised about the format of data to be uploaded (GTEX, SCINTEX). For GTEX, it was recalled that the BIAS correction was an option and the need for consistency over all contributions was therefore highlighted. The meeting agreed that **only data without BIAS correction** would be uploaded onto the Data Server, and to have short guidelines developed about how to generate data in GTEX.

Current status of coordination of two different SCINTEX formats

2.26 Japan reported upon the current status of coordination of two different SCINTEX for mats proposed by ICAO/ISTF and ITU-R with the Chairman of ITU-R WP-3L. Coordination was started to merge both SCINTEX format into a new and better SCINTEX format. The meeting discussed that there would be no backward compatibility problem on APAC's side as there was no data collected in SCINTEX format so far. Coordination should take place and agreement reached with in one month due to planning constraints on ESA's side. Action ITEM 3/1 was closed.

Current status of data conversion tool and database of GTEX

2.27 Japan informed the meeting about the current status of data conversion tool and database of GTEX. RNX2GTEX 1.0, software to convert RINEX data to GTEX (ver. 1.0) data, was now available from a NICT website. All the RINEX data collected by NICT Database were converted to GTEX 1.0 data and ready to be stored on the ENRI data server. One more requirement was considered necessary by the meeting when converting from RINEX to GTEX. Older version of software could be used only when there was a unique combination of observables to derive TEC data.

Readiness of States' data

2.28 During the ISTF Webconference #1 (24 June 2014), Philippines indicated to be almost ready to send out their data in GTEX format and were awaiting the official approval. Australia could make available its data as well. India would send the first set of sample data (3 seasons for 3 years) end of June 14. Interesting dates would then be uploaded to the ENRI server, at the earliest, probably around end of July 14. MICT was ready to upload their data by the end of June 14.

2.29 GTEX SCINTEX would be discussed in ITU-R meeting in Sep. 14 (Geneva) for final validation of the format. Yet data collection could be progressed meanwhile with the draft format currently defined.

<u>Ionospheric Analysis (Task 2)</u>

Periods of Interest

2.30 On behalf of Republic of Korea, Japan presented the selection process of the past periods of interest for ionospheric data analysis by using geomagnetic indices, in response to the Action Item 3/4 (*Task Lead, Task-2 to identify the past periods of interest for data Analysis)*. The dates were selected from 2001 to 2013 based on the value of geomagnetic indices. Two geomagnetic indices; Disturbance storm-time (Dst) index and Kp index are used. The Kp value of 6 and the Dst value of -200nT were determined as selection criteria based on previous studies. The resulting number of selected dates was as follows:

Selection Criteria	Number of selected dates
Kp>6	122
Dst<-200nT	15
Kp>6 or Dst<-200nT	123
Kp>6 and Dst<-200nT	14

2.31 The dates of interest were documented into a file with MS-excel format. The meeting discussed the criteria and opined that they were appropriate for mid-latitudes, but action should be tak en for the equatorial region.

Methodology of scintillation data analysis

2.32 Japan presented a working paper discussing one of the possible analysis methodologies of ionospheric scintillation data. The scintillation mapping as presented in IP/11 in ISTF/3 is one of the possible representation of the ionosphere, where the occurrence rates of ionospheric scintillations can be calculated in a certain size of latitude and longitude grid bins. This was recognized as more suitable for SBAS applications where the characteristics of the ionospheric scintillation in wide area are needed.

2.33 For GBAS, the azimuth-elevation analysis of occurrence probability of ionospheric scintillation at a few selected magnetic latitudes was proposed to be an analysis methodology of ionospheric scintillation for GBAS for ISTF Tasks 4 and 5. The meeting adopted this approach as one method for characterization of scintillation effects. ESA highlighted that this study was of high interest for their own application.

Characteristics of TEC over Indian region

2.34 India presented the characteristics of GPS-TEC based on the iono analysis procedure defined by the paper IP/07 in the Third Meeting of Ionospheric Studies Task Force. The TEC data from GAGAN network at three different regions - Magnetic equator, Anomaly Crest region and Mid-latitude have been used for this analysis.

2.35 A quadratic correlation was calculated for Geomagnetic quiet days and geomagnetic disturbed days for the 3 stations Agatti (Magnetic equatorial station), Raipur (Anomaly Crest region) and Shimla Mid-latitude station for the period between the year 2004 to July 2013.

2.36 During the ISTF Webconference #1 (24 June 2014), it was discussed that data analysis could be based on raw AATR, but the approach would need to be further developed. EGNOS used AATF to detect worst cases. A paper may be presented on the use of AATR based on world IGS data at the Institute Of Navigation (ION) meeting in Sep. 14, including APAC data.

<u>TEC Generation (Task 3) and Scintillation Data (Task 4)</u>

ISTF data processing tasks

2.37 Australia presented a partial list of items for discussion related to ISTF data processin g tasks (Tasks 3 and 4) which were discussed by the meeting:

- the meeting confirmed the need to convert data to a common format, which would be done on the ENRI server;

- about the use of ionospheric gradient estimation tool (LTIAM if approval granted from FAA, or ENRI code, or both?), the meeting was informed that the a pproval by FAA was pending. LTIAM would be used for longer baselines and ENRI's method for shorter ones;

- concerning the manual verification of detected gradients required by both techniques, it was discussed that LTIAM was automated to reduce the work of manual check while for ENRI's tool, manual verification should be used;

- consistency of methods for inter-frequency bias estimation should be ensured. NICT offered to contribute to the verification of BIAS estimation;

- as to the data format for storage of ionospheric gradient data (dependent in part on the decision on software for ionospheric gradient estimation), textual format could be used and the output format of ENRI's tool could be tailored later on for analysis;

- regarding the server(s) needed for data processing tasks, ENRI offered their server's computing power for the data processing, and if further power was needed, the solution should be discussed; and

- concerning the scintillation indices to use, the meeting recognized this should be further discussed

2.38 The Tasks 3 and 4 membership was discussed. During the meeting Australia volunteered with one member (task leader), India with one member, Japan with one member, and Republic of Korea would investigate and confirm their membership by email to the Chairman. More States could join the effort at any time.

Iono Models (Task 5)

Development of two ionosphere models for Indian region

2.39 India presented the development of two ionosphere models: two shell model & a model using Klobuchar-like coefficients for the Indian region. The TEC data from GAGAN network jointly collected by AAI and ISRO was used to validate the two-shell model and to generate Klobuchar-like coefficients for the Indian region. Significant improvement in ionosphere prediction capability over Indian region was observed using both the models.

Presentation by ISRO about GAGAN and IRNSS

2.40 ISRO presented their observations on GAGAN, an ionospheric Model for GAGAN, and grid based & co-efficient based corrections for IRNSS, and the first results of the depletion studies being conducted.

Space Weather (Task 6)

Space Weather considerations

2.41 Japan presented its review of the Space Weather Concept of Operations (Space Weather ConOps) being developed by ICAO and presented some considerations on the use of space weather information for GNSS implementation in the low magnetic latitude regions. Five classes of space weather phenomena are identified:

1) geomagnetic storms
2) solar radiation storms
3) radio (HF) blackout events
4) galactic cosmic rays
5) ionospheric activity

2.42 Solar radiation storms and galactic cosmic rays Intensity of radio (HF) blackout events caused by solar flares are global scale phenomena affecting the aviation in the high latitude region, which should be treated at the global level in ICAO. Geomagnetic storm is a global phenomena and should also be treated at the global level. Geomagnetic storm is closely related to ionospheric activity, and its effects on the ionosphere are different for latitudes. Even in the low latitude region, the effects are very different. For example, during the magnetic storms, eastward electric field is sometimes enhanced in the dayside and transport ionospheric plasma poleward. This causes decrease in the ionospheric density inside the Equatorial Ionization Anomaly (EIA) crests and enhancement outside the EIA crests. Geomagnetic storm can cause the decrease in the ionospheric density, called the negative storm, and lower the maximum useable frequency of HF communications. It is caused the thermospheric composition changes induced by enhanced auroral activities in the high latitude region and propagates lower latitudes. It is noteworthy that the area of the negative storm is not global and relatively localized. Thus, the effects of geomagnetic storms on the ionosphere have local variabilities.

2.43 The thermosphere is a part of space weather, but needs quite different treatment compared with other classes of space weather phenomena listed in the Space Weather ConOps. From the point of view of the low latitude region, ionospheric activity is of the special interest. Focusing on local effects of geomagnetic storms on the ionosphere and EIA variation and plasma bubbles without geomagnetic storms could be effective, because the current Space Weather ConOps that is globally oriented may not cover them.

2.44 The meeting considered this may be valuable feedback to the draft Conops document and discussed the opportunity to direct these comments, along with other potential comments from participants, to International Airways Volcano Watch Operations Group (IAVWOPSG) and considered the following action:

2.45 The meeting was informed of the ongoing assessment by India of the space weather effects on GAGAN. The recent solar storms- geomagnetic and radiation storms were selected to analyze the impact on availability of GAGAN service APV1/1.5 and RNP 0.1. It was observed that due to the geomagnetic storm of 16-18 March, 2013, equatorial ionization anomaly was enhanced on 16 March. The strength of anomaly on 18 March was weaker than previous days. However, the availability of GAGAN APV 1 service decreased to zero on that day. The large spatial and temporal gradients could be one of the reasons for degraded performance of GAGAN. More detailed analysis is required for this verification.

2.46 The availability of GAGAN APV1 service was more affected more on the next day of main phase of storm i.e. during recovery phase of storm, whereas storms during summer months were found to have negligible impact on GAGAN system, implying seasonal dependency of geomagnetic storms on low latitude ionosphere. The space weather effects on GAGAN RNP 0.1 service were noticed to be negligible as GAGAN maintained its required availability and continuity. The meeting considered the paper as valuable information, particularly concerning the degradation of availability and helpful in defining the period of interest for analysis.

Reinforcement of international cooperation for establishment and operation of SBAS in the Future

2.47 Considering the activities on the establishment and operational service of SBAS are being actively implemented around U.S, EU, China, India and Japan, Republic of Korea informed Member States having an interest in the future satellite-based navigation system such as SBAS of its proposal to designate a point of contact sharing information about satellite-based navigation service provision. The meeting discussed that for establishment and coordination of policies and standards, the ANC and its NSP was the right forum. Any specific implementation problem could be handled at the regional level. Informal technical like IWG offered a very valuable opportunity to coordinate early considerations about future standards and implementations, and were tightly working with NSP.

Potential cooperation with ESA

2.48 A brainstorming on an initial list of items of common interest between ISTF and ESA was done during the meeting. The outcome was:

- Data exchange
- Ionospheric effects in low latitude
- System validation with associated models
- Mapping function
- Data format

2.49 Bearing in mind the workload and tight schedules on each side, it was agreed to refine this initial list and assess feasibility considering potential Intellectual Property issues. It was discussed that Action item 4/3 was a simple and short term action that would allow assessing the efficiency of exchanges. If concrete tracks of collaboration were consolidated, the ICAO regional office would coordinate interregional aspects with NSP.

Action table

2.50 The latest action table as updated by ISTF webconference #1 (24 June 14) is placed at **Attachment A**.

3. ACTIONS REQUIRED FROM THE MEETING

3.1 The meeting is invited to note the information provided in this paper about the progress of ISTF activities.

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Action Item	Action	Owner	Contributors	Target date	Status	Result	Comment
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	Open		7 feb. 14: approval from FAA is pending
ACTION ITEM 4/1	to check whether and under which conditions Septentrio data could be shared within ISTF	Australia		31-Aug-14	Open		Australia has to check the status of the project
ACTION ITEM 4/2	To develop guidelines about how to generate data in GTEX	Task 1 Leader		31-Jul-14	Open		
ACTION ITEM 4/3	To finalize SCINTEX format with ITU by email	Dr. Tsukawa, Japan		30-Jun-14	Open		In progress through emails and F2F - Final agreement to take place, depending on ESA side
ACTION ITEM 4/4	To provide the dates relevant for data Analysis relating to equatorial ionospheric anomalies	all participants		31-Mar-14	Open		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.
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-14	Open		In progress -
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 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