Report of Working Group B: Enhancement of GNSS Performance, New Services and Capabilities

9 and 10 November 2016, Sochi, Russian Federation

1. The Working Group on Enhancement of GNSS Performance, New Services and Capabilities, co-chaired by the European Space Agency (ESA), China and the Indian Space Research Organization (ISRO), held its eleventh annual meeting in Sochi, Russian Federation, on 09 and 10 November 2016, preceded by a dedicated session on Space Service Volume (SSV) on 08 November 2016.

2. During the dedicated meeting on the subject of establishing an interoperable GNSS Space Service Volume (SSV) the status of the SSV booklet preparation was reviewed including the progress on the supporting simulations. The specifications of detailed mission profiles (GEO, Scientific HEO, Lunar) was discussed and the specific tasks were assigned to the group members carrying out the simulations. The plan for integrating the results in the SSV booklet was refined, leading to a completion of the booklet in 2017. An outreach activity on the benefits of an Interoperable GNSS SSV is planned for the Munich Satellite Navigation Summit in March 2017. All service providers confirm their support to this event. Additional outreach in form of conference contributions or magazine articles are planned. NASA has available an illustrative video for promoting the Interoperable GNSS SSV. Initial comments on the video are collected for consideration in a future version of the video.

3. At the tenth annual meeting of WG-B the following presentations were given and discussed:

   (a) The Application Subgroup, established within WG-B and co-chaired by China and Japan, presented its latest work resulting in an electronic questionnaire that can be used to identify future GNSS user needs. ICG participants are invited to fill the questionnaire in order to provide feedback and guidance to the work conducted by the Application Subgroup in its collection of future user needs specific to different application domains including among others personal navigation, timing, agriculture and disaster management. The questionnaire is available under the following link: http://121.42.29.87/index.php/377458?lang=en. A future plan identified by the Application Subgroup is to establish a link to the electronic questionnaire from the ICG website once the content of the questionnaire is reviewed and initial feedback is obtained.

   (b) The European Space Agency (ESA) reports on the status of gravitational redshift tests conducted with Eccentric Galileo Satellites. Two Galileo satellites were injected into an eccentric orbit in 2014 due to an anomaly of the launch vehicle upper stage. The high eccentricity of the resulting orbit together with the highly stable on-board Passive Hydrogen Maser clocks allows to test interesting features related to General Relativity, especially on the so-called gravitational redshift. The periodic variation of the gravitational potential along the orbit allows to monitor the gravitational redshift. Averaging the measurements over long periods (> 1 year) allows to push the accuracy of the redshift monitoring by 1 order of magnitude compared to current state-of-the-art. Two parallel activities are executed and first consolidated results of these tests will be reported by ESA at following ICG meetings.

   (c) The European Commission (EC) presents on the Search and Rescue Service (SAR) Status in Galileo. The SAR Service in Galileo consists of two distinct elements, the Forward Link Alert Service as a contribution to the Cospas-Sarsat MEOSAR programme and the Return Link Alert Service, which provides to users in distress an acknowledgement message informing them that the alert has been detected and located. The forward link is according to Cospas SARSAT standard with uplink at 406.05 MHz and downlink at 1544.1 MHz. Three Medium Earth Orbit Local User Terminals (MEOLUT) cover the SAR areas over Europe. The return link service is a unique Galileo feature using the Galileo E1 navigation message for broadcasting the acknowledgment messages. A significant step on the Galileo/SAR service will be achieved at Initial Service Declaration by end 2016. The return link service implementation is on its way and will provide significant added value to the SAR Service.

   (d) BeiDou expresses its interest in Search and Rescue Applications and presents its future conception. BeiDou as a fully operational regional satellite system provides also the capability of Short Message Communication at regional scale in duplex mode, which has the potential to be used as SAR utility. The concept has already been used during an Earthquake event in 2008. Additional use cases are under assessment. The SAR concept based on Short Message Communication uses an uplink frequency of 1671 MHz and a downlink frequency of 2492 MHz. Working group participants identify that this frequency selection is different from the Cospas-Sarsat MEOSAR frequency selection. It is identified that assessments on BeiDou side are ongoing to analyse the relation between BeiDou and Cospas-Sarsat MEOSAR with the objective to improve interoperability. This assessment is appreciated by working group participants. WG-B invites BeiDou to report on the outcomes of this assessment once available.

(e) NASA updates on the activities ongoing on MEOSAR in GPS. The benefits of MEOSAR compared to LEOSAR are discussed, in particular what regards localisation accuracy and availability. The presentation establishes the status of MEOSAR implementation in GNSS. At present Galileo and GLONASS satellites are carrying SAR transparent payloads in support to MEOSAR. A first SAR payload according to MEOSAR standards onboard a GPS satellite is expected to be launched in 2023 with GPS III SV-11. By 2033 24 operational SAR payloads are expected in orbit onboard GPS satellites. The Distress Alerting Satellite System (DASS) implementation is ongoing as a proof of concept for future MEOSAR SAR onboard of GPS II and future GPS III satellites, with a downlink in S-band compared to L-band which is the MEOSAR frequency. In order to provide global SAR coverage around 10-20 MEOLUTS (Medium Earth Orbit Local User Terminal) are considered necessary, out of which 12 are expected to be deployed by Jan. 2017.

(f) In relation to novel integrity concepts, the EU and the U.S. summarise the latest Advanced Receiver Autonomous Integrity Monitoring (ARAIM) Milestone Report available on the internet on www.gps.gov and www.ec.europa.eu websites. ARAIM is considered to be the natural evolution of classical Receiver Autonomous Integrity Monitoring (RAIM) to support multiple constellations, dual frequency services and operations with more stringent integrity needs (e.g. vertical guidance that cannot be supported with classic RAIM). The ARAIM development is meant to take an evolutionary path, starting with horizontal ARAIM (H-ARAIM) first and later to be expanded to vertical ARAIM (V-ARAIM). Availability results are presented identifying the necessary performance to be provided by participating constellations in terms of ranging accuracy, probability of satellite fault and constellation faults as a function of the target service level. The next tasks of the EU/U.S. working group on ARAIM will include research and development activities for aviation as well as other user communities together with activities contributing to the preparation of ARAIM Standards for the Aviation community.

(g) The Russian Federation provides an update in relation to the ongoing SSV activities of WG-B, with particular focus on in-orbit experience of GLONASS-capable space receivers. At present more than 6 GEO and HEO satellites are operated by Russia embarking a GLONASS and GPS space receiver. User antenna gain pattern and receiver sensitivity are identified as important factors determining PVT availability. The space receivers are exploiting the edges of the main lobe and in some cases also the first side lobe of the signals transmitted by the GNSS satellites. Practical experience of using a GLONASS and GPS space receiver onboard a GEO satellite is reported, identifying that the geometrical distribution of the measurement sources should also be considered for SSV analyses (as it is done for on-ground performance assessment). It is also recommended that the C/No level for different operations are considered for the availability analyses.

(h) The Russian Federation presents a proposal for a possible classification of space user navigation equipment. The classification can be approached from different directions. The target mission type, including orbit and application type can be a first classification element. Also the function to be provided by the space receiver can allow a classification. The required performance levels in terms of position/timing accuracy or signal processing sensitivity allows an additional level of categorisation for space receivers. In addition the systems and signals supported by the space receiver provide differentiation capability between space receivers. WG-B participants and related space agencies are reminded on the ongoing work in relation to SSV which also has the objective to establish and maintain a list of existing space receivers and their capabilities (see Recommendation in Attachment 1.2 regarding GNSS Space User Database).

(i) In relation to the WG-B task on improving the ionospheric modelling, the Chinese Academy of Sciences briefs on the introduction of a Global Ionospheric Map and a Ionospheric Monitoring Receiver in China. A global ionospheric model based on Spherical Harmonic function is established to represent variation in ionospheric Total Electron Content (TEC) at global scale. In addition a local ionospheric model based on trigonometric series functions is established at each station to capture the regional ionospheric variation. Integrating both models can improve the accuracy of the ionospheric modelling. The resulting model was validated using available reference data over the period 1998-2015. Significant improvements in terms of accuracy for the Global Ionospheric Maps (GIM) are identified. The new GIM product has been submitted to the International GNSS Service (IGS) for the final GIM Combination. A receiver dedicated to Ionospheric Monitoring (for TEC and scintillations) processing dual frequency GPS, GLONASS and BeiDou observations is presented. This receiver is installed at 35 stations in the southern areas of China, which is the first network for ionospheric monitoring in China. The network plays an important role for Space and weather monitoring in China.

4. The progress of ICG-10 recommendations is assessed.
   - The updated workplan as endorsed during ICG-10 is in place and is followed up. It is noted that the new work item on space Weather Aspects requires additional push.
   - China was appointed at ICG-10 as additional co-chair to WG-B and is since then actively supporting the preparation and organization of WG-B meetings.
   - The recommendation related to the use of GNSS satellites in eccentric, non-nominal orbits for scientific experiments is followed up and initial experimental concepts are presented.

5. WG-B plans to organise at least one WG-B Interim Meeting in June 2017 in conjunction with the ICG-12 Preparation meeting in Vienna with particular focus on SSV, Space Weather and possibly on Future Integrity Concepts.

ATTACHMENT 1.1

WG-B Recommendation 1 Endorsed by Committee Decision

Prepared by: **Working Group B: Enhancement of Performance of GNSS Services**

Date of Submission: **10/11/2016**

Issue Title: **Support to SSV in Future Generation of Satellites**

Background/Brief Description of the Issue:
The importance of establishing an Interoperable GNSS Space Service Volume is acknowledged by Space Agencies and Service Providers. Important progress has been made in establishing the interoperable GNSS Space Service volume also based on data that was released by the Service Providers.

Discussion/Analyses:
Service providers have been actively contributing to the completion of the SSV templates that include the support of the SSV of the different systems. Many GNSS provided data in the SSV template derived from measurement and characterization efforts conducted based on existing satellite designs.

Recommendation of Committee Action:
Service providers and Space Agencies are recommended to define the necessary steps and to implement them in order to support SSV in future generation of satellites. Service Providers and Space Agencies are invited to report back to WG-B on their progress on a regular basis.

ATTACHMENT 1.2

WG-B Recommendation 2 Endorsed by Committee Decision

Prepared by: **Working Group B: Enhancement of Performance of GNSS Services**

Date of Submission: 10/11/2016

Issue Title: GNSS Space User Database

Background/Brief Description of the Issue:
The understanding of user needs is an essential element for any service implementation or service evolution. This in particular also applies to the case of the Space Service Volume as the user needs are highly depending on the specific space mission and the use case of the on-board GNSS receiver.

Discussion/Analyses:
The understanding of the user base is critical for the development of the Interoperable GNSS Space Service Volume. An exhaustive identification of space missions embarking a GNSS receiver is essential in order to ensure a comprehensive view on the mission needs and the use cases of the GNSS receiver.

Recommendation of Committee Action:
All providers and space agencies are recommended to contribute to the IOAG database of GNSS space users. Contributions should be reported to WG-B, which should then contribute to the IOAG via the ICG-IOAG liaison.

The data included in the database should include the following:

Basic details:

- Mission name & agency
- Actual or planned launch date
- Development phase (planned, in development, on-orbit, historical)
- Orbit regime (LEO, HEO, GEO, cis-lunar, etc.)

GNSS usage:

- GNSS constellations used
- GNSS signals used
- GNSS application (navigation, POD, time, radio occultation, etc.)
- Acquisition methods used (traditional, carrier phase)
- Solution method (point solution, filtered solution, etc.)

ATTACHMENT 1.3

WG-B Recommendation 3 Endorsed by Committee Decision

Prepared by: **Working Group B: Enhancement of Performance of GNSS Services**

Date of Submission: **10/11/2016**

Issue Title: **Additional Data for Space Service Volume**

Background/Brief Description of the Issue:
In order to exploit the Interoperable GNSS Space Service volume for space missions or to develop GNSS space receivers, information from the service providers regarding the power emissions for wide off-boresight angles are essential. Initial information on this aspect is available from every service provider.

Discussion/Analyses:
Recognizing the success of WG-B in encouraging all providers to provide SSV service details in templates for their constellations, GNSS space users now have the data necessary to determine if the SSV service is applicable to their needs.

Recommendation of Committee Action:
In order to fully support in-depth mission-specific navigation studies, WG-B invites the providers to consider for the future, to provide the following additional data:

- GNSS transmit antenna gain patterns for each frequency, measured by antenna panel elevation angle at multiple azimuth cuts, at least to the extent provided in each constellation's SSV template.
- GNSS transmit power, after considering any transmission losses inherent to the system

In the long term, also consider providing the following additional data:

- GNSS transmit antenna phase center and group delay patterns for each frequency