Report of Working Group B: Enhancement of GNSS Services Performance

1. The Working Group on Enhancement of Global Navigation Satellite Systems (GNSS) Service Performance (WG-B) of the International Committee on GNSS (ICG) held in accordance with its work plan the following annual meetings

(a) 1st Meeting during ICG-2 on 06 September 2007,

(b) 2nd Meeting during ICG-3 on 11 December 2008,

(c) 3rd Meeting during ICG-4 on 16 September 2009,

(d) 4th Meeting during ICG-5 on 20 October 2010,

(e) 5th Meeting during ICG-6 on 07 September 2011,

(f) 6th Meeting during ICG-7 on 07 November 2012,

(g) 7th Meeting during ICG-8 on 12 November 2013.

In addition to this annual meeting, one WG-B interim meeting on GNSS Space Service Volume and Emerging Applications was held on 12 June 2013 in Vienna.

The WG-B Application Subgroup convened according to its Terms of Reference (ToR) for two meetings on 14 May 2013 in Wuhan, China and on 18 July 2013 in Daejeon, South Korea.

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

(a) A briefing on the outcomes of the two meetings of the WG-B Application Subgroup meetings held during 2013 was given by the co-chairs of the group. The subgroup investigated since its establishment applications in the area of Personal Navigation, Transportation, Disaster management, Liability, Agriculture, Timing and Surveying. Important enablers for these applications were identified to be High Accuracy, Integrity, Authentication and Communication means. The subgroup will continue its work according to its ToR.

(b) Continuing the work of the previous WG-B sessions, the National Aeronautics and Space Administration (NASA) provided further background on the benefits an interoperable GNSS Space Service Volume will offer to all space users. At GEO altitude only the space-service-level interoperability of all four GNSS will ensure a continuous availability of more than four ranging sources. This space-level interoperability of all 4 GNSS enables also an important reduction of the Geometric Dilution of Precision improving this significantly the position accuracy achievable. GNSS space user performance templates have been made available to characterise the performance of the GNSS for Low Earth Orbit (up to 3000 km altitude) and High Earth Orbit (3000 km up to GEO altitude) space users.

(c) In continuation of the SSV discussion, the China Academy of Space Technology gave a presentation on the BeiDou Space Service Volume parameters and its performance. The need and benefits of an interoperable GNSS SSV are confirmed and BeiDou expresses its willingness to support it. Results of BeiDou III availability calculations are presented for different orbital altitudes, exploiting the expected antenna gain characteristics of the BeiDou III spacecrafts. These results further confirm the need for an interoperable GNSS SSV in particular for GEO to allow sufficient ranging source availability. The expected BeiDou III performance characteristics are presented making use of the available GNSS space user performance template.

(d) The presentation of JSC focuses on the existing GLONASS capabilities as provided to space users. A characterisation of the current and future GLONASS space service capabilities is contained in the presentation, which makes use of the existing GNSS

space user performance template. Histograms on the number of available GLONASS and GPS ranging sources at GEO altitude based on real measurements underline the need to establish an interoperable GNSS space service volume. An outlook on the current developments for Radionavigation equipment is given, underlining this the actual need case for the SSV.

(e) The Joint Research Centre (JRC) contributed to the WG-B session in the area of GNSS signal evolution with a presentation identifying a generic Methodology to Estimate the Time To First Fix (TTFF) applicable to any GNSS signal. The TTFF refers to the time span between the receiver switch on and the output of a first position fix. The TTFF is depending on the GNSS signal characteristics as well as on the receiver configuration. The TTFF is an important factor to characterize the quality of the GNSS signal design. A comprehensive analytical methodology is presented where the starting condition of the receiver (i.e. cold, warm and hot start) is considered and the TTFF is broken down into its individual, contributing elements.

(f) The relevance of wideband signals for multipath reduction and thus for high user accuracy was addressed by the Technical University of Moscow. The multipath error can be fought against at various instances, starting at the signal design level, specific antenna features and last but not least at the digital part of the receiver. Multipath envelope measurements for different receiver configuration are presented. The strong link between signal bandwidth and multipath error is re-confirmed.

(g) The U.S. Federal Aviation Administration (FAA) presented its Navigation Programs Update. The raising importance of GNSS during all phases of flight in the frame of the NextGen Navigation Services, to be fully operational by 2030, is underlined. The NextGen Precision Approach strategy is outlined in the presentation. Regarding Satellite Navigation, the plans of WAAS are defined. A guarantee on the semi-codeless tracking of L2P(Y) is only provided until end of 2020 and WAAS needs to utilize another signal to maintain the current service. The on-going deployment of GPS dual frequency capability based on L1/L5 is an important element to further improve the availability and continuity of the WAAS service. The vulnerability of GNSS-based navigation means to intentional interference and spoofing is addressed within the NextGen programme and work is conducted which lead to the identification of a variety of mitigation mechanisms and dedicated recommendations. The acceleration of Alternative PNT (APNT) concepts is one of the recommendations.

(h) The capabilities of the Differential BeiDou System (DBDS) and related research and standardization activities were presented. A test network of more than 30 reference stations has been deployed in China for the DBDS. The technical setup of the architecture is outlined. Experimentations with real data obtained from GPS only, BeiDou only and combined GPS, BeiDou have been carried out and the obtained results show already to be of high quality with a single constellation. However, the improvement that can be obtained when combining both GPS and BeiDou is still significant. Work is currently ongoing within the Radio Technical Commission for Maritime Service (RTCM) to define a Differential GNSS (DGNSS) standard aiming also to include BeiDou.

3. WG-B members were invited to propose recommendations enabling the enhancement of GNSS service performance. The status of previous WG-B recommendations was considered. Two recommendations were presented and adopted by the ICG Plenary on 14 November 2013. The endorsed recommendations of WG-B at ICG-8 are listed in Attachment 1.1 and 1.2 of this report.

ATTCHMENT 1.1:

WG-B Recommendation 1 Endorsed by Committee Decision

Prepared by: **WG-B**

Date of Submission: 13 November 2013

Issue Title: Specifying and Characterizing an Interoperable GNSS Space Service Volume

Background/Brief Description of the Issue:
WG-B has continued the efforts addressed in Recommendation 6 of ICG-6 entitled "Interoperable GNSS Space Service Volume". Since ICG-6, WG-B has made excellent progress in specifying the SSV and populating respective templates that will characterize the expected qualitative and quantitative characteristics of signals within an interoperable GNSS Space Service Volume. The SSV will open new science and technological opportunities through the use of robust, interoperable GNSS navigational signals in space, enabling missions that save lives, understand our Earth and the universe and provide economic advantages worldwide.

Discussion/Analyses:
WG-B has made significant progress in establishing an interoperable GNSS SSV during ICG-8 through significant pre-work, presentations at ICG-8 and additional robust contributions from the administrations of Russia and China. At ICG-8 several administrations presented their SSV signal templates and presented SSV performance expectations. During ICG-8, the WG-B team discussed the importance of common definitions and data needed from the GNSS constellations, in conjunction with the signal template data, to conduct consistent SSV performance analyses. We recommend that WG-B provide an additional template to develop these common definitions and data requirements and gather this data from the appropriate administrations.

Recommendation of Committee Action:
Recognizing the advantages of an interoperable GNSS SSV for the space user community, the ICG is invited to take notice that the WG-B team has taken several actions to compile definitions to support future analyses and gather template data approved by the GNSS system providers. The SSV template data, coupled with the other requested data and definitions, will enable users to analyse GNSS signal availability and navigation performance expectations for space vehicles flying in the SSV.

Providers are invited to send all action responses to the WG-B Co-chairs and Interagency Operations Advisory Group (IOAG) ICG representative. Until recommendation on SSV template is approved by ICG, the members agreed to keep this information within ICG forum. WG-B action items include:

<u>SSV Template Completion</u>

- WG-B team works with the service providers to complete and formally submit the SSV templates to WG-B co-chairs prior to the 2nd interim WG meeting
- Questions and discussion regarding the template will be addressed during a video conference to be held prior to the 1st interim WG meeting.
- WG-B team members shall be prepared to discuss their template inputs at the 1st interim WG meeting

<u>Maturity of Definition</u>

- WG-B team to develop definitions of the minimal service capability of the GNSS constellations (i.e. satellite orbit, number of satellites and constellation geometry). This will be used in conjunction with template data to perform unified GNSS SSV performance analyses

<u>Spaceborne GNSS Receivers</u>

- WG-B encourages the development of interoperable multi-frequency space borne GNSS receivers that exploit the use of GNSS signals in space

Antenna/Electronics Characterization

Stable performance of the GNSS space segment over long time periods is crucial for the scientific community. The scientific community recommends:

- Minimizing phase and group delay variations of GNSS transmit antennas vs. angle during the design phase.
- Measure phase and group delay variations of GNSS transmit antennas vs. angle, and making this information available to the scientific community
- Measure phase centre and group delay centre for GNSS transmit antennas vs. angle, and making this information available to the scientific community
- Spacecraft electronics: Maintain strict coherence of phase and group delay between signals on the same spacecraft.

ATTACHMENT 1.2:

WG-B Recommendation 2 Endorsed by Committee Decision

Prepared by: WG-B

Date of Submission: 13 November 2013

Issue Title: Harmonization of TTFF Methodology

Background/Brief Description of the Issue:
The Time To First Fix (TTFF) is an essential GNSS signal performance Figure of Merit (FoM) fully transparent to the user. The TTFF is driven by a multiplicity of factors, including the GNSS signal and message structure, user receiver configuration and start condition of the user receiver. As a consequence an unambiguous definition of the TTFF is not commonly established.

Discussion/Analyses:
An unambiguous definition of the TTFF FoM is needed in order to assess the performance of the current GNSS and derive conclusions on required performance enhancements driven by the user communities. WG-B discussed on a potential methodology to formalize the TTFF determination, breaking it down into the start conditions cold start, long-off warm start, short-off warm start and hot start. The Working Group also identified the potential need of identifying specific requirements for some classes of receivers (one of them being space receivers). Also, any analytical methodology aiming to assess the impact of different signals and systems into a (multi-system) TTFF should concentrate on the contributions being mainly dependent on signal and system parameters and characteristics, taking reasonable (common) assumptions on technology driven factors (mainly receiver implementation).

Recommendation of Committee Action:
WG-B encourages the service providers and relevant experts to review the proposed TTFF methodology and provide recommendations for its complementation. When consensus on the TTFF definition and the relevant starting conditions has been achieved, the result shall be introduced into the ICG Glossary of Terms.

WG-A and WG-B are invited to consider the above in their future activities.