

## Report of Working Group B: Enhancement of GNSS Services Performance

1. The Working Group on Enhancement of Global Navigation Satellite Systems (GNSS) Services Performance (WG-B) of the International Committee on GNSS (ICG) held in accordance with its work plan the following meetings:
  - (a) 1<sup>st</sup> Meeting during ICG2 on 6 September 2007
  - (b) 2<sup>nd</sup> Meeting during ICG3 on 11 December 2008
  - (c) 3<sup>rd</sup> Meeting during ICG4 on 16 September 2009
  - (d) 4<sup>th</sup> Meeting during ICG5 on 20 October 2010.
2. At the fourth meeting the following presentations were given and discussed:
  - (a) An overview of the US augmentation for aviation was presented by FAA (U.S.) including WAAS and GBAS.. WAAS allows for LPV-200 while GBAS in form of LAAS allows for CAT-I,II,III approaches. The operations of these systems are jeopardized by commercially available GNSS jammers, so-called “Personal Privacy Devices”, which can be purchased over internet and cause harmfully interference.. It is recommended that States and service providers establish controls to mitigate impacts of privacy jammers.
  - (b) The way integrity is considered in the design of BeiDou was presented by Shanghai Jiao Tong University (China). The BeiDou system foresees to provide worldwide integrity and investigates on the feasibility of disposing reference stations beyond Chinese territory. Apart from this, research is carried out on wide area augmentation in China with a performance target of CAT-I. Inter satellite ranging and communication is seen as essential key to provide satellite autonomous integrity monitoring.
  - (c) Activities on monitoring of the ionosphere in China were reported by Beihang University (China). As GNSS performance is impacted to a great extent by the ionosphere, China has set up its own ionosphere monitoring network. A modified Klobuchar model adapted for China Regional GNSS has been produced. New technologies like Computerized Ionospheric Tomography (CIT) can be used for fine Ionospheric parameters reconstruction. In addition a Ionospheric threat model has been developed to over-bound the ionospheric delay errors. China is willing to contribute at international level on iono-monitoring.
  - (d) An approach for compensating ionospheric and tropospheric measurement errors was outlined by the Institute of Space Device Engineering (Russia). The approach presented is based on both a up- and a downlink from a ground station towards the satellite in combination with multi-frequency RNSS signals. In addition the presented method supports the measurement of gravitational frequency shifts, and the frequency control of the onboard frequency standard.
  - (e) Possible ways to enhance GNSS performance for indoor applications were identified by ISRO (India). These include the use of assisted GNSS (A-GNSS), aspects concerning the receiver internal signal processing but also characteristics concerning the RNSS signal itself. Advanced message coding schemes like Low Density Parity Check (LDPC) or Low Density Parity Check Convolutional Codes (LDPCCC) can be considered. Coupling RNSS with terrestrial systems such as FM may support indoor applications as well.
  - (f) The outcomes of the special meeting of ICG WG-B on “GNSS User Positioning Integrity” were presented. A detailed summary report of this meeting can be found at: <http://www.osa.unvienna.org/pdf/sap/gnss/wg/report-wgb.PDF>
  - (g) A presentation was given by ESA highlighting the advantages of multi-frequency multi-system SBAS. Example calculations identified the enlargement of LPV-200

availability area when going from dual-frequency GPS only SBAS towards dual-frequency dual-system SBAS. Apart from enlarging the availability area also a reduction in Vertical Alert Limit (VAL) can be considered as a target while keeping the LPV-200 availability area.

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. In total a number of nine recommendations were provided to WG-B at ICG 5 which resulted after consolidation in a number of seven recommendations adopted by the ICG Plenary on October 22, 2010. The endorsed recommendations of WG-B at ICG 5 are listed in Attachment 2 of this report.
4. An adaptation of the work plan addressing a most important issue brought up at the meeting that has not yet been reflected in the work items was proposed by the chairmen. Radio Frequency Interference (RFI) is known as one of the most severe sources that degrade GNSS user positioning. Intended RFI generated by so-called "Privacy Jammers" needs to be seen as a serious threat to systems like GBAS that are relying on the uninterrupted and undisturbed reception of GNSS signals. Obviously intentional and unintentional interference is not only limited to these "Privacy Jammers". ICG WG-B considers it important to include the examination of techniques for RF inference monitoring and detection in its work plan. Accordingly appropriate items were added to the work plan heading into the direction of RFI mitigation at receiver level but also towards the detection and localization of RFI using existing or planned GNSS infrastructure. The other actions included in the work plan were confirmed by WG-B. The adapted work plan was presented at the Plenary of ICG 5 and was adopted. The work plan is provided in Annex 1 of this report.
5. The next meeting of the group in form of an interim meeting was proposed to be organized in the margins of the China Satellite Navigation Conference (CSNC) taking place in May 2010 (see also Recommendation 7 in Attachment 2.7). Topics to be addressed at this interim meeting of WG-B might include e.g. RF interference, multipath, integrity for land/maritime users. The chairmen will provide the group with a consolidation of topics and an agenda for this meeting well in advance.

## ANNEX 1

**REVISED WORK PLAN**  
**WORKING GROUP B - Enhancement of Performance of GNSS Services**  
**(Leads: India and the European Space Agency)**

As a unique combination of GNSS service providers and major user groups, the ICG and the Providers' Forum will work to promote and coordinate activities aimed at enhancing GNSS performance, recommending system enhancements and meeting future user needs.

Specifically, the following actions will be taken by a working group co-led by India and the European Space Agency:

**Action B1:** Examine the problem of multi-path and related mitigation actions affecting both GNSS systems and user receivers, for static and mobile receivers and recommend any required system enhancements or actions that may contribute to alleviate this problem.

**Action B2:** Examine the extension of GNSS service to indoor applications and recommend any required system enhancements or actions that may support such extension.

**Action B3:** Examine the problem of user position integrity and the related solutions (e.g. ground integrity, satellite autonomous integrity, user Receiver Autonomous Integrity Monitoring (RAIM)), and recommend any required system enhancements or actions that may contribute to meet the user requirements.

**Action B4:** Monitor the techniques proposed by application developers and external augmentation service providers for enhancement of GNSS performance with a view to recommend any required system enhancements or actions that may support the realization of such techniques.

**Action B5:** Examine techniques for RF inference monitoring and detection:

- **Action B5.1:** Examine techniques leading to the mitigation of the effects of RF interference in the GNSS user equipment.
- **Action B5.2:** Examine technical possibilities to add special functionalities on existing or planned GNSS infrastructure to support the detection and location of RF interference in the GNSS bands.

In the execution of its work, WG-B will coordinate its activities with other groups of the ICG, in particular with the Working Group A (WG-A) for those WG-B recommendations related with enhancements of interoperability across systems as well as regarding aspects of RF interference mitigation and detection.

## ATTACHMENT 2.1

### WG-B Recommendation 1 Endorsed by Committee Decision

**Prepared by:** Working Group B

**Date of Submission:** 21/10/2010

**Issue Title:** WG-B Rec. 1: RFI Mitigation

**Background/Brief Description of the Issue:**

Implementation of GBAS has detected the existence of “Privacy Jammers” that cause RFI causing the GBAS facility to cease operations.

**Discussion/Analyses:**

Although the “Privacy Jammer” devices are generally illegal to use, they are easy to obtain from sources over the internet.

**Recommendation of Committee Action:**

ICG-member states are encouraged to take appropriate actions to address this issue including the introduction of barriers to the production and marketing of these devices.

**ATTACHMENT 2.2****WG-B Recommendation 2 Endorsed by Committee Decision****Prepared by:** Working Group B**Date of Submission:** 21/10/2010**Issue Title:** WG-B Rec. 2: Global Multi-Constellation monitoring network to support integrity**Background/Brief Description of the Issue:**

WG-B of ICG had a special meeting on “GNSS User Positioning Integrity” in March 2010 identifying the potential of integrity enhancements based on R&D activities including among others multi-constellation SBAS and ARAIM (Advanced Receiver Autonomous Integrity Monitoring) and/or combinations of these concepts.

Regional SBAS monitoring networks in place today for augmentation of GPS L1 do not provide continuous monitoring of satellites, which would be beneficial for multi-constellation GNSS augmentation with ARAIM.

**Discussion/Analyses:**

A cooperative network of multi-constellation monitor stations could provide global monitoring of all constellations with fewer stations.

Working Group B includes within its work plan the follow up of development on this matter.

**Recommendation of Committee Action:**

ICG is invited to take note of the potential to establish a cooperative global multi-constellation monitoring network to support ARAIM and encourage WG-B to follow further this matter. ICG is encouraged to recognize that transparency at service provider level is an important element in achieving user positioning integrity based on multi-constellation architectures.

**ATTACHMENT 2.3****WG-B Recommendation 3 Endorsed by Committee Decision****Prepared by:** Working Group B**Date of Submission:** 21/10/2010**Issue Title:** WG-B Rec. 3: SBAS Interoperability Working Group**Background/Brief Description of the Issue:**

The SBAS service providers have established an ad-hoc working group to coordinate program strategies and resolve technical issues relative to SBAS interoperability since the 1990's.

**Discussion/Analyses:**

The IWG is beginning to address many of the technical issues identified by the ICG WG-B relative to multi-constellation dual frequency GNSS augmentation for the future. SBAS IWG has a subgroup addressing ionospheric impacts to GNSS.

**Recommendation of Committee Action:**

ICG is invited to encourage SBAS service providers to participate on the SBAS IWG to share current status and define future SBAS integrity architectures for dual frequency multi-constellation SBAS.

**ATTACHMENT 2.4:****WG-B Recommendation 4 Endorsed by Committee Decision****Prepared by:** Working Group B**Date of Submission:** 21/10/2010**Issue Title:** WG-B Rec. 4: Reduction of Vertical Alert Limit (VAL) by multi-constellation augmentation**Background/Brief Description of the Issue:**

Directions of SBAS evolution include multi-frequency, multi-constellation augmentation. This can be made use of in two directions:

- a) Enlargement of today's LPV-200 coverage area
- b) Reduction of VAL while maintaining LPV-200 coverage area.

**Discussion/Analyses:**

Simulations have shown that VAL of 12-10 m is possible based on dual constellation dual frequency SBAS augmentation while maintaining dual frequency single constellation LPV-200 coverage zone. Currently much attention is devoted to the benefit of enlarging the coverage area while reduction of VAL would be also of interest.

**Recommendation of Committee Action:**

ICG is invited to take note of the potential to reduce VAL with the use of multi-constellation dual frequency SBAS and to encourage WG-B to follow further this work.

## ATTACHMENT 2.5

### WG-B Recommendation 5 Endorsed by Committee Decision

**Prepared by:** Working Group B

**Date of Submission:** 21/10/2010

**Issue Title:** WG-B Rec. 5: Benefit of multi-GNSS for maritime and land applications

**Background/Brief Description of the Issue:**

Much of the focus of WG-B has been on the benefits of multi-GNSS constellations for aviation.

**Discussion/Analyses:**

Maritime and land users also will benefit greatly and their requirements may be easier to meet. Analysis should be performed to demonstrate benefits of multi-GNSS constellations to meet the needs of maritime and land user communities and encourage those communities to plan for adoption of multi-GNSS use.

**Recommendation of Committee Action:**

ICG is invited to take note and encourage WG-B to identify an appropriate forum focusing on maritime and/or land navigation (maritime may be easier) and figure out requirements of maritime and land applications and how those requirements could be achieved by multi-GNSS constellations.

**ATTACHMENT 2.6****WG-B Recommendation 6 Endorsed by Committee Decision****Prepared by:** Working Group B**Date of Submission:** 21/10/2010**Issue Title:** WG-B Rec. 6: Enhancement of GNSS services for Indoor**Background/Brief Description of the Issue:**

One possible enhancement of GNSS services is to make it available for in-door applications.

**Discussion/Analyses:**

1. Possibility of improvements in the GNSS receivers like receiver loop bandwidth optimization or by introducing an FEC (Forward Error Correction) scheme such as LDPC/LDPCCC to increase the detection threshold.
2. Possibility of augmenting satellite based navigation signals with terrestrial signals such as assisted GNSS or PNT information through internet in the perspective of 3GPP, 3GPP2, OMA (standards for personal communication).

**Recommendation of Committee Action:**

ICG is invited to take note and encourage WG-B to explore the possibility of enhancing the GNSS services for in-door application/navigation, paying attention to the evolution of standards in this area.

**ATTACHMENT 2.7****WG-B Recommendation 7 Endorsed by Committee Decision****Prepared by:** Working Group B**Date of Submission:** 21/10/2010**Issue Title:** WG-B Rec. 7: Interim meeting of WG-B during CSNC 2011**Background/Brief Description of the Issue:**

Chinese Satellite Navigation Conference (CSNC) is the largest navigation related conference in China with more than 1000 participants in CSNC 2010. CSNC 2011 will be held in May 2011 in Shanghai together with CPGPS (Chinese Professionals on GPS) and Shanghai Navigation Forum.

**Discussion/Analyses:**

China offers the opportunity to host an interim meeting of WG-B during CSNC 2011

**Recommendation of Committee Action:**

ICG is invited to take note that WG-B considers the organization of an interim meeting during CNSC 2011. Topics to be addressed are still under discussion and might include e.g. RF interference, multipath, integrity, land/maritime users and will be coordinated as part of the preparation.

## ATTACHMENT 3

## ICG-5 WG-B Meeting Agenda

Wednesday, October 20, 09:00 – 13:00

09:00 – 09:15	Welcome and adoption of agenda	
09:15 - 11:00	Discussion of Inputs for WG-B recommendations	
09:15 - 09:35	<ul style="list-style-type: none"> <li>U.S. Augmentation Systems</li> </ul>	L.Eldredge <i>FAA</i>
09:35 – 09:55	<ul style="list-style-type: none"> <li>Performance Enhancement in Beidou System: Integrity and Accuracy</li> </ul>	Xingqun Zhan <i>Shanghai Jiao Tong University</i>
09:55 – 10:15	<ul style="list-style-type: none"> <li>Ionospheric Monitoring in China</li> </ul>	Dongkai Yang <i>Beihang University</i>
10:15 – 10: 35	<ul style="list-style-type: none"> <li>Alternative Ionosphere and Troposphere Compensation</li> </ul>	V. Tyubalin <i>Institute of Space Device Engineering</i>
10:35 – 10:50	<ul style="list-style-type: none"> <li>Outcomes of WG-B Special Meeting “GNSS User Positioning Integrity”</li> </ul>	S.Wallner <i>ESA</i>
10:50 – 11:05	<ul style="list-style-type: none"> <li>GNSS In-Door Application</li> </ul>	N. Neelakantan <i>ISRO</i>
11:10 – 11:30	Coffee break	
11:30 – 12:00	WGB workplan Discussion	All
12:00 – 12:30	Identification of topics for special meetings of WGB until ICG6 and planning of special meetings	All
12:30 – 13:00	Organization of Preparation of Report of Working Group B to ICG Plenary	All