Report of Working Group B: Enhancement of Global Navigation Satellite Systems 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 ICG2 on 06 September 2007,
   (b) 2nd Meeting during ICG3 on 11 December 2008,
   (c) 3rd Meeting during ICG4 on 16 September 2009,
   (d) 4th Meeting during ICG5 on 20 October 2010,
   (e) 5th Meeting during ICG6 on 07 September 2011.

   In addition to the annual meetings, two interim meetings on dedicated subjects related to GNSS Service Performance Enhancement were conducted:

   (a) WG-B interim meeting on "GNSS User Positioning Integrity" on 08 March 2010,
   (b) WG-B interim meeting on "GNSS Service Performance Enhancement and Applications" on 17 May 2011.

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

   (a) A briefing on the outcomes of the interim meeting of the group on "GNSS Service Performance Enhancement and Applications" that was held on 17 May 2011 in Shanghai in the frame of the China Satellite Navigation Conference (CSNC) was provided by X. Zhan co-chair of the meeting. The meeting included discussion on topics of Performance Enhancement, Interference Detection & Mitigation, Integrity and Multi-GNSS Applications and was attended by about 60 participants from 8 countries. A number of five recommendations resulted from the interim meeting that were further discussed during the annual WG-B meeting and are reflected in the recommendations that can be found in the Attachments 2.1 – 2.7 to this report.

   (b) Following up WG-B Recommendation 5 of ICG5 (Benefit of multi-GNSS for maritime and land applications) a presentation on "Multi-Constellation GNSS and Maritime Applications" was given by a maritime expert from Kongsberg Seatex, Norway. The presentation identified the integrity related performance requirements for different phases of maritime navigation (from port operations up to ocean navigation) as identified in different International Maritime Organization (IMO) documents. The relevance of GNSS in maritime ship operations including integrity was underlined. The maritime standardization roadmap including the involved key bodies were indicated and the current status of the maritime standardization for GPS, GLONASS and Galileo was recalled.

   (c) The relevance of GNSS in the field of Transportation in China was presented by the China Transport Telecommunication & Information Center. GNSS has a broad field of application in the transportation systems of China including cars, expressways, watercrafts and waterways. This makes GNSS to a critical infrastructure element in China. Therefore it is considered as important to further enhance its accuracy, reduce its vulnerability and protect privacy within Location Based Service (LBS) applications. In addition the hybridization of navigation and communication is identified as a potential trend for future development.

(d) The concept of a potential Emergency Service based on GNSS was outlined in a presentation the European Space Agency (ESA). In the event of a natural disaster classical ground- or satellite-based communication means might not be available any more to alert people in distress situation. These links might be either destroyed by the disaster itself or be unavailable due to heavy overload situations. The one-way nature of the GNSS signals is considered to be an elegant way to provide at short notice precisely those people affected by the natural disasters with disaster specific instructions. A test bed activity is currently conducted within the European GNSS Evolution Programme (EGEP) to investigate the concept of an Emergency Service within Galileo or EGNOS.

(e) A concept for seamless outdoor/indoor positioning based on an Indoor Messaging System (IMES) was presented by JAXA/Lighthouse Ltd. An IMES station transmits its position in three dimensions based on a GPS C/A code like signal and thus allows the IMES capable receiver without pseudorange measurement and time synchronization to determine its position at moderate accuracy (10-20 m) also in deep indoor environment. A frequency offset of +/- 8.2 kHz with respect to the GPS L1 carrier frequency together with regulations on the maximum emitted power are elements to achieve compatibility of the IMES transmitters with the space-based GNSS signals. Approaches to control the IMES transmitters were indicated, the development of efficient IMES transmitter management schemes and methods is initiated.

(f) The Ionosphere Modelling in India for the Indian systems GAGAN (GPS Aided GEO Augmented Navigation) and IRNSS (Indian Regional Navigation Satellite System) was presented by the Indian Space Research Organization (ISRO). A new multi layer grid based ionosphere model using data fusing technique is proposed for GAGAN. This model is compliant with the existing SBAS message structure and in consequence does not require any changes at legacy user equipment. Preliminary results for this SBAS iono-grid model were presented showing good performance over the Indian core region. A model for the ionospheric corrections for IRNSS has been developed based on the GAGAN Total Electron Content (TEC) derived from GAGAN Indian Reference Station (INRES) data.

(g) A concept for signal authentication for GPS/QZSS was outlined by JAXA/University of Tokyo. Low Density Parity Check (LDPC) coding is proposed to be applied to time varying portions of navigation message bits of different navigation satellites. The resulting authentication bit stream can be disseminated either via the Quasi Zenith Satellite System (QZSS) Sub-meter class Augmentation with Integrity Function (SAIF) signal or the SBAS/MSAS signal. In this way the proposed concept can be applied to authenticate e.g. GPS signals by QZSS message content. Authentication procedure details to be applied at receiver side involving an authentication database center were outlined.

(h) A presentation given by NASA identified the relevance of GNSS for space users. The growing interest to operate GNSS receivers at higher altitude than Low Earth Orbit (LEO) was underlined what brings along additional challenges due to large dynamic signal strength ranges, large Doppler etc. GPS technical documents identify the space between 3000 km altitude and Geosynchronous altitude as Space Service Volume (SSV). Performance requirements for the GPS SSV have been developed addressing satellite antenna patterns (side lobes) and group/phase delay variations that translate to signal availability, minimum received power levels and pseudorange accuracy.

(i) The latest developments in the areas of Space Based Augmentation Systems (SBAS), Ground Based Augmentation Systems (GBAS), Advanced Receiver Autonomous Integrity Monitoring (ARAIM) and Alternative Position Navigation and Timing (APNT) were recalled by the Federal Aviation Administration (FAA). The U.S. Wide Area Augmentation System (WAAS) is currently preparing its transition activities towards GPS L1/L5 augmentation which are expected to be completed by 2014. After the jamming incidence at Newark airport, system modifications for GBAS have been identified and are being implemented to reduce the operational impact of jammers at the ground stations. ARAIM is considered to be an interesting concept that could enable worldwide LPV-200 performance under specific conditions including core constellation performance and monitoring. Next Generation Air Transportation System (NextGen) APNT provides a backup in the event of a GPS interference event or outage according to U.S. National Policy. Possible APNT solutions include an enhanced Distance Measurement Equipment (DME), Wide Area Multi-Lateration (WAM) and a Pseudolite Network.

(j) Aspects related to accuracy positioning enabled by multi-system receivers were highlighted in a presentation by the Technical University of Moscow. The probability of time-to-fix of the ambiguities for GPS only, GLONASS only and combined GPS/GLONASS Real Time Kinematic (RTK) solutions was contrasted against the achievable RTK positioning accuracy of the different options. For a medium baseline of 40 km the probability of a time to first fix within a given time increases by a factor of 3 for a dual constellation GPS/GLONASS solution compared to a single constellation solution based either on GPS or GLONASS. The accuracy of the dual constellation RTK solution increases at least by a factor of 3 compared to the single constellation one. The problem of so-called “GLONASS biases” in carrier phase differences is present for Frequency Division Multiple Access (FDMA) signals requiring additional calibration efforts. The Radio Technical Commission for Maritime Services (RTCM) Special Committee (SC) 104 has taken a leading role in resolving problem for more optimum processing of GLONASS carrier phase observables. This problem will not be present for new GLONASS Code Division Multiple Access (CDMA) signals.

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. The recommendations originating from the interim WG-B meeting held on 17 May 2011 were presented, discussed and consolidated together with the newly submitted recommendations. A number of seven recommendations were presented and adopted by the ICG Plenary on 09 September 2011. The endorsed recommendations of WG-B at ICG6 are listed in Attachment 2.1 – 2.7 of this report.

4. The work plan of WG-B as endorsed by the Plenary Meeting during ICG5 was reviewed and the existing actions were confirmed.

(a) In line with the WG-B interim meeting on “GNSS Service Performance Enhancement and Applications“ and according to recommendation 4 as listed in Attachment 2.4 WG-B proposed to the ICG Plenary the establishment of a dedicated subgroup on Applications within WG-B. ICG WG-B is tasked within Action B4 to monitor techniques proposed by application developers and therefore considers it important to review within a dedicated subgroup different areas of applications. Based on the feedback from application developers aspects shall be identified where the current GNSS services show some shortcomings and recommendations for future GNSS performance enhancements shall in consequence be derived. Within an initial period of two years this WG-B subgroup on applications shall be co-chaired by China and

Japan. The co-chairs have been tasked to propose a draft Terms of Reference (TOR) document by February 2012. A first meeting of the WG-B subgroup on Applications is planned to take place on 12/13 March 2012 in the margins of the Munich Satellite Navigation Summit with specific focus on Location Based Service (LBS) and mass market applications. An amendment of Action B4 within the work plan of WG-B was proposed to reflect the WG-B subgroup on Applications. The generation of a WG-B subgroup on applications was established by the ICG Plenary Meeting on 09 September 2011 by the endorsement of the corresponding recommendation (see Attachment 2.4).

(b) The management of the consequences of natural disasters is a considerable challenge, in particular the provision of latest status information on the current situation to the affected citizens. Satellite navigation can provide substantial support in this area, however the concepts for satellite navigation in natural disasters are not yet fully established. Also taking note of the growing interest in natural disaster management via GNSS ICG WG-B considers it important to reflect this in its work plan, to progress further on this subject and therefore proposes a dedicated work item B6 on this subject.

The adapted work plan was presented at the Plenary of ICG 5 and was endorsed. The work plan is provided in Attachment 1 of this report.

ATTACHMENT 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. The work on action B4 will be supported by the dedicated sub-group of WG-B on Applications

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.

Action B6: Monitor and examine techniques supporting the disaster management via satellite navigation. Potential provision schemes shall be proposed within WG-B.

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 for Committee Decision

Prepared by: Working Group B

Date of Submission: 07/09/2011

Issue Title: Integrity via ARAIM

Background/Brief Description of the Issue:

Advanced Receiver Autonomous Integrity Monitoring (ARAIM) is attracting interest at various fora as it shows the capability to provide integrity for aviation users suitable to conduct precision approach procedures.

Discussion/Analyses:

By the end of this decade there will be multiple global and regional navigation satellite systems all providing dual frequency services allowing thus for the cancellation of the first order Ionospheric error and for an improved user geometry. This sets the basis to consider an extension of the classical, horizontal Receiver Autonomous Integrity Monitoring (RAIM) towards more demanding phases of flight, in particular precision approach procedures requiring vertical guidance. However, the Vertical Protection Levels (VPL) for these procedures are this demanding that new algorithms, assumptions and concepts need to be investigated which are labelled as Advanced RAIM (ARAIM).

Recommendation of Committee Action:

ICG is invited to encourage global and regional satellite navigation service providers and stakeholders interested in integrity to

- Include regional systems in the concepts for ARAIM
- Clarify the use of augmentation systems for ARAIM
- Encourage the further work on broadcast parameters to enable multi-constellation ARAIM
- Address certification related issues for ARAIM

ATTACHMENT 2.2

WG-B Recommendation 2 for Committee Decision

Prepared by: Working Group B

Date of Submission: 07/09/2011

Issue Title: Satellite Navigation in Natural Disasters

Background/Brief Description of the Issue:

The management of the consequences of natural disasters (earthquake, floods, storms, etc.) is a considerable challenge, in particular the provision of latest status information on the current situation to the affected citizens.

Discussion/Analyses:

In case of natural disasters ground based infrastructure used for information dissemination/communication may be destroyed or may suffer from significant overload making them unavailable. Due to the single way nature of the radio navigation satellite links these links show significant advantages over any ground based infrastructure or satellite communication system. In particular these links could allow the dissemination of relevant information precisely to those people affected by the disaster.

Recommendation of Committee Action:

ICG is invited to further discuss the use of satellite navigation in natural disasters. ICG should consider that WG-B proposes to update its work plan addressing the work on Satellite Navigation in Natural Disasters in a dedicated action B6.

ATTACHMENT 2.3

WG-B Recommendation 3 for Committee Decision

Prepared by: Working Group B

Date of Submission: 07/09/2011

Issue Title: Workshop on New Message Broadcasts in New Signals

Background/Brief Description of the Issue:

The definition of the international standard for satellite based navigation signals/augmentation signals is currently ongoing, in particular the definition of the future SBAS L5 standard.

Discussion/Analyses:

Within the definition of new navigation/augmentation signals that are foreseen for international standardization enough spare capacity within the data message should be reserved allowing for future service enhancements.

Recommendation of Committee Action:

ICG is invited to take not that WG-B is considering organizing a cross-working group workshop (system providers/users) including also non-ICG WGs (e.g. SBAS IWG) to identify opportunities for new message broadcasts using existing or planned spare capacity in new signals (e.g. SBAS L5/GLONASS CDMA, …).

ATTACHMENT 2.4

WG-B Recommendation 4 for Committee Decision

Prepared by: Working Group B

Date of Submission: 07/09/2011

Issue Title: Establishment of a sub-group on 'Applications' in WG-B

Background/Brief Description of the Issue:

Workgroup B covers many aspects of GNSS performance enhancement. Since more and more application-related issues are introduced and discussed in WG-B, there is a necessity to establish a sub-group on 'Applications' for better discussion.

Discussion/Analyses:

A sub-group on 'applications' may help both the system providers and the user communities to exchange views on the utilization of GNSS and help to identify potential shortcomings of the current systems, their signals and services. The identification of shortcomings shall foster the identification of potential ways to increase the performance for the future evolution of GNSS. This sub-group will create a convenient channel for user communities to present the status of current GNSS applications and state the requirements and feedbacks. Both users and system providers will benefit from this. The subgroup of WG-B is tasked to support the work identified under Action B4 of the Work Plan of WG-B.

Recommendation of Committee Action:

ICG is invited to take note that WG-B considers the establishment of a WG-B sub-group oriented on 'Application '. This sub-group is tasked to support the work identified under Action B4 of the Work Plan of WG-B, and report its findings on a yearly basis to WG-B. For the first 2 years this sub-group shall be co-chaired by China and Japan.

ATTACHMENT 2.5

WG-B Recommendation 5 for Committee Decision

Prepared by: Working Group B

Date of Submission: 07/09/2011

Issue Title: Meeting of WG-B subgroup on "Applications" during Munich Satellite Navigation Summit.

Background/Brief Description of the Issue:

The concept of having interim meetings on dedicated aspects within WG-B and other WGs of ICG has shown in the past to be very fruitful. The Munich Satellite Navigation Summit with its large number of participants offers the possibility to conduct an interim meeting of WG-B subgroup on Applications.

Discussion/Analyses:

An interim meeting shall be organized by the WG-B sub-group on Applications. The meeting shall include topics on LBS, mass market applications etc. It will provide a good opportunity for broad and thorough discussion, as a complement to the annual ICG meetings.

Recommendation of Committee Action:

ICG is invited to take notice that the WG-B subgroup on Applications would like to convene a meeting in the margin of Munich Satellite Navigation Summit on 13 March 2012 (TBC) addressing user communities including at least LBS and mass market applications.

ATTACHMENT 2.6

WG-B Recommendation 6 for Committee Decision

Prepared by: Working Group B

Date of Submission: 08/09/2011

Issue Title: Interoperable GNSS Space Service Volume

Background/Brief Description of the Issue:

The initial introduction of the GPS Space Service Volume (SSV) concept was presented by Dr. Larry Young/NASA/JPL at the ICG-5 as an information paper. The GPS SSV concept was further expanded on by James Miller/NASA at ICG-6 WG B on September 7, 2011.

Discussion/Analyses:

An ICG definition of the "space service volume" out to GEO (36,000km), with subsequent related Provider documentation of GNSS characteristics (in the form of ICDs, ISs, etc.,) available to that domain is needed to provide agreed upon levels of service for space application developers and SSV users of signals-in-space. ICG recognition of the SSV domain and identification of the required GNSS performance parameters to support GNSS applications in the SSV domain will facilitate Provider Administrations' documentation of SSV supporting GNSS system performance parameters.

The goal is to provide ICG stakeholders a more comprehensive "GNSS Service Volume" that would also include the Galileo, GLONASS, and Beidou/COMPASS constellations.

Recommendation of Committee Action:

In order to address these issues it is recommended that WG B:

- Develop a ICG definition of the "space service volume" out to GEO (36,000km) with identified levels of service,
- Develop a template for documenting the Provider GNSS performance parameters necessary to support GNSS applications in the SSV domain, and
- Using the above template, survey the Providers and decide on further action as appropriate.

ATTACHMENT 2.7

WG-B Recommendation 7 for Committee Decision

Prepared by: Working Group B

Date of Submission: 08/09/2011

Issue Title: Standardization for Maritime Applications

Background/Brief Description of the Issue:

Today the standardization procedures for aviation applications and receivers are well established and understood by the GNSS community. For maritime applications and receivers the procedure to be followed is not this clear yet.

Discussion/Analyses:

Maritime users will benefit greatly from use of multi GNSS. Analysis should be performed to demonstrate benefits of multi-GNSS constellations to meet the needs of maritime user communities and encourage maritime users to plan for adoption of multi-GNSS use. The International Maritime Organization (IMO) is the organization developing requirements for maritime use of GNSS. Reference IMO documents include A.915(22), A.953(23), NAV 56/12.

Recommendation of Committee Action:

ICG is invited to encourage WG-B to liaise with IMO on how maritime requirements could be achieved by multi-GNSS constellations and to foster the future standardization for maritime users. ICG may take note that WG-B considers to invite IMO for one of its future sessions.