Report of Special Meeting of Working Group B on "GNSS User Positioning Integrity"

1. The Working Group on Enhancement of Global Navigation Satellite Systems (GNSS) Services Performance (WG-B) within the framework of the United Nations Office for Outer Space Affairs (UNOOSA) International Committee on GNSS (ICG) reconvened for a Special Meeting on "GNSS User Positioning Integrity" on March 08, 2010 in Munich, Germany.
   This meeting was attended by 41 persons from 26 different organizations and 7 countries, stressing the high interest and importance in the subject discussed. The agenda of this meeting can be found here at the UNOOSA ICG website:
   http://www.unoosa.org/pdf/icg/2010/workgroupb1/Agenda.pdf

2. At the special meeting of ICG WG-B on "GNSS User Positioning Integrity" the following presentations were given and discussed:
   a. I. Mozharov, TSNIIMASH on "*Challenges of Providing Integrity in Future GNSS"*
      The presenter highlighted that the assurance of integrity is one of the key trends for the future development of a multisystem GNSS. In order to achieve this goal both the system developers and the users have to participate in the development of current as well as in the definition of advanced integrity assurance techniques. Future GNSS integrity assurance techniques should be based on advanced technologies including a global service, minimization of the Time To Alarm (TTA), high reliability and service versatility. Algorithms to assess the integrity solution based on the whole set of augmented info to be derived from GNSS, SBAS and transmitted through WiFi and FM should be taken into account. The establishment of an international coordination council on GNSS user position integrity monitoring is listed by the presenter as a goal to be achieved.
   b. H. Trautenberg, EADS Astrium on "*Wishes for Interoperable GNSS Integrity Systems from a User Point of View"*
      The presentation stressed the need to achieve also interoperability between the different systems at integrity level for better availability and continuity also in challenging environments. It is necessary to achieve commitments from the individual service providers on the signal, service and the monitoring quality. The users should be informed on the way these data is computed at system level and about system failure modes and the corresponding failure rates. The expected failure rate should be transmitted via the data message. The data informing about the quality of the signal and the monitoring quality should use adequate overbounding approaches and allow for asymmetric, biased multimodal distributions. The paired bounding with excess mass provides these characteristics. Further on, the explicit ranges of biases should be transmitted by the integrity message data. Moreover the service providers should be as transparent as possible and most specific regarding the assertions used.
   c. M. Azaola, GMV on "*Interoperability for Liability Critical Applications"*
      The presenter addressed liability critical applications (LCA) in the automotive, insurance and justice area and draw the bridge towards integrity. LCA need to provide their services in highly challenging environments, suffering there from Non-Line of Sight (NLOS) multipath, interference as well as from limited satellite visibility. The integrity provided by the mission segment may not be sufficient in these environments. Different approaches can be thought of to solve these problems, two of them being the Measurement Rejection Approach (MRA) and the Error Characterisation Approach (ECA). The MRA excludes the faulty measurements, i.e. the Non Line of Sight (NLOS) measurements by the help of an Fault Detection and Exclusion (FDE) module while ECA attempts to characterize the magnitude of the resulting error without attempting to separate between faulty measurements or not. The number of visible satellites is an essential parameter for both approaches. Preliminary analysis using a Multiple Hypothesis Separation Solution (MHSS)

algorithm indicate that for reaching the required availability of integrity for a road-tolling application in urban areas, up to three constellations may be needed.

d. C. Stöber, University FAF Munich on *"Assessment of Combined Integrity Algorithms"*
   The author pointed out the fact that GPS/SBAS and Galileo are following different concepts to define their system integrity respectively. Being this the starting point it was underlined that the protection levels provided by GPS/SBAS and the integrity risk at the alert limit of Galileo are mathematically an inversion of the same context. However they cannot be compared directly due to the different risk allocations. Therefore solution strategies are required in order to end up in a common integrity observation. Direct (Galileo) and indirect (GPS/SBAS) integrity formulations were presented and different solving strategies in dependence of the risk allocation (horizontal/vertical) were discussed. The authors pointed out that a combined integrity algorithm can be defined. Current weak points within this algorithm might be eliminated if full insight into the SBAS ground segment algorithms would be available. To underline the benefits of a combined integrity algorithm, simulations have been carried out on the Institute's Integrity Simulation Tool.

e. H. Delfour/D. Lekaim, ThalesAleniaSpace on *"Multi Constellation Regional System (MRS) - A Step Towards Multi Constellation Interoperability"*
   The evolution, modernization and deployment of GNSS fosters the MRS concept, with special focus onto multi-constellation interoperability including integrity. The concept of MRS offers a number of opportunities. For aeronautical users better ionospheric monitoring, increased robustness as well as better service performance and increased coverage can be listed. Non-aeronautical users can benefit as well. Different means for MRS data transmission were highlighted, e.g. transmission via GEO, MRS Data Access Server making use of terrestrial networks but also the Galileo SIS. Moreover MRS can provide a contribution to extend the LPV200 coverage area. The implementation of MRS for Safety of Life (SoL) can be accomplished in three steps, starting with the ionospheric monitoring improvements making use of the growing Galileo constellation. The second step consists of dual frequency operations, based on monitoring GPS and Galileo in L1/E1 and L5/E5. The final third step requires the additional monitoring of GLONASS.

f. H. Zhang, Wuhan University on *"Multi-Constellation Augmentation Service System (MASS): Primary Results of Wide Area Real-Time Differential GPS Prototype System in China"*
   The author points out that developments for a prototype SBAS in China are ongoing. The concept of MASS was outlined, providing wide area service as well as local area service. Further on the capability of the Positioning and Navigation Data Analyst (PANDA) software was shown. Most recent achievements at Wuhan University in the field of Precise Point Positioning (PPP), real time Precise Orbit Determination (POD) and satellite clock determination were presented. Measurements presented show the impact of the Wenchuan earthquake on the ionosphere.

g. V. Kurshin, Russian Space Systems on *"Current Status and Future Development of Russian System of Differential Corrections and Monitoring (SDCM)"*
   The presentation outlined the concept, objectives and the service performance to be expected from SDCM. SDCM will consist of 3 GEO satellites, namely Luch-5A (16° West), Luch-5B (95° East) and Luch-4 (167° East) to be launched between 2011 and 2013. SDCM will be based on a number of 27 measurement stations, 13 of them already deployed. More information on SDCM is available in the internet at www.sdcm.ru

h. L. Eldredge, FAA on *"Aviation Considerations for Dual Frequency and Multi-Constellation SBAS"*
   The presenter stated that WAAS users do not make use of Receiver Autonomous Integrity Monitoring (RAIM). The introduction of a GNSS service in a second protected band enables the direct estimation and thus a removal of the iono-delay. Being the single largest source of vertical position uncertainty removed by dual

frequency observation, the most significant remaining threats are satellite failure based. The improvements in LPV200 coverage extension due to dual frequency and the introduction of SDCM and GAGAN are presented. Further network extension towards southern hemisphere leads to LPV200 performance covering 67.6% of the earth. The concept of Advanced RAIM (ARAIM) for multi-constellation GNSS in combination with Integrity Support Message (ISM) was presented. An update rate of 1 hour for the ISM would be sufficient. Based on this concept, assuming a weak constellation of 21 GPS and 24 Galileo satellites, LPV200 performance could be achieved almost on a worldwide basis also for weaker satellites. In conclusion, current GPS SBAS single frequency coverage is good within the areas covered by the existing reference stations. Dual frequency SBAS would extend this coverage without additional stations. Extending the current networks, global coverage of land masses, is possible. ARAIM has a good potential to support multi-constellation GNSS integrity solutions.

i. V. Tyubalin, IKOSP on *"Experimental Results of the Baseline Length Definition on Signals: GPS, GLONASS and GPS/GLONASS"*
The presenter underlines that the potential of high accuracy relative determination of position based on GLONASS is given. Therefore three experiments have been carried out with GLONASS and GPS only measurements on the one side and combined GLONASS/GPS observations on the other side for different base lengths from 50 m up to 108 km. It turns out that relative measurements using GLONASS are possible. According to the author the GLONASS Frequency Division Multiple Access (FDMA) scheme does not turn out to be an obstacle.

j. J.Tang, CNAGA, on *"Primary Analysis of Multi-constellation Interoperability"*
The author lines out the benefits of integrated positioning with multi-constellation in the frame of interoperability. Dilution of Precision (DOP) analyses for various elevation masks (5°, 30° and 40°) were presented for different constellations like Compass only and Compass in combination with GPS or Galileo. This was underlining the benefits of multi-constellation. The integrated navigation based on multi-constellation will improve the coverage remarkably in cases of high elevation mask angles, as it is the case in urban environment.

3. The following conclusions of this Special Meeting of ICG WG-B on "GNSS User Positioning Integrity" were drawn at mutual agreement:

   a. Worldwide Interoperability of PNT Integrity using combined constellations is one of the most important and urgent topics to be solved both on the technical as well as on the standardization side. GNSS interoperability will lead to higher availability, lower alarm limits and improved robustness of PNT integrity solutions.

   b. The solution should take into account the different user requirements and their particular environmental conditions (aviation, land, maritime).

   c. More discussions are needed in the different standardization bodies in order to achieve early user acceptance of proposed solutions.

   d. R&D efforts are necessary to develop integrity solutions for combined constellations as well as for the user side (Advanced RAIM, etc.) in order to consolidate the various roles of multi-regional SBAS, global GNSS integrity, and (A)RAIM.

   e. Transparency at service provider level is an important issue to reach optimum performance levels.

4. The next meeting of ICG WG-B will take place at ICG5 from October 17-22, 2010 in Turin, Italy.