GNSS FOR AVIATION
a Brief Background

DEFINITION

- *"GNSS: A worldwide position and time determination system that includes one or more satellite constellations, aircraft receivers and system integrity monitoring, augmented as necessary to support the required navigation performance for the intended operation."*
  - (from ICAO Annex 10, Volume I)

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PRESENTATION STRCUTURE

1. GNSS Infrastructure
2. Regional Initiatives
3. Background Information
5. Future GNSS
6. Recommendations

CORE SYSTEMS

- GNSS based services are made possible by two core satellite constellations' (at presebt) Global Positioning System (GPS) and Global Navigation Satellite System (GLONASS)
- GPS Offer (1994)
  - *GPS standard positioning service (SPS) made available on a continuous worldwide basis and free of direct user fees for foreseeable future. At least 6 year notice prior for termination of service.*
- GLONASS Offer (1996)
  - *GLONASS standard accuracy channel to be provided to the worldwide aviation community for a period of at least 15 years with no direct charges collected from users*
- Offers reiterated at various occasions, most recently in February 2007 (180th Session of the ICAO Council)
- Europe, China are developing core systems (GALILEO & COMPASS), will be compatible with next generation of GPS, GLONASS Constellations.
- ICAO "Charter on the Rights and Obligations of States relating to GNSS Services" highlights GNSS principles including Safety as the paramount factor with non-discriminatory access, State sovereignty, provider State to ensure reliability, cooperation and mutual assistance as other significant factors.

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AUGMENTATION SYSTMES

- Aircraft-based Augmentation System (ABAS), Satellite-based Augmentation System (SBAS), Ground-based Augmentation System (GBAS) & Ground-based Regional Augmentation System (GRAS) included in ICAO SARPs.
- Wide Area Augmentation System (WAAS) – commissioned for safety-of-life operations in July 2003
- European Geostationary Navigation Overlay Service (EGNOS) – initial operations started July 2005
- Multi-functional Transport Satellite (MTSAT) Satellite-based Augmentation System (MSAS) – started operations in September 2007
- GPS aided Geostationary Earth Orbit (GEO) Augmented Navigation (GAGAN) – expected to start operation in 2013

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GAGAN

- Indian geostationary communication satellite GSAT-8 is planned to be launched on an Ariane 5 launcher on May 19 from French Guiana. The Satellite will contain a transponder for GAGAN. GSAT-8 will be positioned at 55^0 east and use PRN 128

ANC informal briefing

BENEFITS

- Implementation of GNSS provides reduced flying time and no requirement for ground aids.
- Uniform global performance
- Navigation coverage over oceanic/remote airspace.
- No investment requirement by the States (not providing GNSS systems) for replacing conventional Navigation Aids
- Possibility of meeting performance requirements for different phases of flight using the same GNSS system
- Potential elimination of ground facilities (like VOR, DME, ILS etc.)
- Increased access to the runways

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GNSS IMPLEMENTATION CHECKLIST

- APANPIRG through Conclusion 11/22 adopted ‘Strategy for Implementation of GNSS Navigation Capability in the Region’
- Through Conclusion 11/23, APANPIRG adopted a proposal to conduct a workshop.
- Workshop conducted from 8 to 11 May 2001 developed a checklist with a view to assist the States in the implementation of GNSS in their administration.
- A copy of the checklist is available on the ICAO Asia/Pacific website and can be accessed on the address ‘http://www.bangkok.icao.int/edocs/cns/checklist_GNSS.pdf’. It also refers to various types of guidance materials available on the subject which can be used as reference.

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APANPIRG/19 (Sept 2008)

- APANPIRG 19, after reviewing Navigation and GNSS Strategies, decided to merge them.
  Conclusion 19/31 adopted the merged strategies
- Revised Strategy
  Implement GNSS with augmentation as required for APV and precision approach operations
- GBAS only known feasible service to support GNSS based Cat III approach and landing.
- Implementation of GBAS in some States of the region (Japan, Australia, India, ROK, USA etc.) planned.
- MSAS, put into operation in September 2007 is interoperable with other SBAS e.g. WAAS, EGNOS and GAGAN. Mitigation of ionospheric activity still a challenge, since Japan is in low latitude region. Studies on the new algorithm to calculate ionospheric error was conducted. Based on the results, improvement plan for MSAS is under consideration
- ABAS, GBAS and SBAS use different methods for generating, transmitting and applying corrections to mitigate the ionospheric delay.
- There is no statistics available on the effect of undetected depletions on the performance of GBAS and SBAS

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APANPIRG/20 (Sept 2009)

- Australia expressed the view that characterization of ionosphere in region will be useful for the implementation of GNSS applications.
- Meeting identified ICAO undertaking characterization as one of the options.
- Study on the subject is being conducted in many States
- Focal Contact Points in the States to be identified, who will coordinate matters regarding collection of ionospheric data & development of a model
- US in the final stages of Cat – 1 GBAS (Honeywell SLS – 4000) approval
- US continuing to support international development of GNSS augmentations. MOC signed with Australia, Brazil, Spain, Germany and Chile for GBAS development.
- RTCA published Minimum Operating Performance Standards (MOPS) DO 253C to complement ICAO Standards and support avionics development.

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APANPIRG/21(Sept 2010)

- Though GNSS is there since 16/17 years, yet some resistance in its adoption.
- While some progress in use of GNSS is there in oceanic/remote en-route phase, but less progress is there in terminal/approach phases
- Conclusion 21/36 recommended bringing slow progress of GNSS implementation in the aviation field to the attention of forums like 47th DGCA Conference & raise the awareness of existence of GNSS Manual amongst the aviation Community.
- Japan has developed a prototype GBAS that provides Cat I performance.
- Australia, Hong Kong China informed the meeting about the work being done in their administrations.
- Hong Kong China informed about installation of GNSS monitoring system to commence ionospheric data collection from 2010 end.
- Japan was invited to provide technical leadership with ICAO providing support for the development of a measurement campaign.

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REGIONAL ACTIVITIES

- To meet the requirements of APANPIRG/20, nominations for Focal Contact Points were invited from the States to coordinate ionospheric data collection and other related activities.
  - 11 nominations for Focal Contact Points from 11 States received
- APANPIRG/21 noted slow progress in GNSS implementation. A survey was carried out to assess the status of implementation
  - 16 States responded.

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ICAO PAPER - IONOSPHERIC EFFECT ON GNSS

- Ad-hoc expert group formed by NSP in October 2005 wrote 'Ionospheric Effects on GNSS Aviation Operations' in Dec 2006
- Initial work on ionospheric effect on GNSS was limited to mid-latitudes, where delays are mild and gradual, scintillation virtually non-existent.
- Current ABAS uses simple models with parameters broadcast on navigation message
- Single freq SBAS uses ionospheric corrections updated in real-time by the ground system. Ground system uses dual freq pseudo-range and phase measurement to get ionospheric delay.
- Single freq GBAS corrects combined effects of satellite clock, ephemeris error, ionospheric delay etc. using differential correction broadcast. This is adequate for Cat I performance.
- Future of satellite navigation resides in dual-frequency multi-constellation receiver design.

ICAO PAPER

DECEMBER 2006

- 'GNSS data collected near a solar cycle peak is highly desirable in order to evaluate the full effect of the ionosphere on potential GNSS implementations.'
- Equatorial region characterized by the presence, during local evening hours, of two crests of TEC located at approximately +/- 15^0 to +/- 20^0 both sides of equator, with lower TEC value along equator. This region sees highest values of TEC and the gradient. Limited data available so far in equatorial region.
- Scintillation, after sunset and may be for hours. Phenomenon occurs generally during solar maximum with higher values from March to October.

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IONOSPHERIC EFFECT

- Un-corrected ionospheric delays can cause position errors of several tens of meters even on quiet ionospheric days, which is not acceptable for Approach with Vertical Guidance (APV) and Precision Approach.
- ICAO recommends correction for ionospheric delays (may not be required for en-route/NPA)
- The main operational impact on en-route/NPA is expected to be from scintillation, but loss of service is not expected to be severe. Service degradation as function of solar activity, geographical region, number of core constellation satellites yet to be evaluated.
- Partial loss of APV service may be experienced during severe ionospheric storms
- Ionospheric storm effect on GBAS should be explored using local area assumptions.
- Amount of delay is inversely proportional to square of frequency. So with two frequencies, ionospheric range delay can be estimated.

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ADDITIONAL INFORMATION
(Ionospheric effect)

- SBAS reference stations more robust than airborne receivers
- Scintillations occur in numerous narrow patches, so effect on all satellite signals at receiver not same.
- Two important receiver parameters are bandwidth of signal tracking loop and ability of receiver to quickly re-acquire signal after it has lost tock.
- High intensity of scintillation on GPS L5 and GALILEO E5 will not result in greatly increased sensitivity of these signals to scintillation, as compared to GPS L1, because of greater signal power of L5/E5 compared to L1.
- In most regions, ionosphere will affect APV service from single-frequency receivers. Most obvious mitigation to this problem is to maintain sufficient number of ILSs and legacy avionics in at least high-end aircraft.

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SOME MORE INFORMATION
(Ionospheric Effect)

- Initial assessment (Klobuchar et. al. 2001) showed difference between actual slant ionospheric range delay obtained from a 3D model and those obtained by SBAS could be as large as 27 meters for a GPS satellite at low elevation.
- In the thin shell model, even if absence of steep depletions can be assumed, slant-to-vertical and vertical-to-slant errors remain a significant problem
- Scintillation measurement campaign currently in progress using receivers in low latitudes (South America, Africa, Vietnam, Indonesia) and high latitudes (Sweden)

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MORE INFORMATION
(Ionospheric Effect)

- In 1999, SBAS Interoperability Working Group (IWG) established Working Group to provide all information regarding ionospheric threat to SBAS.
- In Japan, ionospheric research related to GNSS being performed by Electronic Navigation Research Institute (ENRI), it covers both SBAS & GBAS.

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FUTURE GNSS

- New and modernized GNSS core constellations transmitting civil signals on 2 or more freq.
- Eventually, receivers will be able to track two civil signals from both GPS and GALILEO (L1, L5/E5) with about 18 satellites. So it continue to support even if some satellites are lost due scintillation.
- Dual-frequency, multi-constellation receiver may also support APV without augmentation.
- Will particularly benefit GBAS, since risk of integrity failure due to sharp difference in ionospheric delays seen by aircraft and GBAS station will be avoided.

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CONCLUSION

- To meet APANPIRG expectation of characterizing ionosphere, States and other agencies are urged to cooperate and coordinate in exchange of information/data on the subject and share archival data
- Through cooperation/coordination Group should aim at developing an ionospheric model which is suitable for the region
- Work out an agreed mechanism for the collection of data, particularly during the approaching solar maximum period

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THANK YOU