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GNSS Space Service Volume & Space User Data Update
ICG Providers Forum

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Space User/Space Service Volume Summary from ICG-8 (Dubai) Working Group-B

• Discussions
  – Significant progress has been made in establishing an interoperable Global Navigation Satellite System (GNSS) Space Service Volume (SSV) through pre-work, presentations, and additional robust contributions from the administrations of the Russian Federation and China
  – The Working Group further discussed the benefits of an interoperable GNSS SSV
  – All WG-B participants believe that a fully interoperable GNSS SSV will result in significant benefits for future space users as it will allow for performance no single system can provide on its own

• Recommendations from ICG-8
  – **SSV Template Completion**: recommend all providers complete and formally submit SSV template. (Russia, China, Japan completed the templates, but not formally submitted)
  – **Definition Maturations**: Develop standard definitions of minimum number of satellites, constellation geometry, etc (this will help to perform unified GNSS SSV analysis)
  – **Spaceborne GNSS Receivers**: Build multi-frequency, and multi-constellation GNSS receivers to exploit the SSV
  – **Antenna / Electronics Characterization**: Measuring satellite transmit antenna patterns (pseudorange and phase vs. angle), and designing spacecraft electronics with strict requirements on phase and group delay coherence
Space Service Volume (SSV)
- Development and specification of a SSV and solidification of specifications that define signal strength and availability of GPS signals in space for all locations and all users within the SSV

GPS Antenna Pattern Publication
- GPS Block II-R and II-R(M) antenna pattern pre-flight testing & post-flight publication
  - Quantifies antenna characteristics, including main & side lobe gain
  - Enables space users to perform pre-flight analyses to determine end-to-end navigation performance and signal availability
  - Enables space users to leverage side lobe information (per SV) to enhance GPS availability, particularly for space missions above the GPS constellation, including missions in High Earth Orbit (HEO) & Geostationary/Geosynchronous Orbit (GEO/GSO)

International Forward Work
- Highly encourage GNSS, and regional navigation systems, partners to participate
  - Complete SSV templates
  - Develop SSV specification for your constellation
  - Publish your constellation antenna data

Partners: Galileo, GLONASS, Beidou, & IRNSS
Expanding the GPS SSV into a multi-GNSS SSV

- At least four GNSS satellites in line-of-sight are needed for on-board real-time autonomous navigation
  - GPS currently provides this up to 3,000 km altitude
  - Enables better than 1-meter position accuracy in real-time
- At GEO/GSO only one GPS satellite will be available at any given time.
  - **GPS-only** positioning still possible with on-board filtering, but only up to approx. 100-meter absolute position accuracy.
  - **GPS + Galileo** combined would enable 2-3 GNSS sats in-view at all times.
  - **GPS + Galileo + GLONASS** would enable at least 4 GNSS sats in-view at all times.
  - **GPS + Galileo + GLONASS + Beidou** would enable > 4 GNSS sats in view at all times. This provides best accuracy and, also, on-board integrity.
- However, this requires:
  - Interoperability among these the GNSS constellations; and
  - Common definitions/specifications for use of GNSS signals within the Space Service Volume (3,000 km to GEO/GSO altitudes)

≥ 4 GPS satellites in line-of-sight here (surface to 3000 km)

Only 1-2 GPS satellites in line-of-sight at GEO/GSO altitudes

... but, if interoperable, then GPS + Galileo + GLONASS + Beidou provide > 4 GNSS sats in line-of-sight at GEO/GSO altitudes
Why is an Interoperable Space Service Volume Important?

*Global, interoperable SSV specifications are crucial for real-time GNSS navigation solutions in High Earth Orbit*

- Supports increased satellite autonomy for missions, lowering mission operations costs
- Enables new/enhanced capabilities for HEO and GEO/GSO future missions, such as:

- Improved Weather Prediction using Advanced Weather Satellites
- Space Weather Observations
- Astrophysics Observations
- En-route Lunar Navigation Support
- Formation Flying & Constellation Missions
- Closer Spacing of Satellites in Geostationary Arc
• Substantial pre-flight ground measurement of IIR & IIR(M) antenna patterns performed by Lockheed Martin for each GPS spacecraft

• Data now publically released. To access: www.gps.gov & click on support, technical documentation, GPS antenna patterns

• Hemispherical gain patterns for each GPS satellite can be developed by combining data along (+/- 90 degrees) and around (0-360 degrees) antenna boresight

• Enables high fidelity analyses and simulations for HEO/GEO missions

• Information bolsters confidence in developing new mission types

• Enhances navigation performance capabilities of current missions

Special thanks to Willard Marquis/Lockheed Martin & Air Force GPS Program for publicly releasing this information!!