

GPS and Galileo Integration

Presented to: Interoperability and Space
Exploration

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**Federal Aviation
Administration**



Overview

- **GPS and Galileo Systems**
 - Hardware Interoperability – Issues
 - Open-Source vs Proprietary Standards
 - Single-Source vs Parallel Development
 - Degree of Harmonization
- **International Aviation Standards**
 - Organization Interoperability Issues
 - Approving State responsible for compliance
 - Stakeholder coordination and concurrence



The Global Positioning System

- **Baseline 24 satellite constellation in medium earth orbit**
- **Global coverage, 24 hours a day, all weather conditions**
- **Satellites broadcast precise time and orbit information on L-band radio frequencies**
- **Two types of signals:**
 - Standard (free of direct user fees)
 - Precise (U.S. and Allied military)
- **Three segments:**
 - Space
 - Ground control
 - User equipment

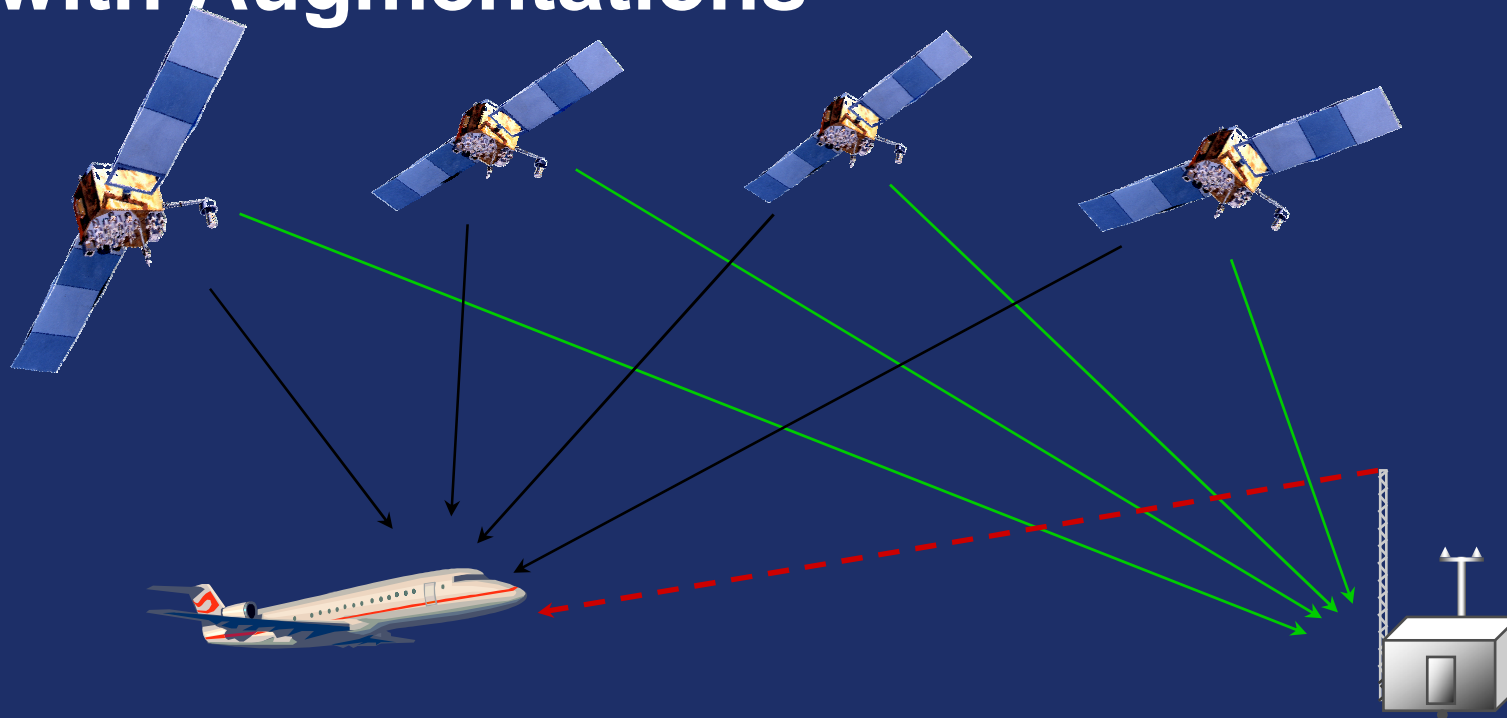


GPS is a Global Public Service

- **Free access to civilian signals**
 - One-way broadcast, like FM radio
- **Public domain documentation**
 - Anyone can develop user equipment
- **Worldwide utility providing consistent, predictable, dependable performance**
 - Critical component of global information infrastructure
- **Owned and operated by the U.S. Government**
 - Paid for by U.S. taxpayers
 - Guided at a national level as multi-use asset
 - Acquired and operated by Air Force on behalf of USG



Improving GPS Performance with Augmentations



Augmentations enhance GPS accuracy, monitor integrity

- Sub-centimeter accuracy for geodesy, geology, etc.
- 2-5 cm accuracy for real-time positioning, surveying, etc.
- <3 m vertical accuracy with 6 second time to alarm for aviation

Galileo

- Public – Private Partnership
- Services Relevant to Aviation:
 - Open Service (OS):
 - Free of charge to users worldwide
 - Service (SoL):
 - Improved OS through integrity
 - Service guarantee envisaged
 - Air and marine navigation, rail etc



GPS-Galileo Agreement

- In 2004, United States and European Community signed historic agreement on GPS-Galileo cooperation, recognizing importance of compatibility and interoperability for all parties
- Agreed to spectrally separate signals for military, civilian, and public regulated services
- Agreed to implement a common, open, civil signal on both Galileo and GPS III, free of direct user fees
- Working groups established to continue dialogue:
 - Compatibility & Interoperability
 - Trade & Commercial Applications
 - Next-Generation GNSS
 - Security Issues



June 26, 2004, press conference at U.S.-EU Summit in Ireland (U.S. Sec. of State Colin Powell, Irish Foreign Minister Brian Cowen, EU Vice-President Loyola De Palacio)

Hardware Interoperability (1)

- **GPS Standard Positioning Source (SPS) is Open-Source Standard, Single-Source Development**
 - Open access to standards facilitates adoption
 - US as only provider of GPS signals simplifies coordination of change
 - Ensure backward compatibility to preserve service to existing installed base of equipment
- **Galileo will include Open-Source and Proprietary Standard, Single-Source Development**
 - Encryption of Safety of Life Service?
 - Aviation concerns over inadvertent denial-of-service
 - Authentication could enhance security without establishing proprietary standard



Hardware Interoperability (2)

- **Aviation Augmentation Systems are Open-Source Standards, Multiple-Source Development**
 - Space-Based Augmentation Systems (SBAS) were developed by US, Europe and Japan in parallel with completing the standards
 - **Timing** of contracts vs standards left some challenges
 - Wasted bits in a severe bandwidth-constrained system (User Range Accuracy, Issue of Data, Data ID)
 - Standard forced design change after contract to ensure interoperability
 - Increased **complexity** to be flexible to different objectives
 - SBAS: European system to augment GLONASS
 - GBAS: Flexibility to implement approach-only service



Hardware Interoperability (3)

- **Extensive discussion of compatibility and interoperability in US/EU negotiations**
 - Compatible: not interfere with each other
 - Interoperable: can be integrated within the user equipment
- **All signals must be compatible**
- **Signals to be interoperable to greatest extent possible**
 - Degree of harmonization?



Improving GNSS Interoperability

Characteristic

- Common time and reference frames, or broadcast offsets

Interoperability Benefit

- Navigation solutions can blend measurements from different systems

Most Important for Future Interoperability

- Common carrier frequencies

- Common antenna and receiver front end—lower power and cost; common carrier tracking for higher accuracy

New L1C Signal to use common modulation

- Similar spreading modulation spectra
- Common spreading code lengths and common code family
- Common data message structure and encoding

- Common-mode dispersive errors removed in navigation solution for higher accuracy
- Lower cross-correlation sidelobes for better weak-signal reception; common receiver processing for acquisition and tracking
- Common receiver processing for data message decoding and processing



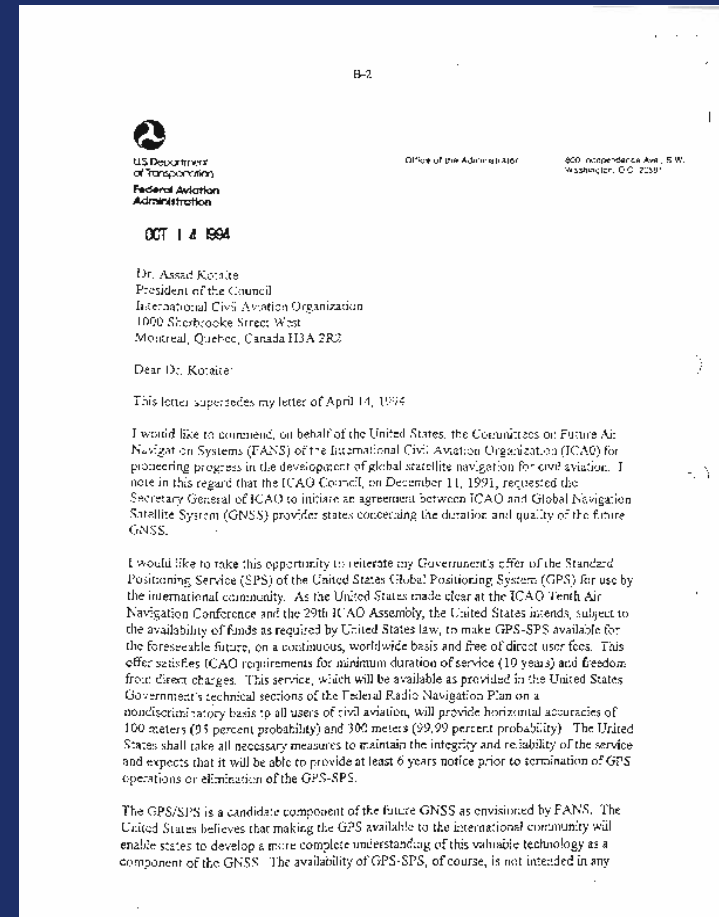
Organizational Aspects: Aviation Standards

- **Convention on International Aviation, 1944**
 - Each contracting State undertakes, so far as it may find practicable, to provide, in its territory, airports, radio services, meteorological services and other air navigation facilities to facilitate international air navigation, in accordance with the standards and practices recommended or established from time to time, pursuant to this Convention;
- **Each State responsible for air navigation services within their territory**
 - Services may be contracted to third party, but the State is responsible for compliance with the Convention



GPS and International Aviation

- **FAA Administrator offered GPS to ICAO (1994)**
 - Worldwide
 - Free of direct user fees
 - Six years notice prior to termination
- **ICAO accepted and adopted Charter on the Rights and Obligations of States Relating to GNSS Services**
 - Nondiscriminatory
 - No change in State authority and responsibility



Organizational Interoperability (1)

- US is GPS signal provider
- Each contracting State (approving GPS within their territory) is responsible for safety and compliance with standard
 - States can fulfill responsibility through monitoring GPS (off-line, data archiving), requirement for receiver augmentation integrity monitoring (RAIM)
 - States can also use augmentation systems to preserve authority
 - Space-Based, Ground-Based augmentations provide integrity override to assure safe operations with GPS
 - State responsible to **approve use** of GPS as appropriate



GPS Aviation Ops Approvals



Organizational Interoperability (2)

- **Stakeholder Coordination and Concurrence:
Discontinue Selective Availability (May 2000)**
 - Selective Availability (SA) originally degraded performance for Standard Positioning Service (SPS) users
 - When SPS was discontinued, US standards were modified (Oct 2001)
 - SA was dominant error source, so original standards written at user receiver
 - Without SA, atmospheric effects are dominant error source so new standards written at satellite antenna
 - Other States asked for validation that the change in specification was backward compatible (ie, performance got no worse under all conditions)
 - New ICAO Standards adopted (Feb 2004)



Additional Information

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U.S. Policy History



- **1983: President Reagan offers free civilian access to GPS**
- **1996: GPS declared a dual-use system under joint civil/military management**
- **1997: Congress passes law requiring civil GPS to be provided free of direct user fees**
- **2004: President Bush issues new U.S. policy on space-based PNT**

Space-Based PNT Policy Objectives

- **Provide civil GPS and augmentations** free of direct user fees on a continuous, worldwide basis
- **Provide open, free access to information needed to use civil GPS and augmentations**
- **Improve performance of GPS and augmentations**
 - Meet or exceed that of international systems
 - Improve resistance to interference for civil, commercial, homeland security, and scientific users worldwide
- **Seek to ensure that international space-based PNT systems are interoperable with civil GPS and augmentations**
 - Or, at a minimum, are compatible



Space-Based PNT Policy Objectives

- **Provide uninterrupted access to U.S. space-based PNT services for U.S./Allied national security purposes**
- **Improve capabilities to deny hostile use of PNT without unduly disrupting civil and commercial access**
- **Maintain GPS as a component of multiple sectors of the U.S. Critical Infrastructure**
 - Plan for backup capabilities and services

