Aviation Considerations for Multi-Constellation GNSS

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Introduction

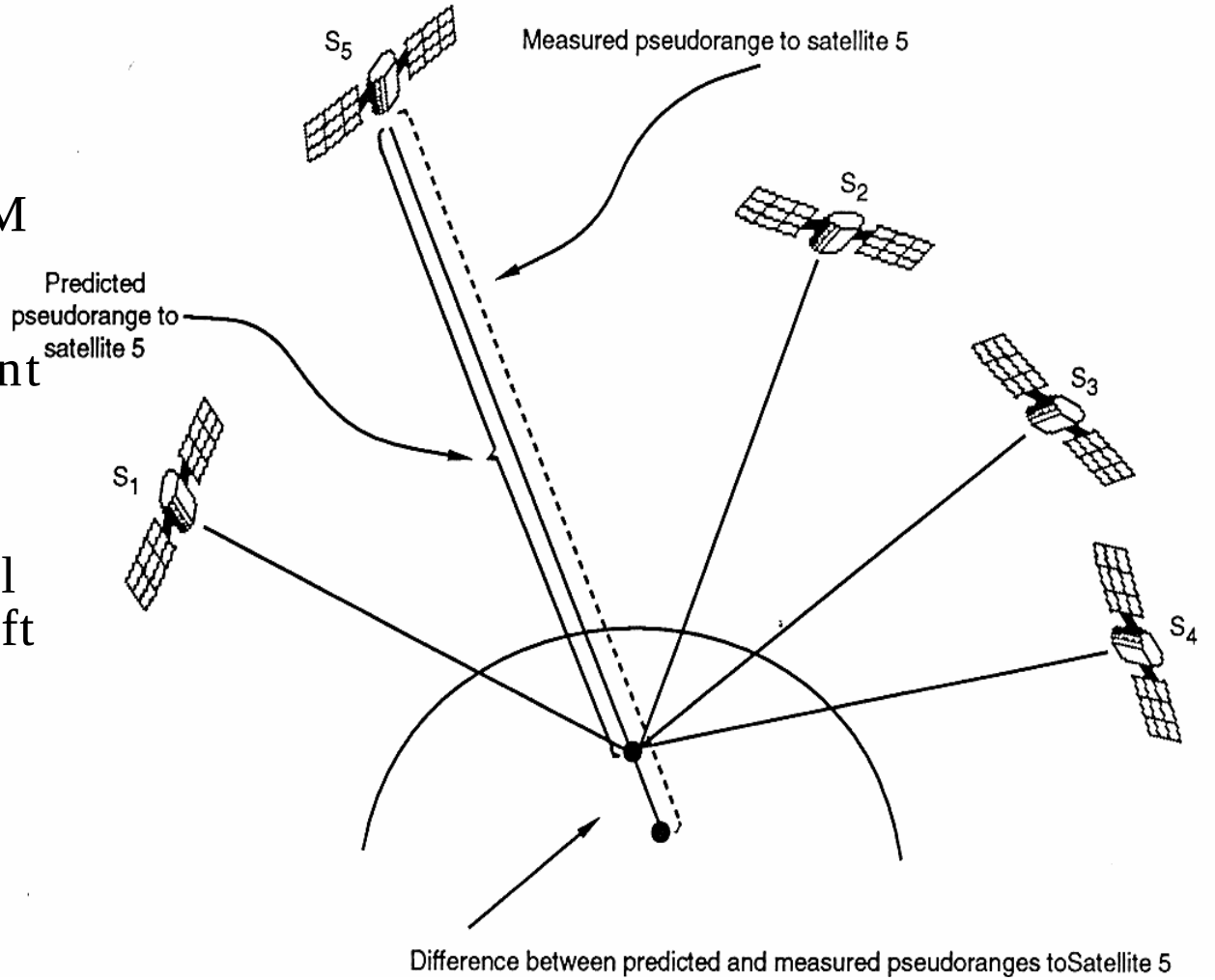
- GPS is an important component of today's aviation navigation infrastructure
  - Its role will continue to increase over the coming years
- Future GNSS constellations will also become important to contributors
- However, their incorporation must be done with great care as the integrity requirements for aircraft guidance are very stringent
  - Less than 10^{-7} probability of misleading information
  - International standards define different types of GNSS augmentations to achieve this level of integrity

Integrity Monitoring

- Space-based and ground-based augmentation systems provide independent monitoring of the GPS signals through calibrated ground monitors
  - Requires ground monitoring network communication channel to aircraft
- Receiver Autonomous Integrity Monitoring (RAIM) compares redundant satellite measurements against each other to determine identify and eliminate large faults
  - Requires a larger number of ranging measurements

GPS Supplemental Use - 1995

- Key Feature:
  - Integrity Determination by the User with RAIM
- Key Enabler
  - Requires Redundant Ranging Sources
- Key Benefit
  - Provides horizontal guidance for aircraft
- Key Challenge
  - Accuracy & Availability



Horizontal and Vertical Navigation

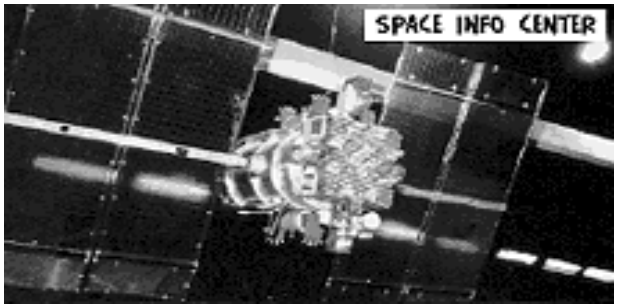
- GNSS vertical accuracy is worse than horizontal
- Aviation requirements are more strict in the vertical
  - Vertical maneuvers bring the aircraft closer to the ground
- Therefore, it is much harder for GNSS to meet aviation vertical guidance requirements
- But, absolute vertical guidance from GNSS offers a strong safety benefit
  - Enables smooth, continuous precision approach paths
- Want to provide vertical and horizontal guidance

Two Civil Frequencies

- The ionosphere creates the largest source of uncertainty affecting today's use of GPS for aviation
- When GPS L5 becomes widely available it will become possible to directly remove the ionospheric influence
  - May allow RAIM to support vertical navigation
- Unfortunately, the two frequency combination increases the effects of other noise sources
- It is desirable to reduce these noise terms and/or add more satellites to offset this increase

Future Considerations

Galileo (EU)



GLONASS

COMPASS

GPS

Interoperability of Integrity

- Interoperability should be a goal not just for GNSS signals, but for integrity provision as well
  - Augmentation systems already internationally coordinated
- Open service signals should target performance comparable to or better than GPS L1 signals today
- Different providers may make different design choices and different assurances
  - However, it is important to establish a common understanding of how RAIM depends on GNSS performance and how signals from different services could be combined to improve RAIM
  - Cooperation and transparency are essential

Benefits of Multi-Constellation RAIM

- Combining signals from multiple constellations can provide significantly greater availability and higher performance levels than can be achieved individually
- Potential to provide a safety of life service without requiring the GNSS service provider to certify each system to 10^{-7} integrity levels
- Creates a truly international solution
  - All service providers contribute
  - Not necessarily dependent on any single entity
  - Coverage is global and seamless

Requirements on New Signals and Constellations

- Assure good nominal signal accuracy
  - On order 1 m ranging accuracy
- Perform a fault modes and effects analysis
  - Understand and make transparent potential faults and their effects
- Assure low fault rates
  - Of order 10^{-5}/SV/Hour
- Assure good continuity of signals
  - Less than 10^{-5}/hour probability of unexpected outages
- Assure good availability of signals

Summary

- RAIM allows for worldwide aviation navigation without requiring additional ground infrastructure
- Additional GNSS constellations can significantly improve performance and availability
- New GNSS constellations should assure that their open service signals support RAIM
- International cooperation and coordination will be essential to achieving this goal