The Ionospheric Challenge to Flight Safety, and the International Solution

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Commercial aircraft are 5 times more likely to have an accident flying a non-precision approach than flying a precision approach.

Flight Safety Foundation, March 1996
SBAS System Overview

GNSS satellites broadcast ranging signals to airborne receivers and SBAS reference stations.

Reference stations pass data to master stations, which:
- Compute ranging corrections
- Calculate $10^{-7}$ integrity values for two main sources of errors
  - Satellite clock and orbit errors
  - Ionosphere induced distortions

SBAS messages are sent to uplinks

SBAS messages are broadcast to hosted GEO payload

SBAS messages are re-broadcast to airborne receivers, which:
- Correct for error positions
- Calculate integrity protection bound

Entire sequence must be completed in 6 seconds to support precision approach.
ICAO ASSEMBLY RESOLUTION

• **Resolution A36 - 23**
  – All approaches APV by 2016
    • Unachievable!!

• **Resolution 37 / 11**
  – All approaches APV by 2016
  – However, if unable then straight in approaches (with limits!)
The Ionospheric Challenge

http://www.cpi.com/products/pim.html#1
The Ionospheric Challenge

Ionosphere and GNSS errors
- Electron density affects signal transmission time
- Total Electron Count varies with time and location
- Solar storms can cause sudden and extreme variations
- Equatorial region is particularly affected by ionospheric changes and scintillation.

1st Generation SBAS solution
- Map of ionosphere is constructed and transmitted to user
- Vertical delay values are transmitted to user receiver
- User receiver calculates slant delays based on its location within map of vertical delays.
- Works well in mid-latitudes; very challenging in equatorial regions.
A Better Option—Fully Exploit Dual Frequencies, Multiple Constellations

L1/E1 and L5/E5a frequencies on GPS IIF, Galileo, GPS III
• 2nd frequency in protected band
• User receiver makes ionospheric corrections
• Simplifies SBAS architecture
• Solves equatorial challenge

Multiple Constellations
• More ranging signals in view
• Redundancy of GNSS providers
• Addresses sovereignty concerns

ESA - European Space Agency, A. Le Floc’h, CC BY-SA 3.0 IGO
2nd Generation SBAS Testbed

International Collaboration

• Galileo and GPS IIF: Open service signals on 1575.42 MHz and 1176.45 MHz
• GMV: Master station and control console
• Lockheed Martin: Uplink station and signal generator at Uralla, Australia
• Inmarsat: I-4F1, on orbit at 143.5° East
• Geoscience Australia and Land Information New Zealand:
  – Existing geodetic reference stations (CORS)
  – Coordinate with other countries for stable access to dispersed CORS data
  – Intra-systems communication links

• Testbed architecture will use existing assets to maximum extent possible
• Testbed system configuration will anticipate operational system topology
Future: Global SBAS Topology

- Reference Station
- Master Station
- Control Centre
- Uplink Stations (Sites are notional)
2\textsuperscript{nd} Generation SBAS Advantages

- **Improved performance**
  - Equatorial ionospheric challenge solved by user-receiver corrections
  - Global monitoring of GNSS satellites

- **Lower cost**

- **Same architecture supports:**
  - Civil aviation
  - Emerging Safety Critical Users
    - Positive Train Control
    - Intelligent Transportation Systems
    - Maritime Navigation
    - Unmanned Aerial Vehicles
    - Automated mining

Technical approach has been validated in simulation; next step is to demonstrate with a signal-in-space testbed.

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