# The Ionospheric Challenge to Flight Safety, and the International Solution

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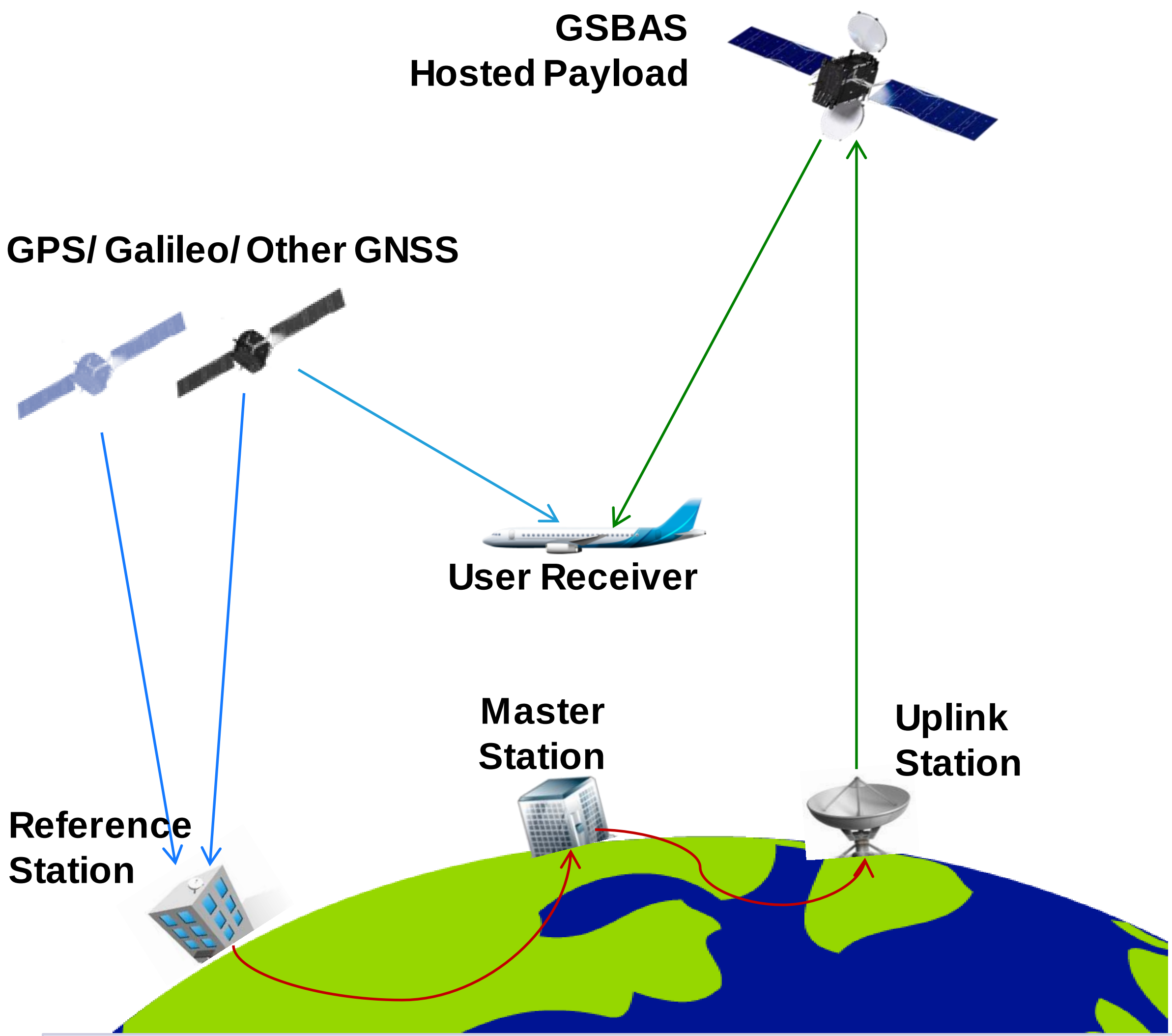
# Flight Safety and Precision Approach

**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.

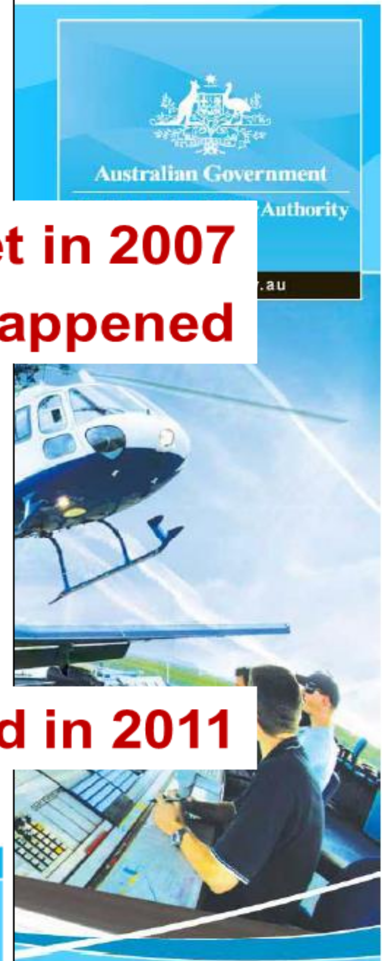
# International Civil Aviation Organization

## ICAO ASSEMBLY RESOLUTION

- **Resolution** A36 - 23
  - All approaches APV by 2016 ← **Goal set in 2007**
    - Unachievable!! ← **Physics happened**
- **Resolution** 37 / 11
  - All approaches APV by 2016
  - However, if unable then straight in approaches (with limits!) ← **Goal posts moved in 2011**

*safe skies for all*

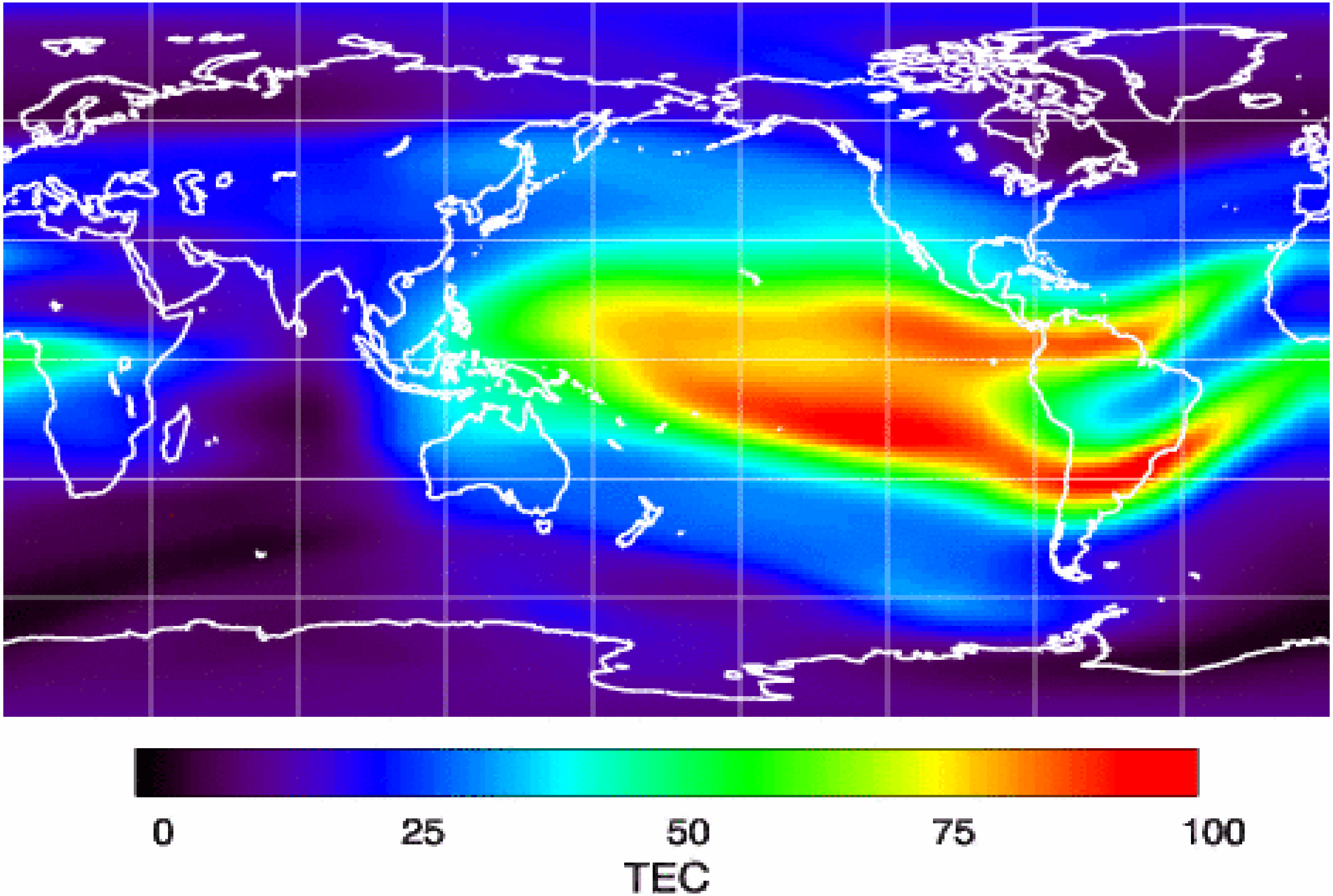
CIVIL AVIATION SAFETY AUTHORITY




*safe skies for all*

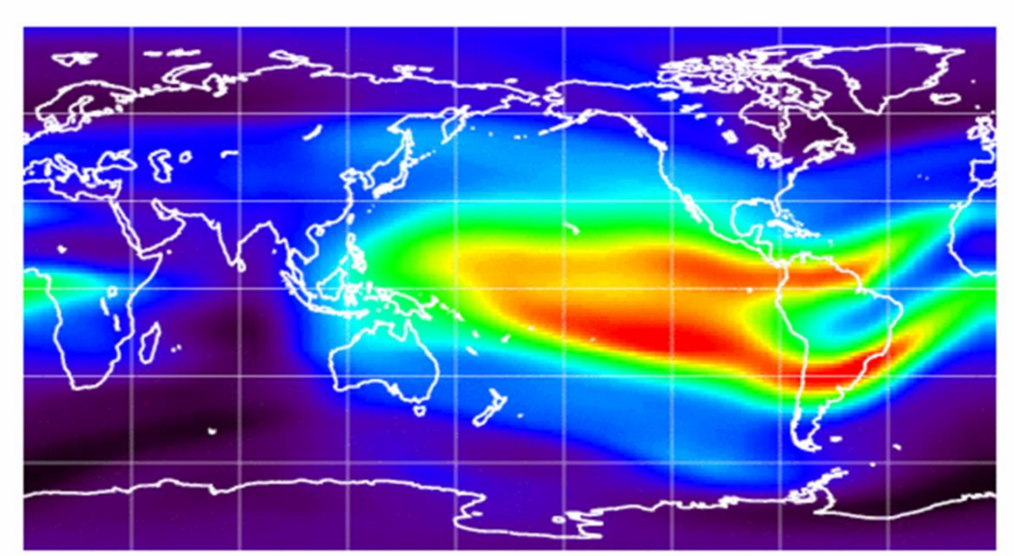
Ian Mallett

# The Ionospheric Challenge




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

# The Ionospheric Challenge

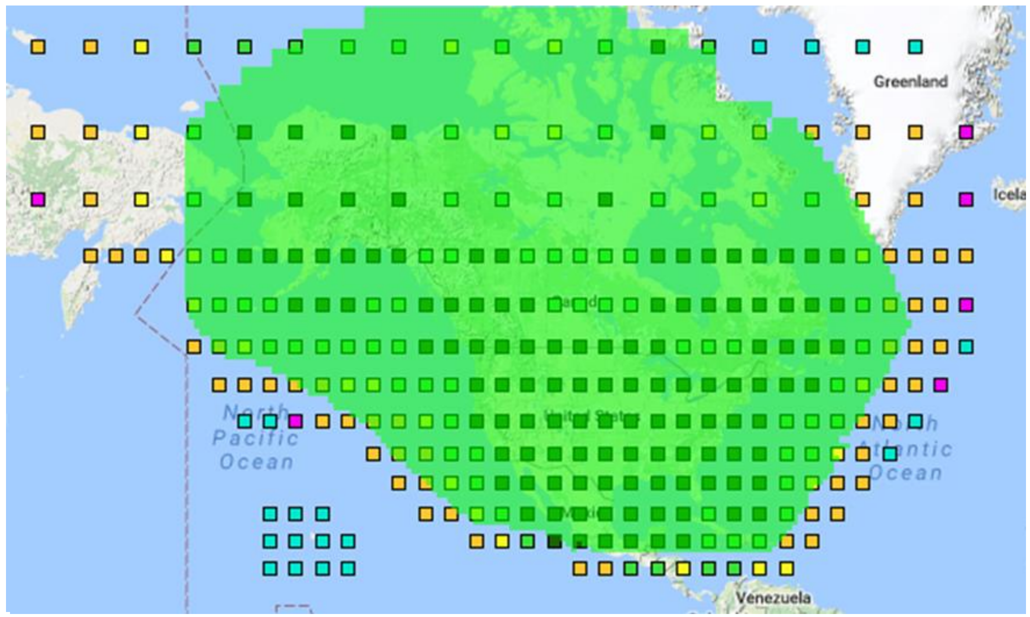


## Ionosphere and GNSS errors

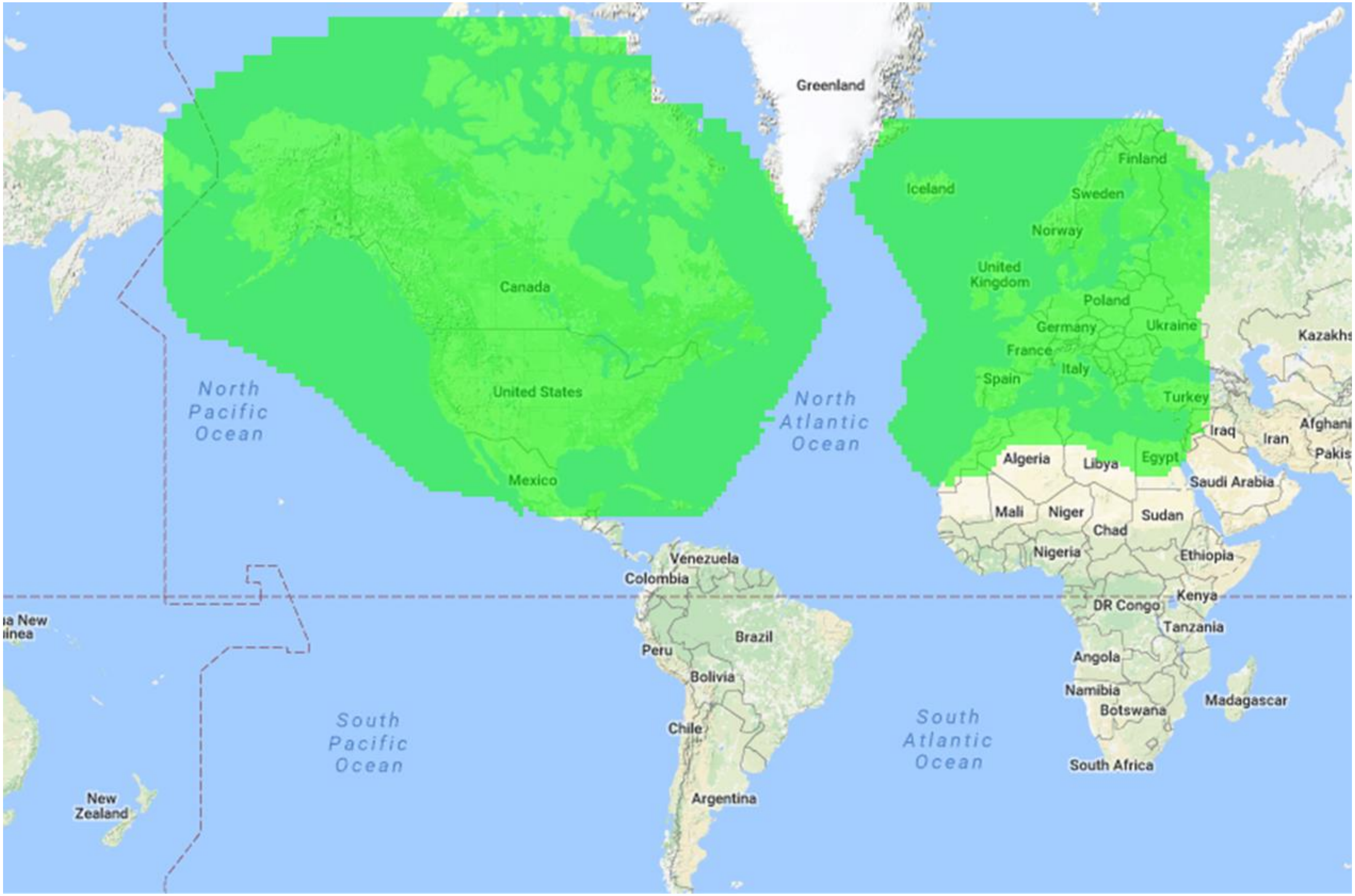
- Electron density affects signal transmission time
- Total Electron Count varies with time and location
- Solar storms can cause sudden and extreme variations
- Equatorial region is particularly affected by ionospheric changes and scintillation.

## 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.



# SBAS LPV Coverage




Courtesy of FAA Tech Center

# 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

Galileo

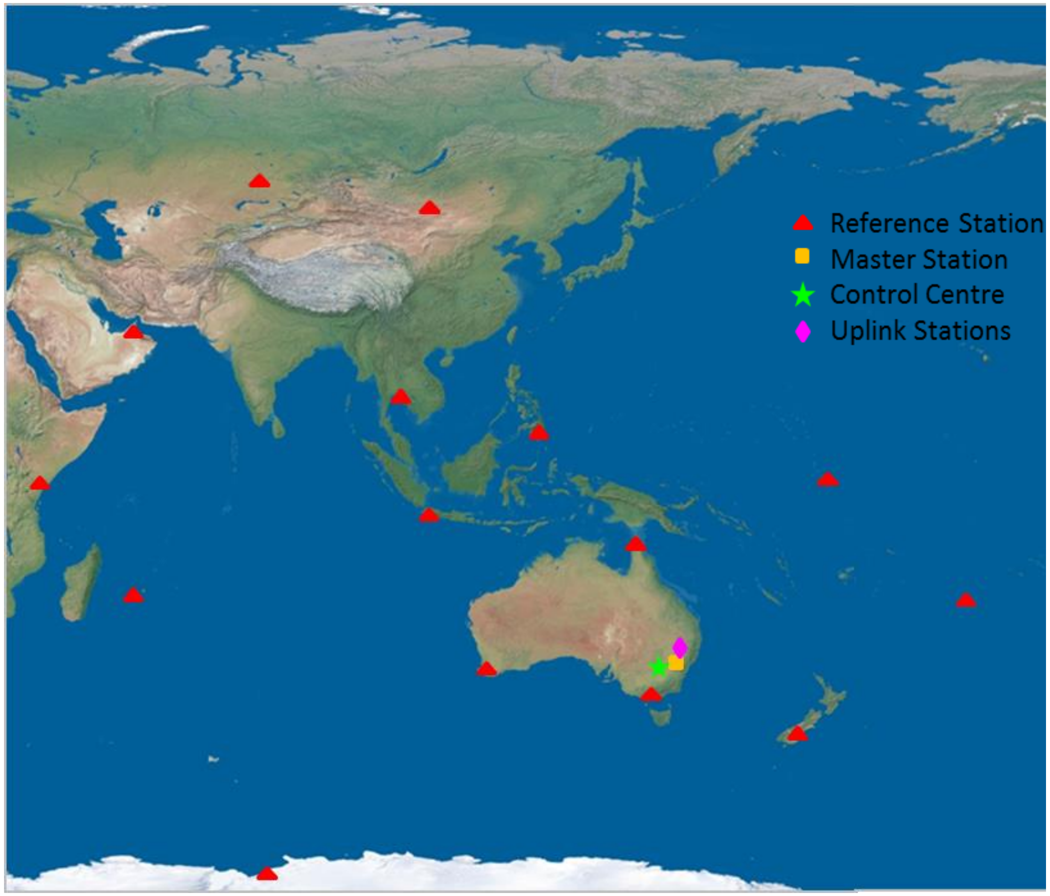
ESA - European Space Agency, A. Le Floc'h, CC BY-SA 3.0 IGO

GPS III

## Multiple Constellations

- More ranging signals in view
- Redundancy of GNSS providers
- Addresses sovereignty concerns

# 2nd Generation SBAS Testbed

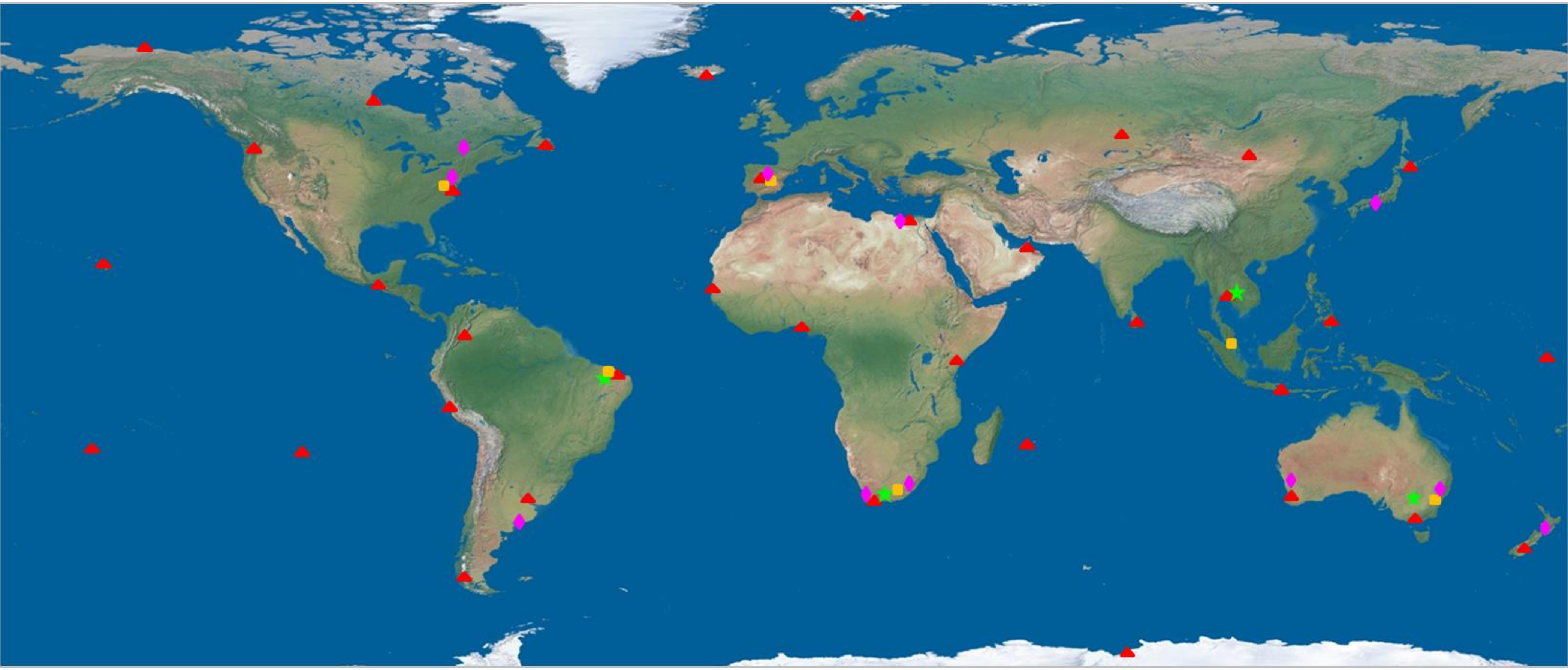



## International Collaboration

- **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$^0$ 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)

# 2nd 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.