Enabling Multi-Constellation Advanced Receiver Autonomous Integrity Monitoring (ARAIM)

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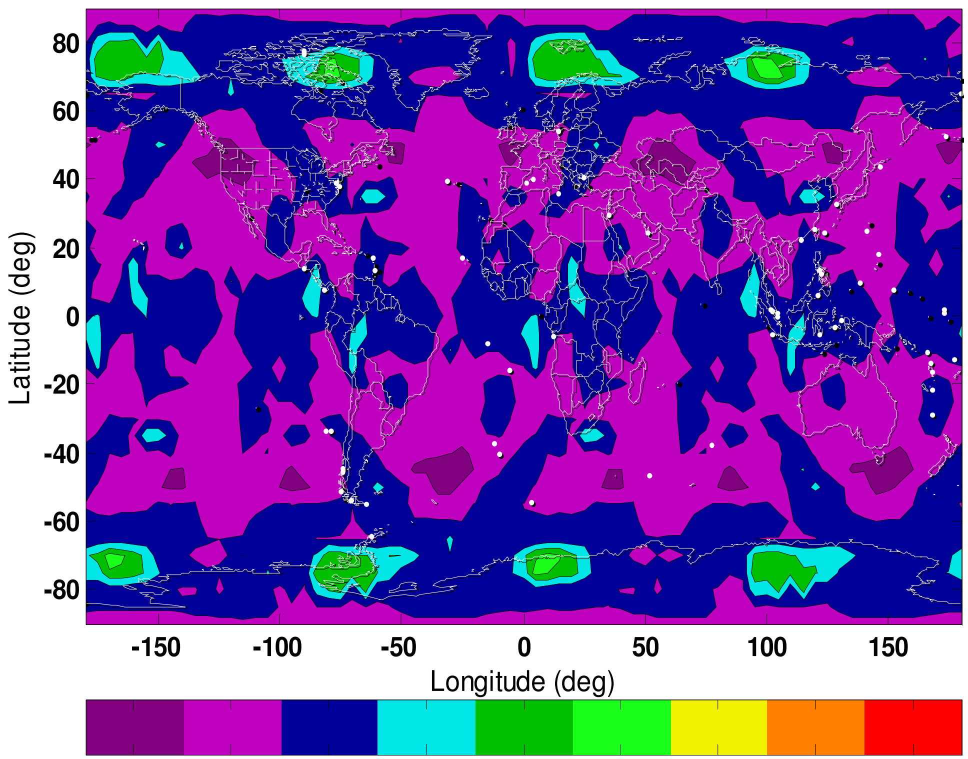
ARAIM Overview

- GNSS Evolutionary Architecture Study (GEAS) Phase II Report Recommendations
  - Development of dual frequency SBAS
  - Development of architectures and algorithms for Advanced Receiver Autonomous Integrity Monitoring (ARAIM), based on
    - Dual frequency ARNS (L1 and L5) signals
    - At least two independent GNSS core constellations for civil aviation.
- GEAS determined ARAIM could enable worldwide LPV-200 performance, provided:
  - Measurement redundancy and geometric diversity was assured
  - Results based on assumed knowledge of specific "parameters" for the core GNSS constellations

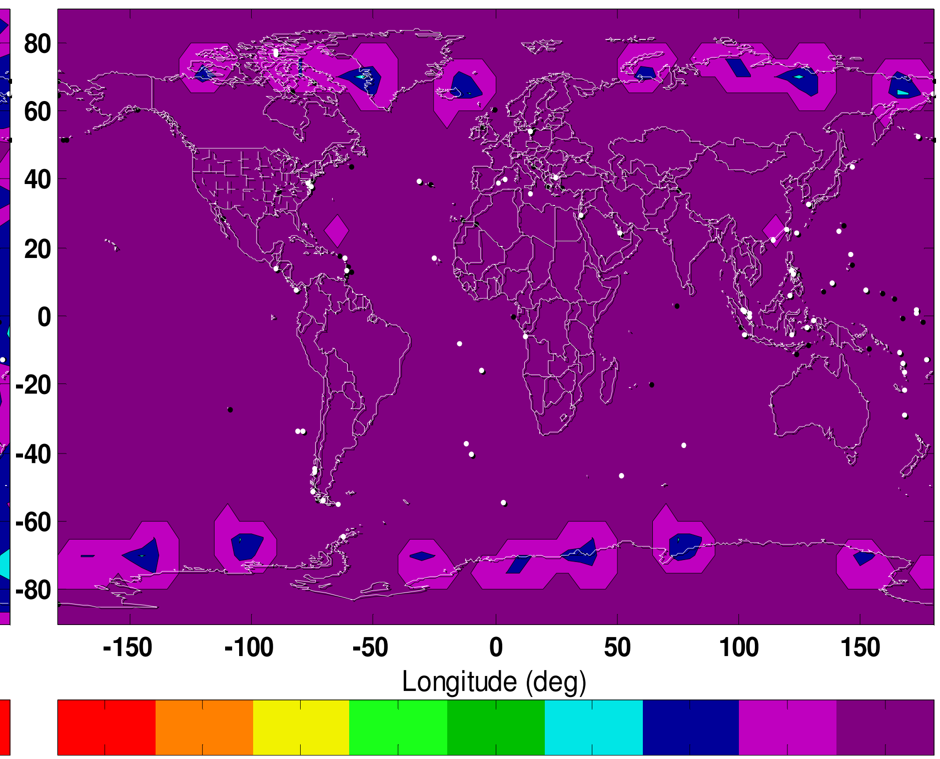
ARAIM Results for 30 SVs & URA = .5 m

URA = 0.5m, Bias = 0.5m



99.5% VPL - 20.46 m avg., 35m avail = 99.99%

URA = 0.5m, Bias = 0.5m, URE = 0.25m, rBias = 0.1m



For VAL = 35m, NDP & Acc: 97.77% coverage at 99.5% availabilit

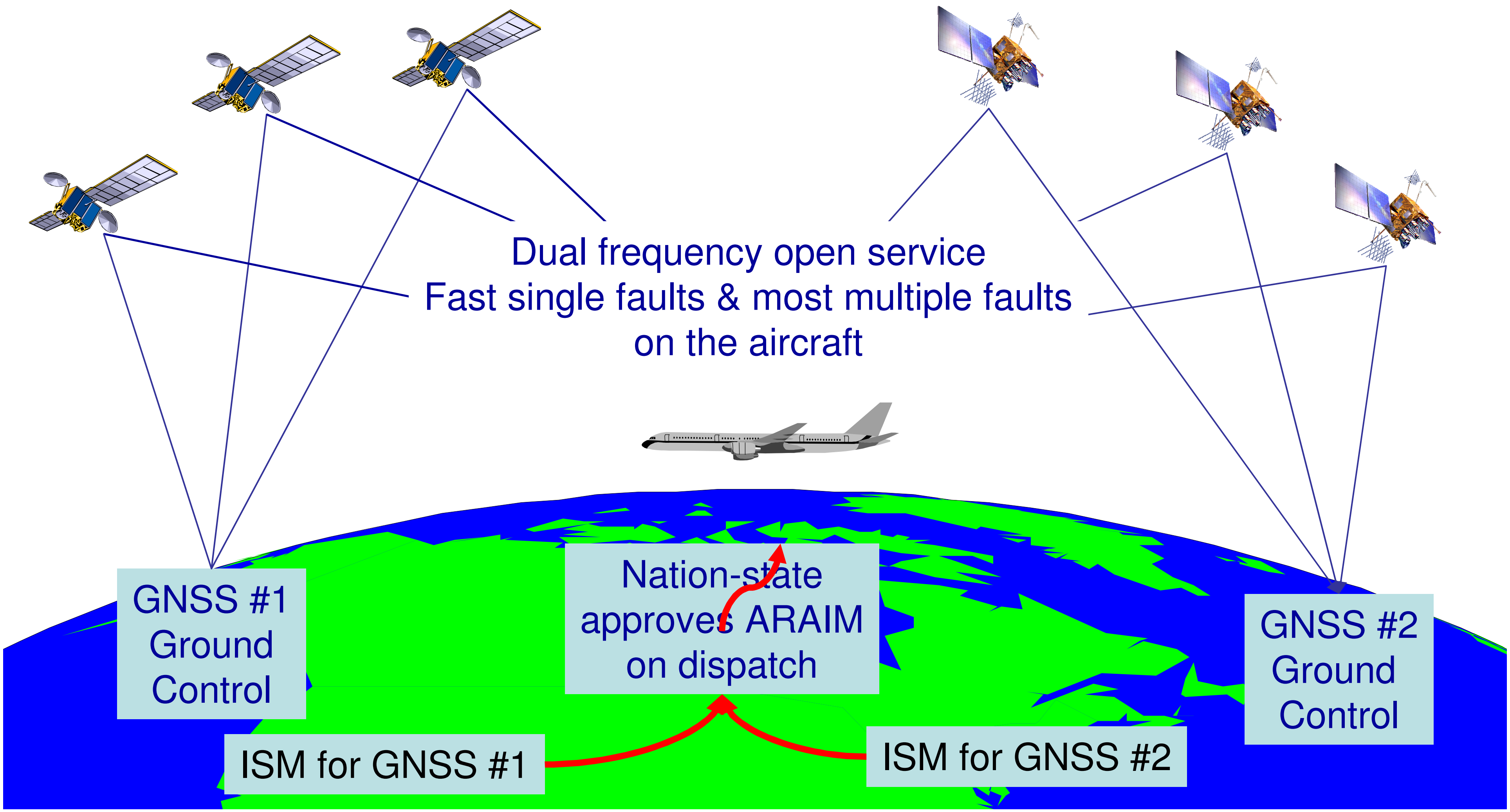
ARAIM currently predicated upon a user update rate of ~ 1hour

Performance Parameters for ARAIM

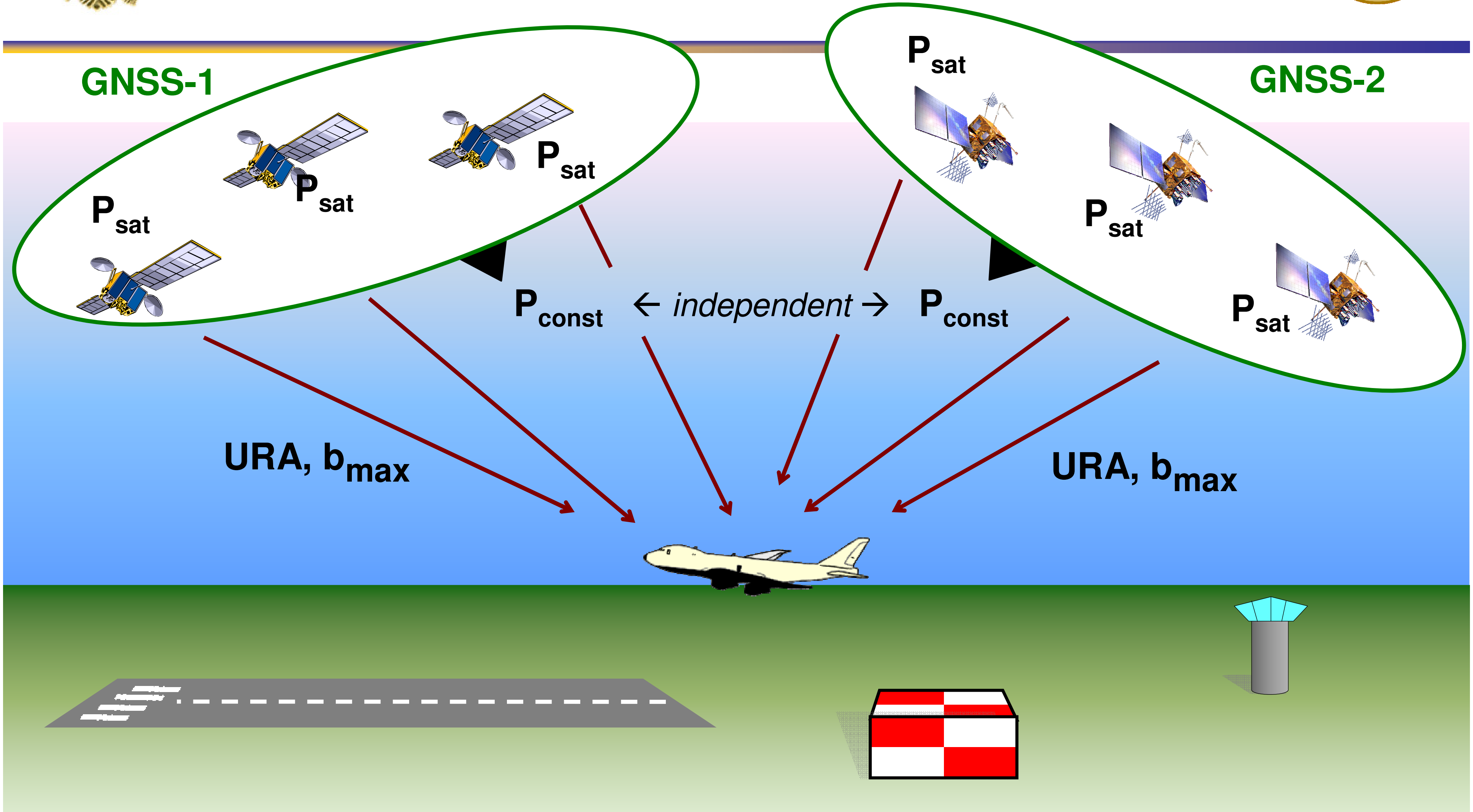
- ARAIM depends on GNSS specific constellation performance parameters:
  1. Bounding of fault-free clock and ephemeris error distributions
  2. Prior probability of SV faults
  3. Independence of faults between core constellations.

- ARAIM users receive an integrity support message (ISM)
  - GNSS service provider provides ISM to aviation users directly
  - ARAIM ISM generated by civil aviation authority with independent monitoring capability and broadcast to users

Integrity Support Message (ISM)



ARAIM Parameters



Example: Worldwide coverage results

less accuracy (URA) →

Less satellite reliability ↓

Less constellation reliability ↓

$P_{const} < 10^{-8}$

P_{sat}/URA	.5 m	1 m	1.5m	2 m	3 m	3.5 m	4 m
10^{-5}	100%	100%	100%	100%	100%	42.9%	3.4%
10^{-4}	100%	100%	100%	100%	100%	0	0
10^{-3}	100%	100%	100%	99.6%	6.6%	0	0

$P_{const} = 10^{-6}$

10^{-5}	100%	100%	95.0%	51.5%	0	0	0
10^{-4}	100%	100%	95.0%	51.5%	0	0	0
10^{-3}	100%	100%	95.0%	51.3%	0	0	0

$P_{const} = 10^{-4}$

10^{-5}	100%	98.5%	79.2%	.1%	0	0	0
10^{-4}	100%	98.5%	79.2%	.1%	0	0	0
10^{-3}	100%	98.5%	79.2%	.1%	0	0	0

GPS 27 + Galileo 27

P_{sat} = Prob. of satellite fault

P_{const} = Prob.of constellation fault

$b_{max} = 0.75$ m

Parameters Needed From GNSS Provider

- User Range Accuracy → **'URA'**
  - Standard deviation of the overbounding Normal distribution for clock and ephemeris errors
- Bias parameter → '$\mathbf{b_{max}}$'
  - May be needed to bound potential non-zero mean error distributions
- Fault state probability (fault-rate×time-to-notify) → '$\mathbf{P_{sat}}$'
  - Needed for faults that ***are*** independent between satellites
- Probability of constellation-wide fault → '$\mathbf{P_{const}}$'
  - For multiple faults that are ***not*** independent between satellites
    - Example is Earth Orientation Parameter (EOP) fault undetected by GNSS ground system

Summary

- Four basic parameters are needed to enable ARAIM integrity:
  - URA and b_{max} to describe nominal performance of clock and ephemeris
  - Prior probability of satellite fault
  - Prior probability of constellation failure
- A common understanding of these parameters must be developed and agreed upon by the service providers for interoperability
- ISM is a mechanism to deliver these parameters to users
- Delivery of ISM could be from multiple sources
- GNSS service providers need to include these parameters in Performance Standards