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

International Committee on GNSS (ICG-5)

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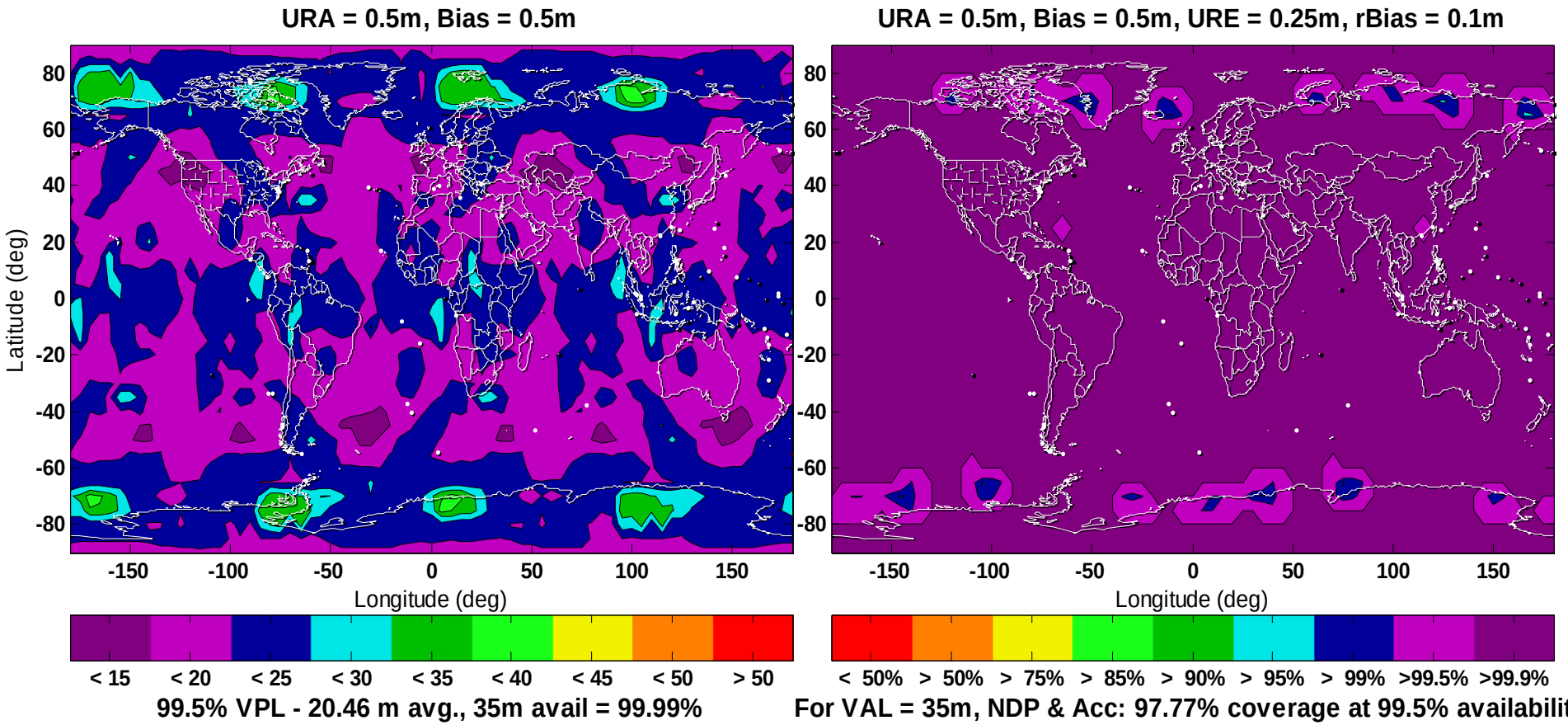
ARAIM Overview

- **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



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

Performance Parameters for ARAIM

- **ARAIM depends on GNSS specific constellation performance parameters:**

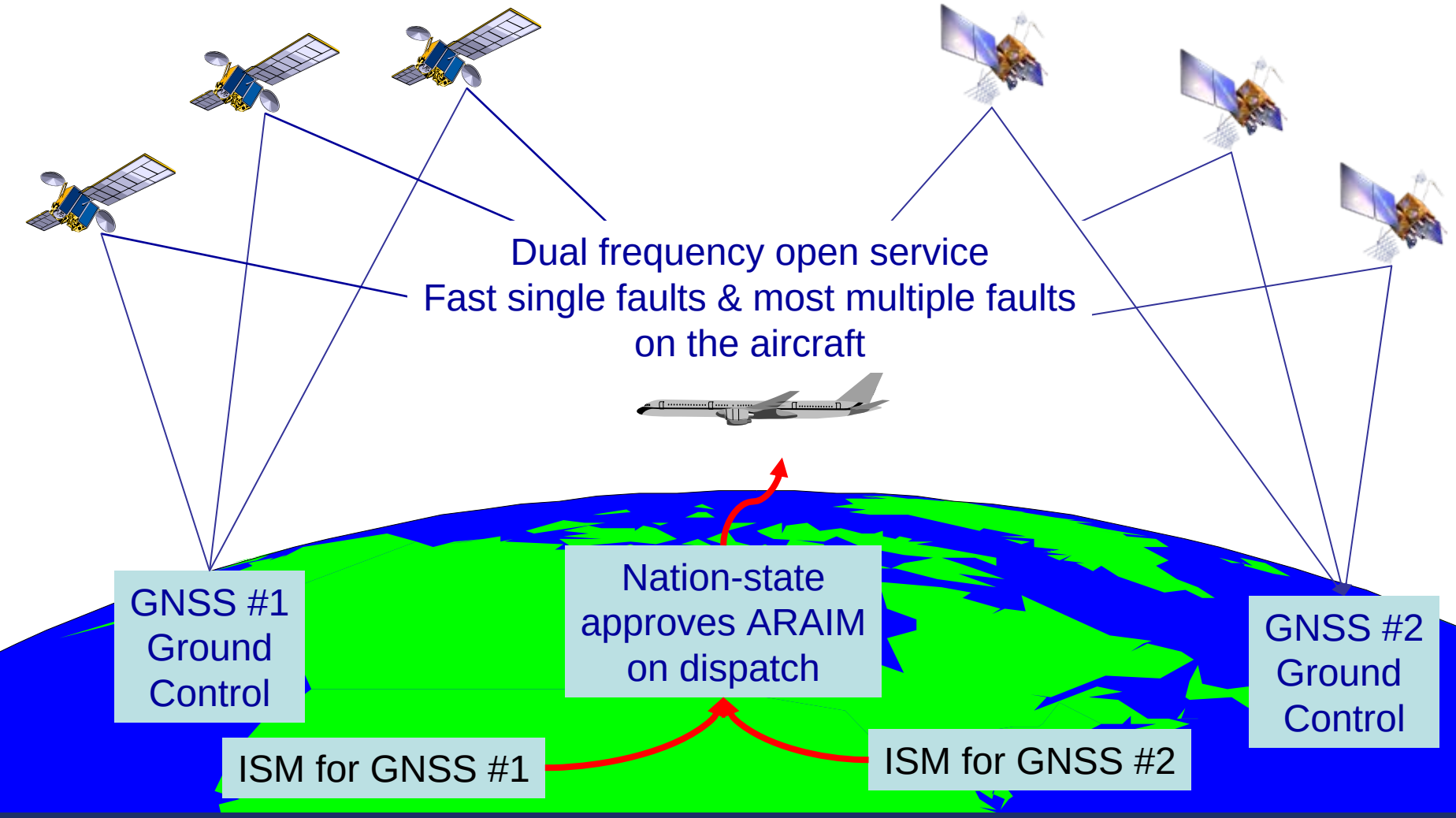
  ① Bounding of fault-free clock and ephemeris error distributions

  ② Prior probability of SV faults

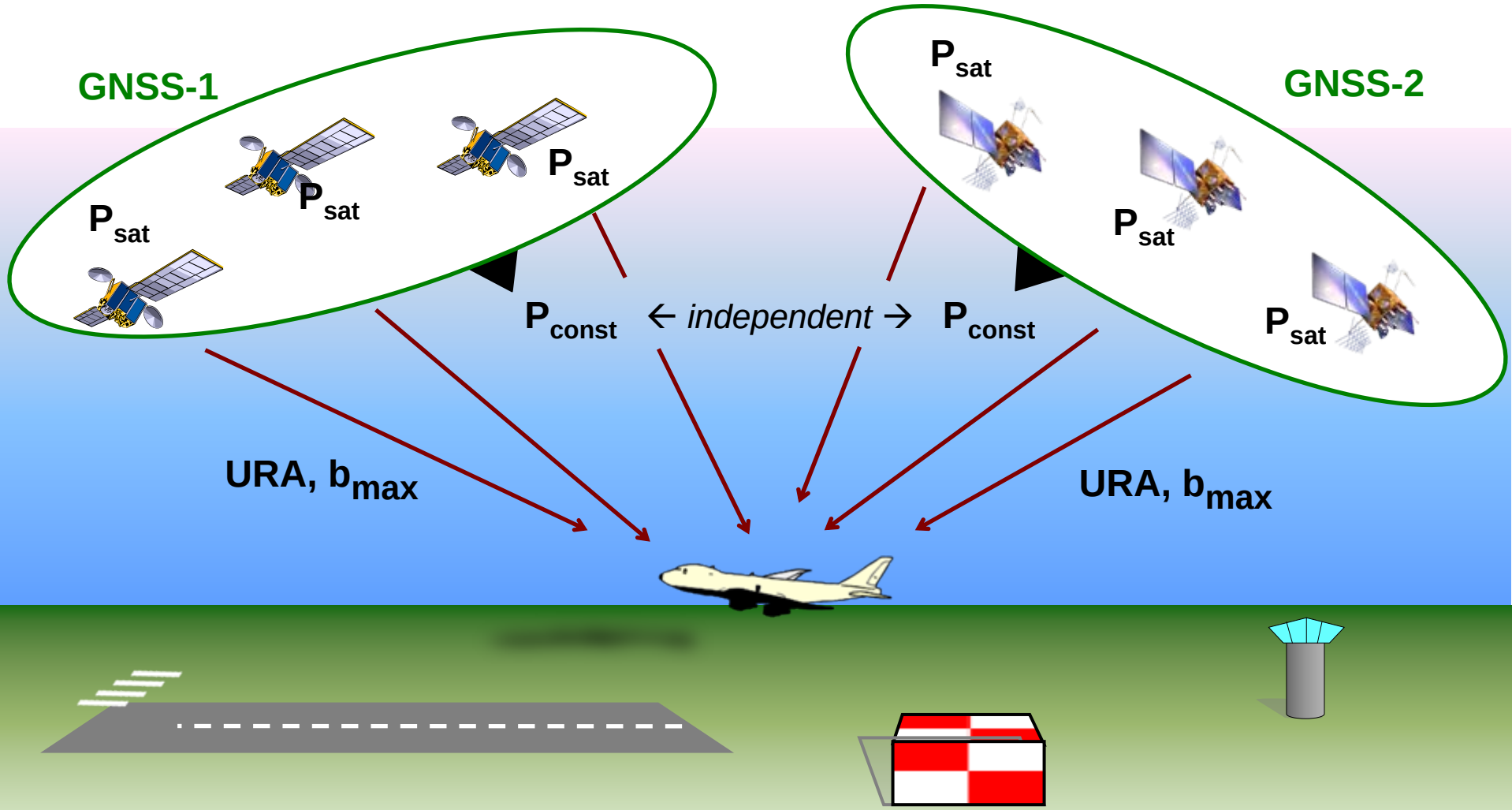
  ③ Independence of faults between core constellations.

- **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 constellation reliability

Less satellite reliability

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%	$P_{const} < 10^{-8}$
10^{-4}	100%	100%	100%	100%	100%	0	0	
10^{-3}	100%	100%	100%	99.6%	6.6%	0	0	
10^{-5}	100%	100%	95.0%	51.5%	0	0	0	$P_{const} = 10^{-6}$
10^{-4}	100%	100%	95.0%	51.5%	0	0	0	
10^{-3}	100%	100%	95.0%	51.3%	0	0	0	
10^{-5}	100%	98.5%	79.2%	.1%	0	0	0	$P_{const} = 10^{-4}$
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 → 'b_{max}'**
  - May be needed to bound potential non-zero mean error distributions
- **Fault state probability (fault-rate × time-to-notify) → 'P_{sat}'**
  - Needed for faults that ***are*** independent between satellites
- **Probability of** constellation-wide **fault → '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**