2nd Generation SBAS Testbed: Capabilities and Issues

5 December, 2018

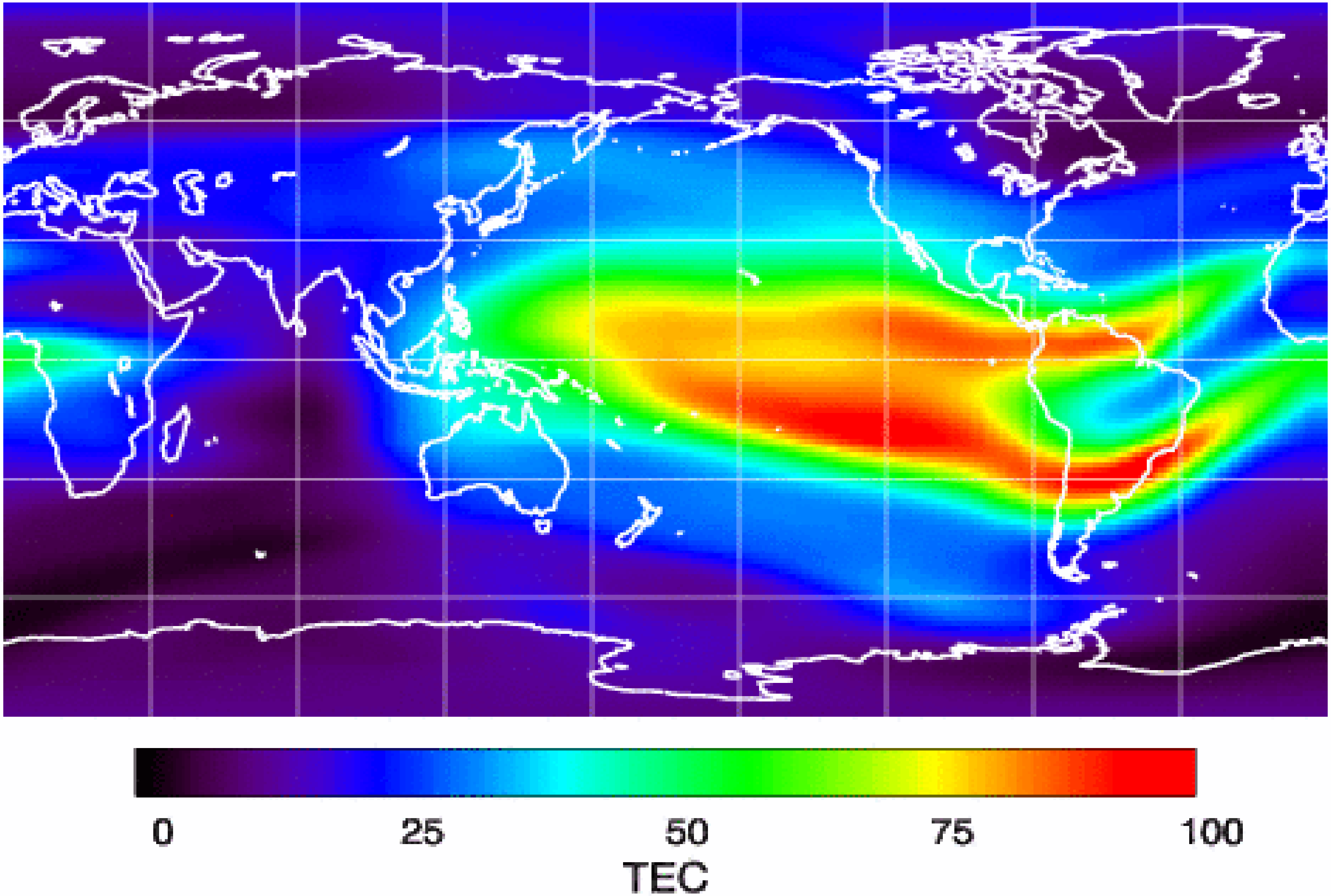
LOCKHEED MARTIN

gmv INNOVATING SOLUTIONS

GNSS

- ICAO Resolution A36-23 adopted in 2007
  - Envisioned global precision approach by 2016
  - Technical, cost, and political obstacles
- Opportunities created by dual frequencies and multiple constellations
- Issues still to be addressed

The Ionospheric Challenge



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

The Cost Challenge

EGNOS-Africa Joint Programme Office

EGNOS SBAS implementation in Africa - 'Modules' creation

- Four modules have been recommended for Africa:
  - Northern (**M1**),
  - West-Central (**M2**),
  - Eastern Africa(**M3**),
  - Southern (**M4**)
- Status: initial consultations RECs on-going for the modules

SAFIR

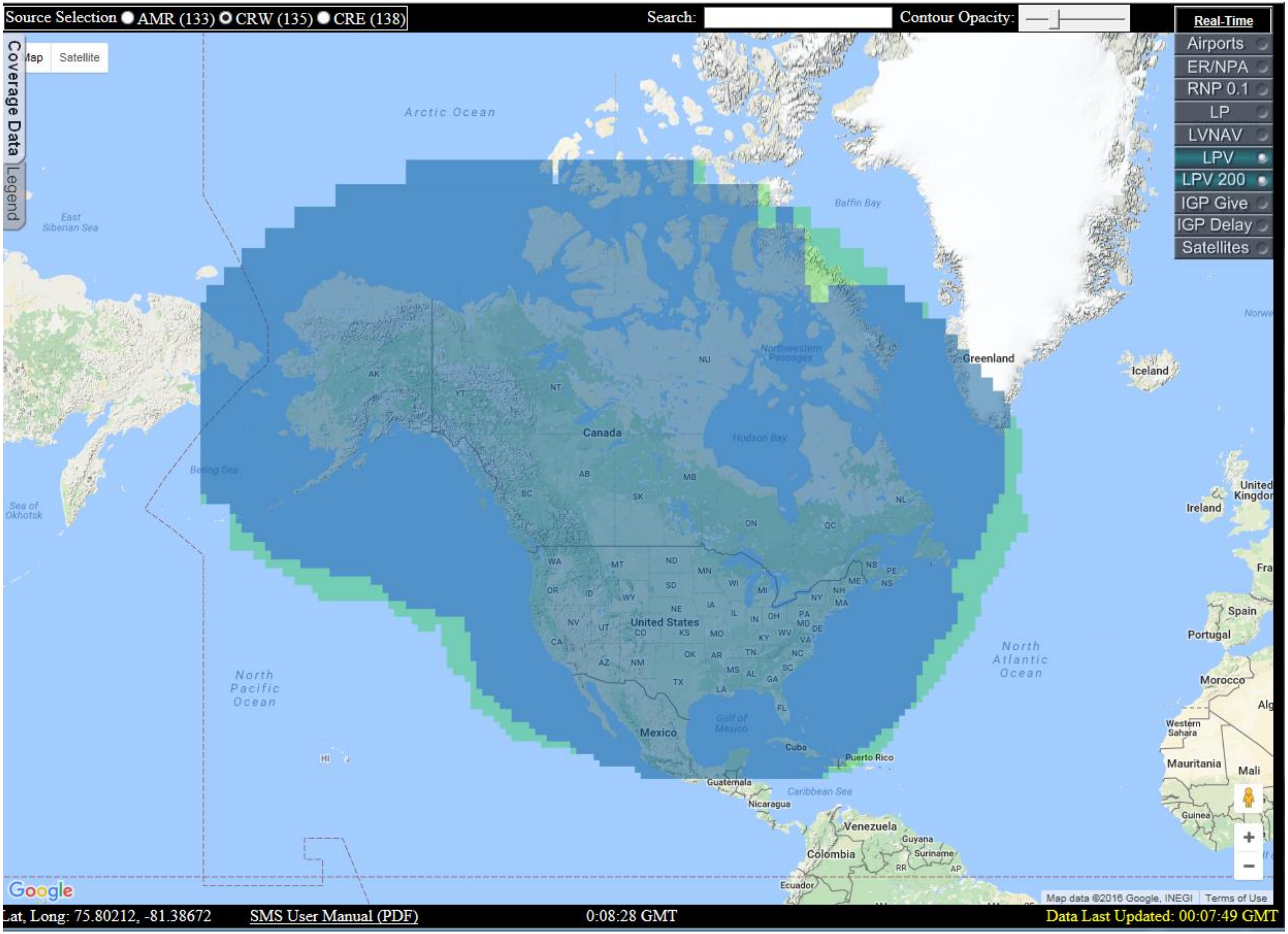
SBAS PRN Expansion

Presented to: RTCA WG 2

By: Jason Burns, Chris Hegarty, Joseph Dennis, Roland Lejeune

Date: March 7-11, 2016

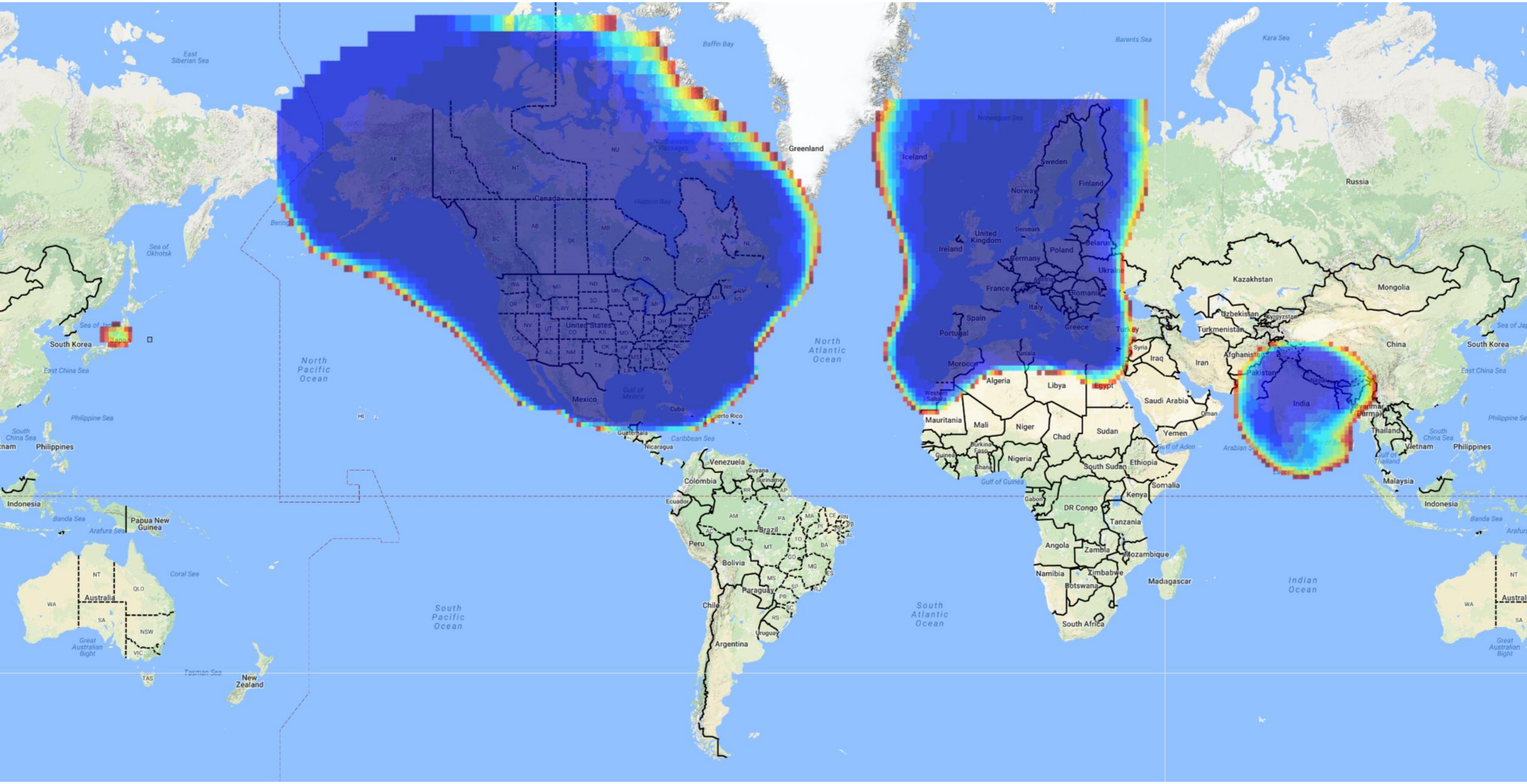
The Sovereignty Challenge



Derived from tool at www://ntsb.tc.faa.gov/sms/

SBAS Precision Approach Coverage

May 1, 2016



Courtesy of FAA Tech Center

Basis of 2nd Generation SBAS

Galileo

GPS III

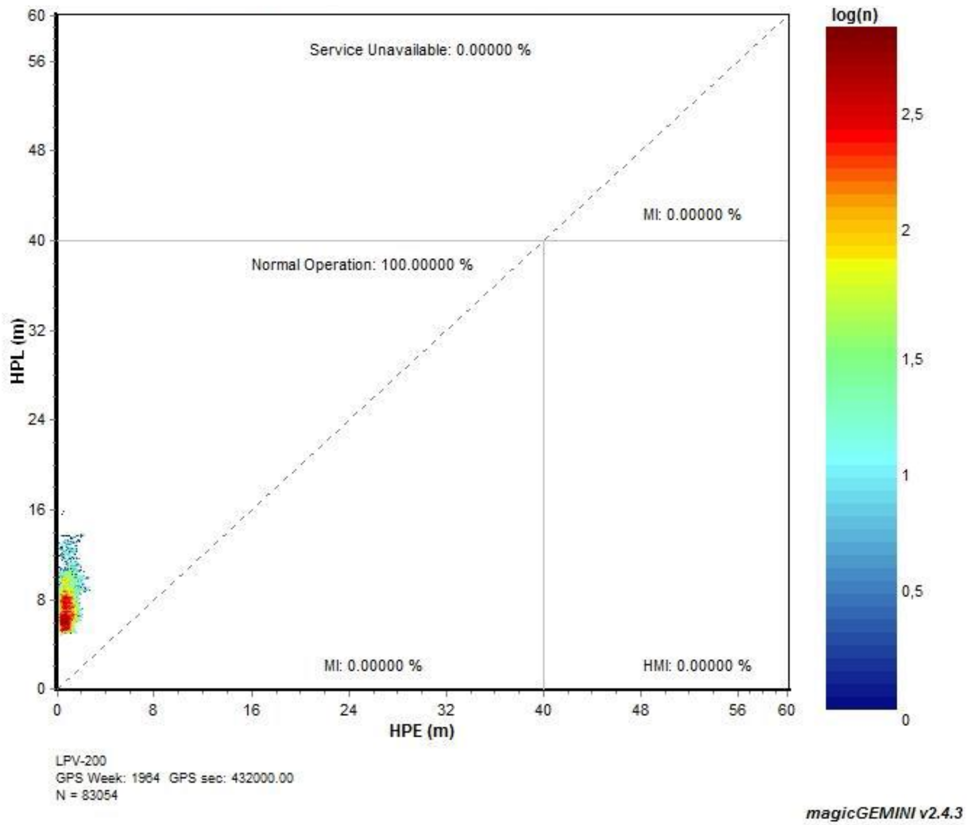
GPS IIF

- **Introduction of L5/E5a signal**
  - User receiver makes iono corrections
  - Solves equatorial challenge
  - Simplifies SBAS architecture
- **Multiple GNSS constellations**
  - GPS and Galileo now
  - Beidou & GLONASS K in future
- **New delivery business model**
  - Global collaboration—distribute key assets across multiple countries
  - Multi-modal applications and benefits
  - Spread costs across wider base
  - Operating company provides augmentation data as fee-for-service

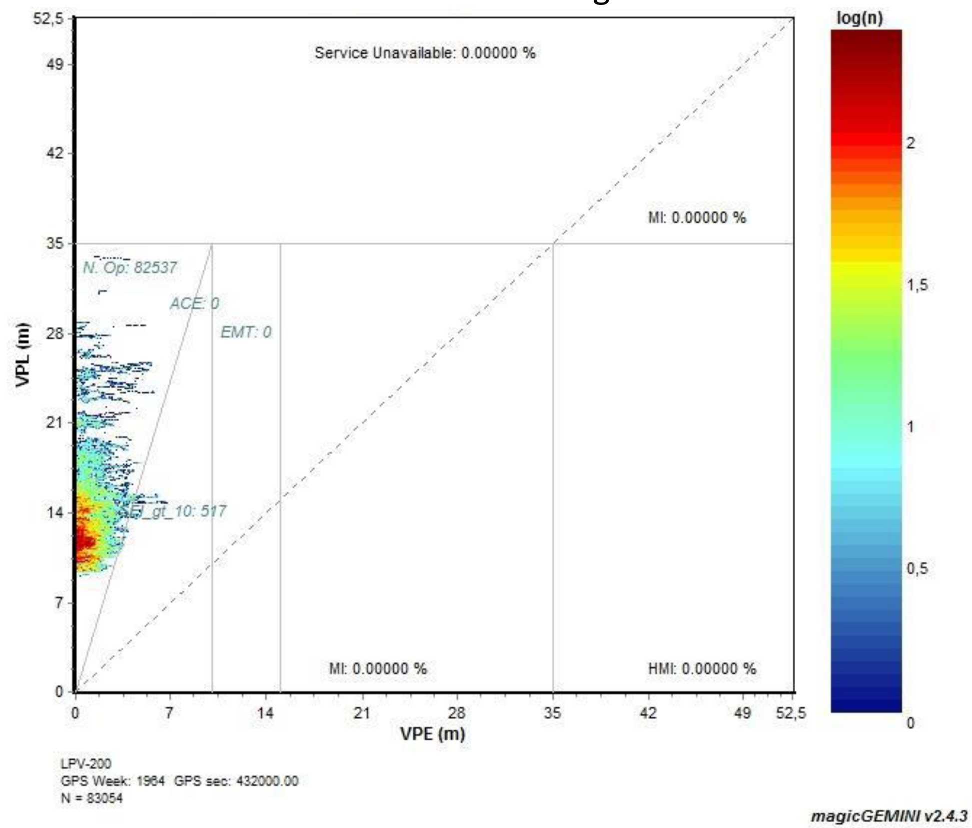
Current DFMC Performance

- **SBAS L5 DFMC message: GPS (L1/L2) + Galileo (E1/E5a)**

Horizontal Stanford Diagram



Vertical Stanford Diagram



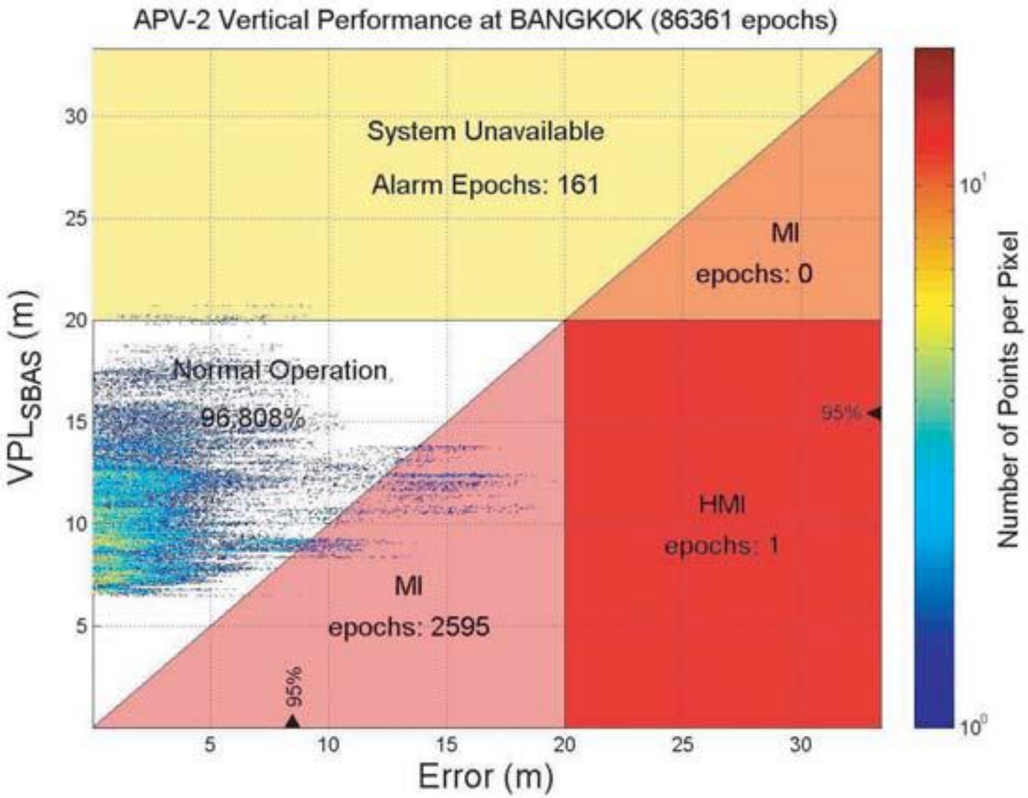
20/12/2017 – RSBY station

In collaboration with Geoscience Australia and Land Information New Zealand

L1 vs DFMC SBAS at Bangkok

L1 SBAS—2006

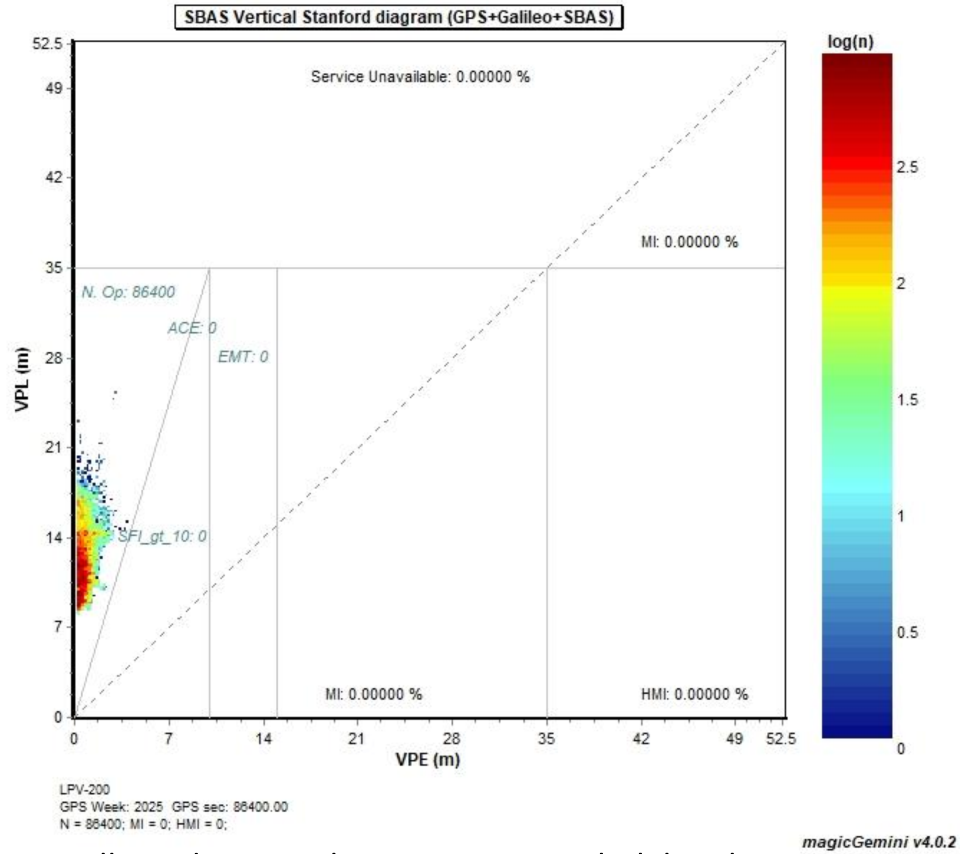
VPL/VPE



"SBAS Algorithm Performance in the Implementation of the ASIAPACIFIC GNSS Test Bed."
Noppadol Pringvanich and Chalermchon Satirapod
Chulalongkorn University, Bangkok, Thailand
THE JOURNAL OF NAVIGATION (2007)

DFMC SBAS—2018

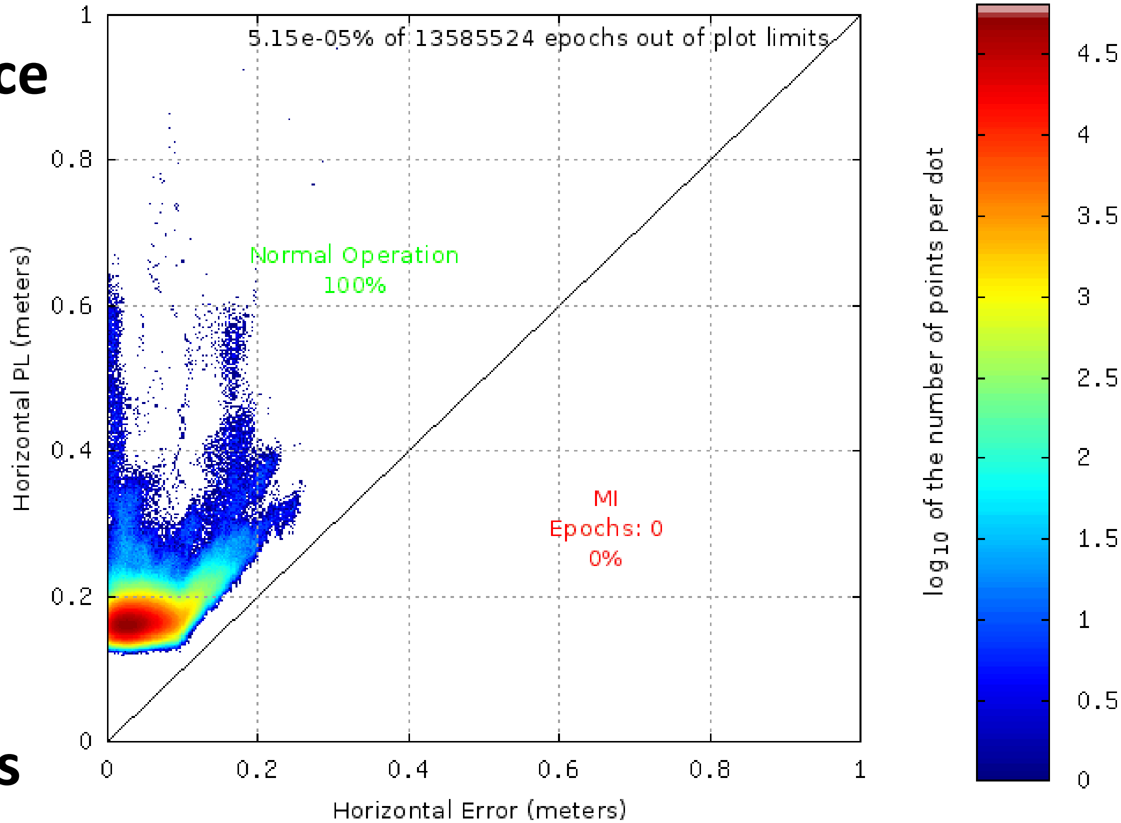
VPL/VPE



Collected on October 29, 2018, at Chulalongkorn University, from Aus/NZ 2nd Generation SBAS Testbed. In collaboration with Geo-Informatics and Space Technology Development Agency (GISTDA)

Precise Point Positioning Service

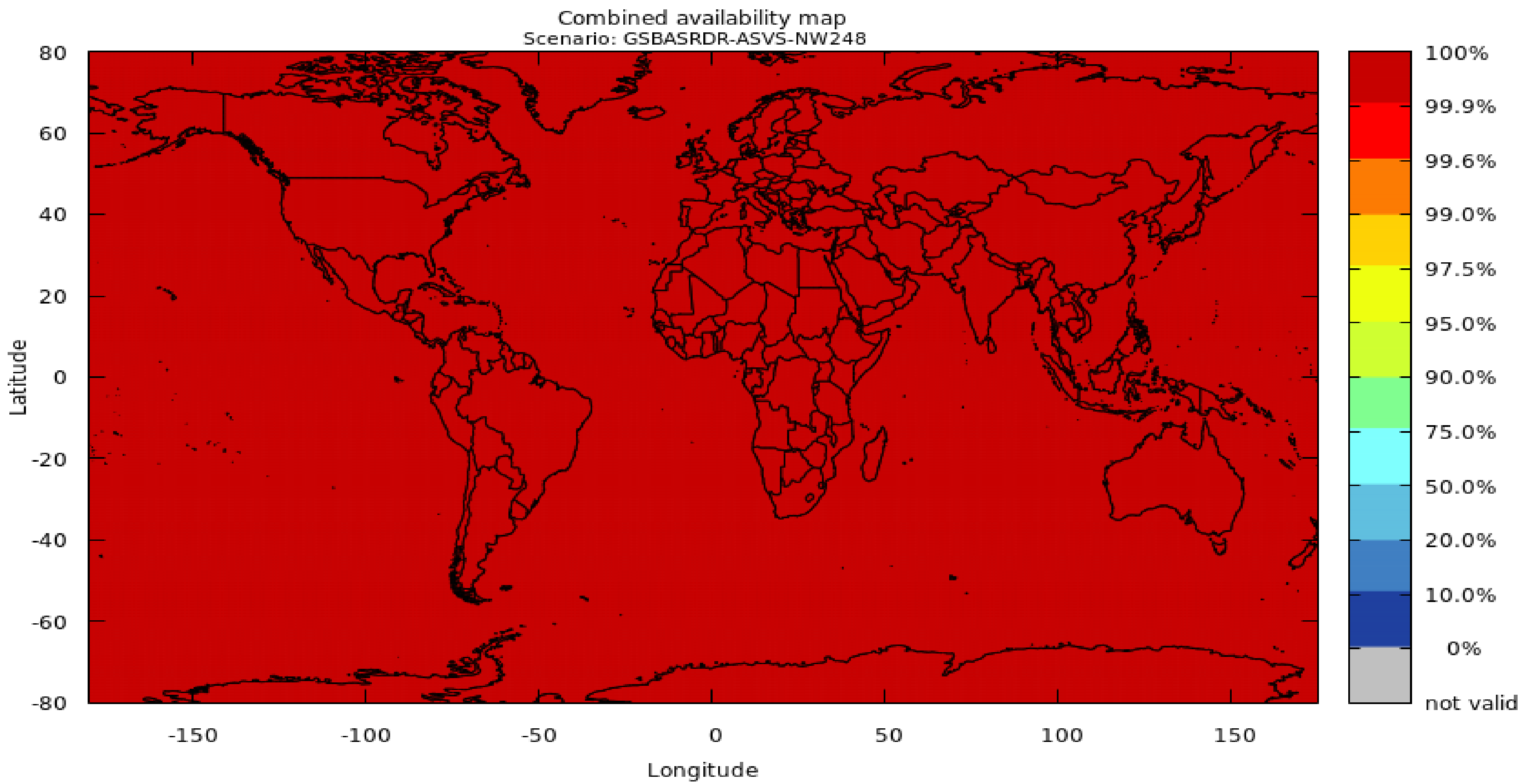
- **Very high precision with assurance bounds:**
  - Horizontal Accuracy: < 10 cm (95%)
  - Horizontal Protection Levels < 1 m
  - (P)HMI being assessed
- **Intended to support emerging safety-of-life applications:**
  - Maritime
  - Positive Train Control
  - Intelligent Transportation Systems
- **Integrity scheme based on GMV's K-IBPL patent**



Confidence Level	Horizontal Error (cm)	HPL (cm)
68	4.89	28.85
95	8.67	30.80
99.99	21.97	63.94

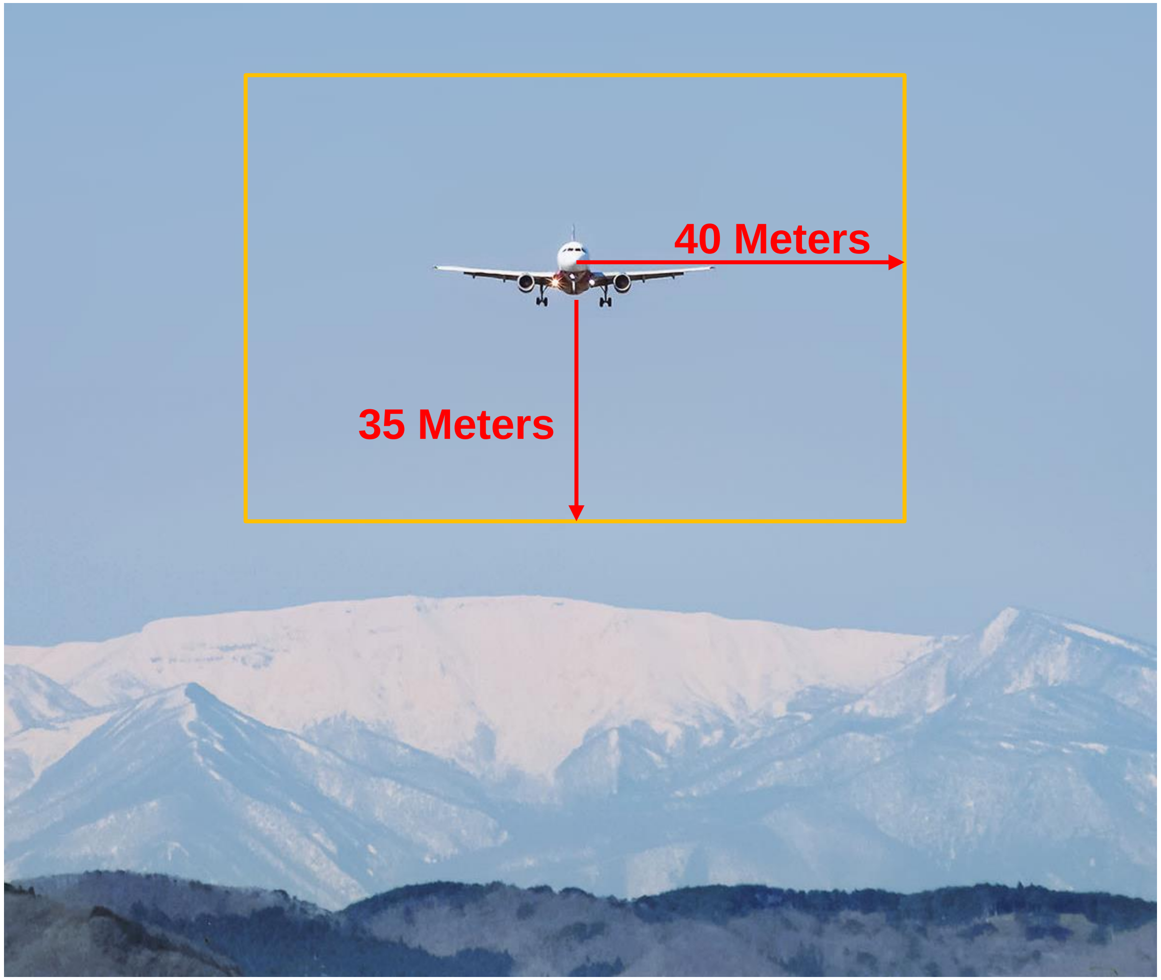
LPV-200 Availability

35 meter Vertical Alert Limit



Projected availability based on 24 GPS and 24 Galileo satellites broadcasting L1/E1 and L5/E5a, monitored by a global network of 26 reference stations.

Mature Requirement: Civil Aviation



ICAO SARPs published for L1 SBAS, being drafted for DFMC SBAS

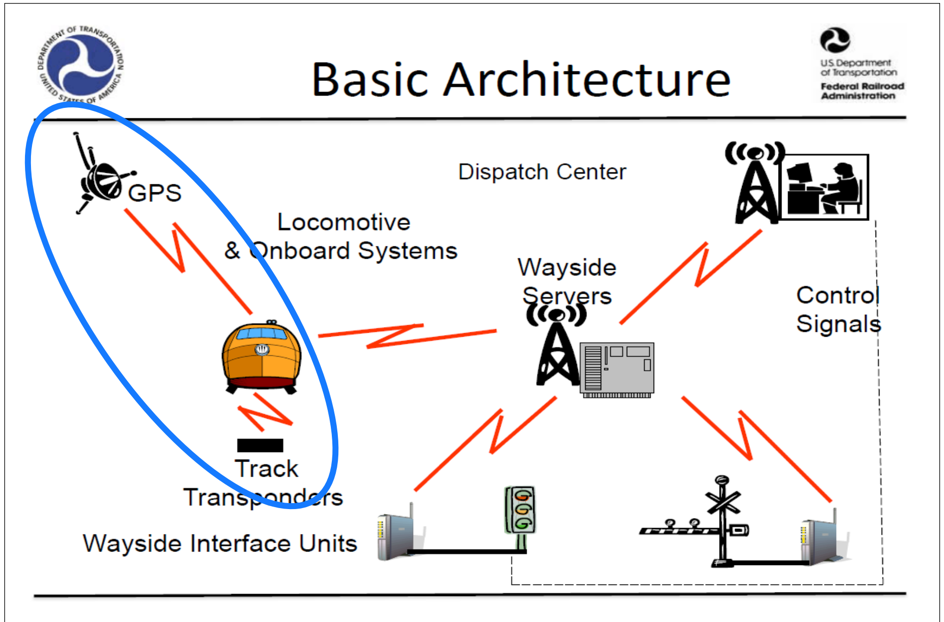
0.9999999, or 1 - 1 x 10^{-7} Integrity Probability of Hazardous, Misleading Information

6 seconds Time-To-Alarm

LPV-200, similar to CAT-1 ILS, supporting 200’ Decision Height

Better vertical performance could support CAT-1 Auto-Land

Evolving Requirement: Positive Train Control



Use	Accuracy	Integrity	TTA
Positive Train Control	1m	2m	6s
Track Defect Location	0.3m	0.6m	30s
Auto Asset Mapping	0.2m	0.4m	30s

Source: US Federal Navigation Plan, 2017

2 meter
Horizontal Alert Limit
0.99999, or 1 - 1 x 10^{-5} P(HMI);
— but P(HMI) could range from 10^{-1} to 10^{-9}

Emerging Requirement: Intelligent Transportation Systems

Public focus is on self-driving vehicles, but first applications are likely to be interconnection and collaborative traffic management

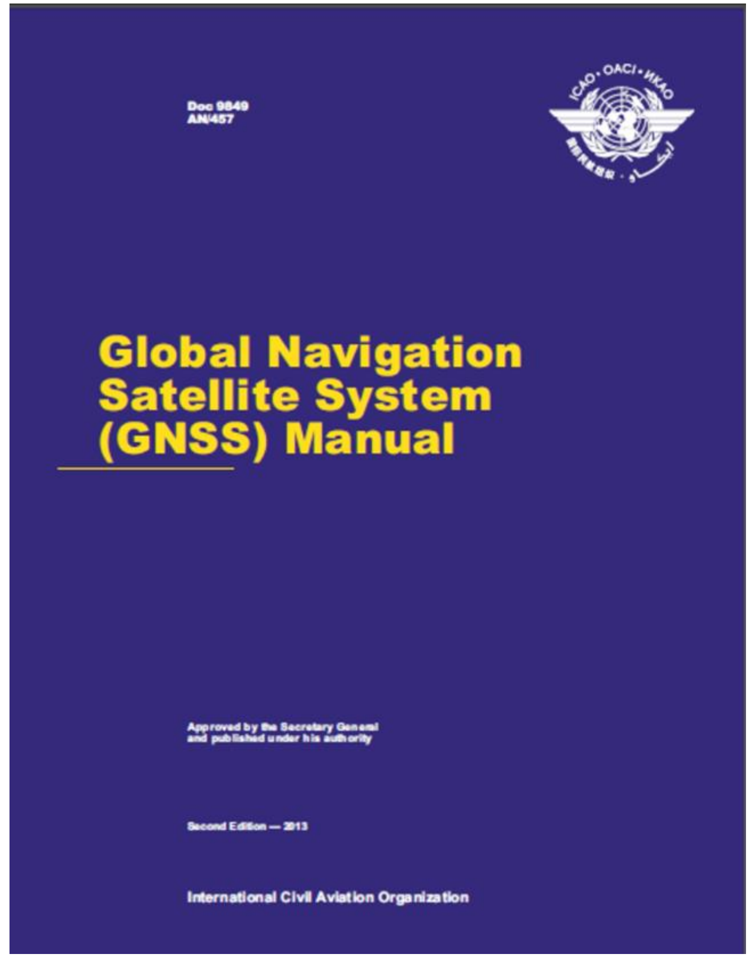
- **Range of applications, from inter-connection to autonomous steering**
- **Evolution of capability:**
  1. Function-specific Automation
  2. Combined Function Automation
  3. Limited Self-Driving Automation
  4. Full Self-Driving Automation
- **Navigation systems begin with augmented GNSS, then add sensors**
- **US automated highway requirements exceed aviation requirements:**

Use	Accuracy	Integrity	TTA
Navigation	1-20m	2-20m	5s
Monitoring	0.1-30m	0.2-30m	5s-5m
Collison	0.1m	0.2m	5s

Source: US Federal Navigation Plan, 2017

SBAS Service Delivery Model

- **Public and private sectors have unique contributions to GNSS evolution**
- **Replicate model of aeronautical communication and surveillance systems**
  - ARINC and SITA
  - Aireon ADS-B and Inmarsat ADS-C
- **Consistent with ICAO policies**
  - **Doc. 9849**, Sec. 7.5.1: "States can either provide GNSS signals or can authorize the use of signals provided by other entities"
  - **Doc. 9082**, Appendix 2: "GNSS and its associated augmentation systems in support of all phases of flight"
  - **Doc. 9161**, Sec. 3.99: "A group of states or a regional organization might also undertake to operate the augmentation satellite service required, either by themselves or by contracting a commercial or government organization to do so on their behalf."



Outstanding Issues

- Finalize DFMC SBAS SARPs
  - Service Area Message required in DFMC SARPs
  - Similar to MT 27 in L1 SBAS
- Alignment on regulatory requirements for emerging applications
- Expand options for SBAS delivery model