GPS & U.S. Augmentations Policy and Status

National GNSS Research Center Workshop

Daejeon, KOREA

08 April 2011

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Overview

- U.S. National Space Policy
- International Cooperation Activities
- GPS Status Update
- GPS Interface Specifications & Performance Standards
- U.S. Augmentations to GPS

Need for A New Space Policy

- Since 2006, various domestic and international developments have changed the opportunities, challenges, and threats facing the U.S., including its space capabilities
- **New opportunities for international cooperation; evolving/maturing commercial capabilities and options**
  - **More space actors, increased debris, need for enhanced transparency and stability**
- The National Space Policy accounts for those changes and reflects the integral role space plays in U.S. economic, national, and homeland security
- Continuity of fundamental policy precepts
- Every President since President Eisenhower has issued a space policy

New U.S. National Space Policy

Space-Based PNT Guideline: Maintain leadership in the service, provision, and use of GNSS

- Provide civil GPS services, free of direct user charges
  - Available on a continuous, worldwide basis
  - Maintain constellation consistent with published performance standards and interface specifications
  - Foreign PNT services may be used to complement services from GPS
- Encourage global compatibility and interoperability with GPS
- Promote transparency in civil service provision
- Enable market access to industry
- Support international activities to detect and mitigate harmful interference

Planned GNSS

- Global Constellations
  - **GPS (24+)**
  - GLONASS (30)
  - Galileo (27+3)
  - Compass (27+3 IGSO + 5 GEO)
- Regional Constellations
  - QZSS (3)
  - IRNSS (7)

- Satellite-Based Augmentations
  - **WAAS (3)**
  - MSAS (2)
  - EGNOS (3)
  - GAGAN (2)
  - SDCM (2)

U.S. Objectives in Working with Other GNSS Service Providers

- Ensure **compatibility** — ability of U.S. and non-U.S. space-based PNT services to be used separately or together without interfering with each individual service or signal
  - Radio frequency compatibility
  - Spectral separation between M-code and other signals
- Achieve **interoperability** – ability of civil U.S. and non-U.S. space-based PNT services to be used together to provide the user better capabilities than would be achieved by relying solely on one service or signal
  - Primary focus on the common L1C and L5 signals
- Promote fair competition in the global marketplace

Pursue through Bilateral and Multilateral Cooperation

Bilateral Cooperation

- **U.S.-EU** GPS-Galileo Cooperation Agreement signed in June 2004
  - Four working groups set up under the Agreement
- **U.S.-Japan** Joint Statement on GPS Cooperation 1998
  - Quasi Zenith Satellite System (QZSS) designed to be fully compatible and highly interoperable with GPS
  - Bilateral agreements to set up QZSS monitoring stations in Hawaii and Guam
- **U.S.-Russia** Joint Statement issued December 2004
  - Working Groups: compatibility/interoperability, search/rescue

Bilateral Cooperation (continued)

- **U.S.-China** operator-to-operator coordination under ITU auspices is complete
  - Bilateral Meetings in 2007, 2008, 2009, 2010
- **U.S.-India** Joint Statement on GNSS Cooperation 2007
  - Technical Meetings focused on GPS-India Regional Navigation Satellite System (IRNSS) compatibility and interoperability held in 2008 and 2009
  - Continuation of ITU compatibility coordination is pending
- **U.S.-Australia** Joint Delegation Statement on Cooperation in the Civil Use of GPS in 2007
  - Bilateral meeting in Washington, D.C., Oct. 26-27, 2010
  - GNSS and applications to be included in expanded space cooperation, as discussed in an October 27 Joint Announcement

International Committee on Global Navigation Satellite Systems (ICG)

- Emerged from 3rd UN Conference on the Exploration and Peaceful Uses of Outer Space July 1999
  - Promote the **use of GNSS** and its **integration into infrastructures**, particularly in developing countries
  - Encourage **compatibility and interoperability** among global and regional systems
  - Met annually since 2006
- Members include:
  - **GNSS Providers —** China, EU, India, ***Japan***, Russia, ***United States***
  - Other interested Member States of the United Nations
  - International organizations/associations

APEC GNSS Implementation Team (GIT)

- Established in 2002
- Promote implementation of regional GNSS augmentation systems to enhance inter-modal transportation and recommend actions to be considered in the Asia Pacific Region
- Reports to Transportation Working Group (TPT-WG) through the Inter-modal Experts Group (IEG)
- Japan hosted the third meeting in 2003 (Kobe) and the 11th meeting in 2007 (Tokyo) and has been an active participant

Outcome of APEC GNSS Implementation Team-14

- Met in Seattle (21-24 June 2010)
  - Co-Chaired by Noppadol Pringvanich (Thailand) and Karen Van Dyke (USA)
  - 12 economies and 85 participants attended
- Attendees included:
  - Government
  - GNSS industry
  - International Federation of Surveyors
  - European Commission
  - UN Office on Outer Space Affairs
- Adopted a Strategy for 2010-2015
  - Focus on seamless intermodal transportation
- Adopted new action items and called for development of project proposals in four areas

APEC-GIT Concept Papers

- Regulatory Roadmap for Performance Based Navigation (Aviation) – USA
- Multi-GNSS Constellation – Japan
- Regional Receiver Autonomous Integrity Monitoring (RAIM) Prediction System – Thailand
- Space Based Augmentation System Cooperation Opportunities – Republic of Korea

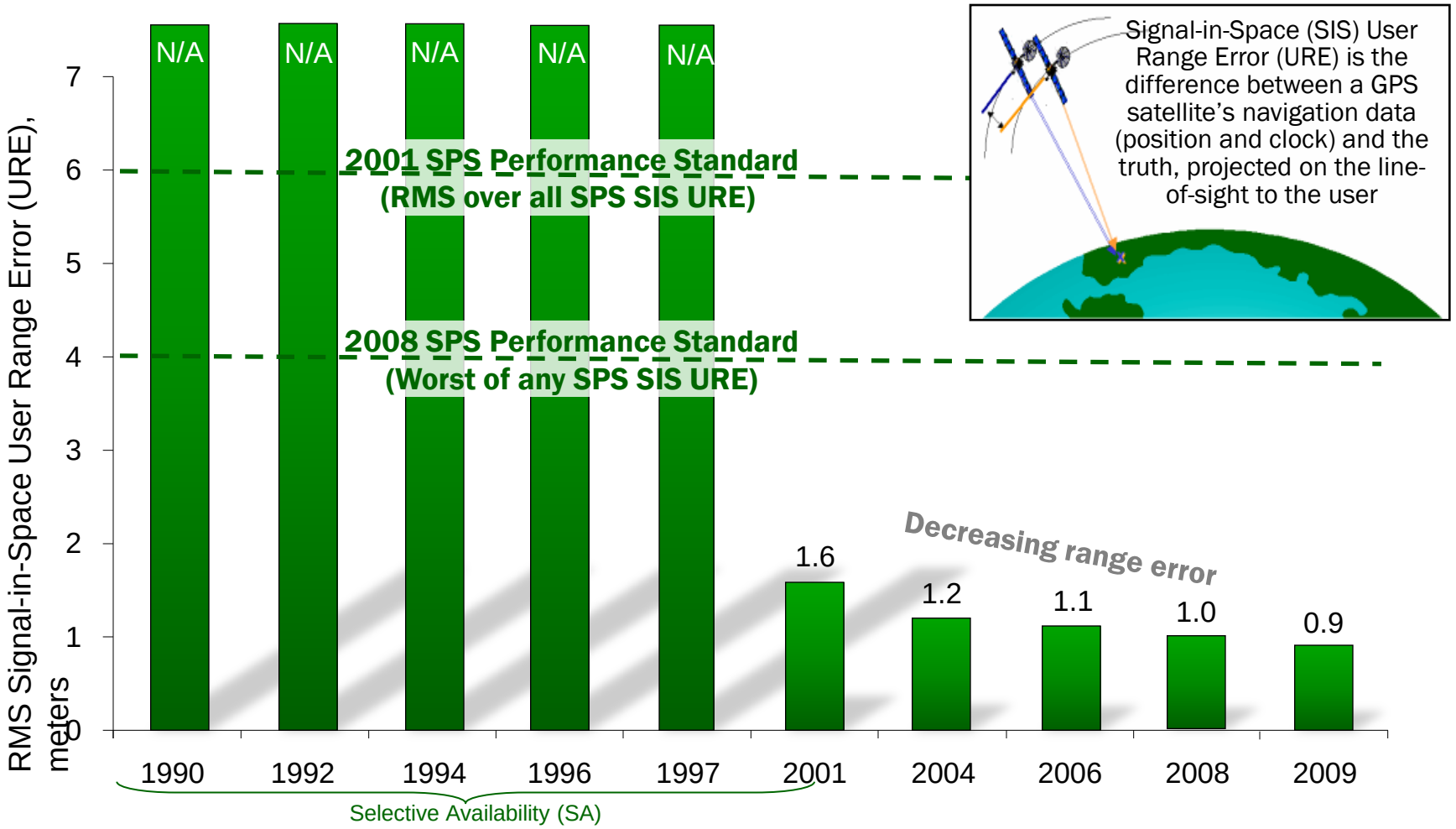
GPS Status Update

GPS Constellation

- 32 space vehicles, 31 currently set healthy
  - 11 GPS IIA
  - 12 GPS IIR
  - 8 GPS IIR-M (SVN 49 set un-healthy)
  - 1 GPS IIF
- 3 additional satellites in residual status
- IIF SV-2 scheduled to launch by June 2011
- IIIA SV-1 scheduled launch 2014
- Continuously assessing constellation health to determine launch need

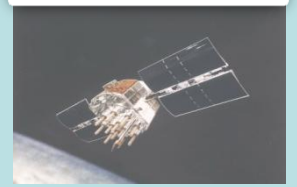
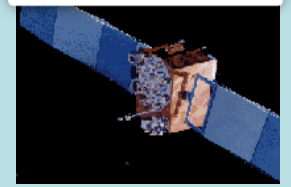
Global GPS service performance commitment met continuously since December 1993

GPS SPS Signal in Space Performance



System accuracy exceeds published standard

GPS Modernization Program

1978 - 1985	1989 – 1997	1997- 2004	2005 - 2009	2010 - Present	2014 – 2024
					
Block I	**Block II/IIA**	**Block IIR**	**Block IIR-M**	**Block IIF**	**Block III**
11 (10) Satellites	**28 Satellites**	**13 (12) Satellites**	**8 Satellites**	**12 Satellites**	**32 Satellites**
Demonstration system • L1 (CA) Navigation signal • L1 & L2 (P Code) Navigation signal • 5 Year Design Life	**Basic GPS Provides Initial Navigation Capabilities** • Standard Service • Single Frequency (L1) • C/A code navigation • Precise Service • Two frequencies (L1 & L2) • P (Y) -Code navigation • 7.5 Year Design Life	**IIA/IIR Capabilities "Plus"** • 2nd Civil Signal L2 (L2C) • Earth Coverage M-Code on L1/L2 • L5 Demo • Anti-Jam Flex Power • 7.5 Year Design Life	**IIR -M Capabilities "Plus"** • 3rd Civil Signal L5 • Reprogrammable Nav Processer • Increased Accuracy requirement • 12 Year Design Life	**IIF Capabilities "Plus"** IIIA • Increased accuracy • Increased Earth Coverage power • 15 Year Design Life • 4th Civil Signal (L1C) IIIB • near-real-time commanding IIIC • Navigation Integrity • Spot Beam for AJ	

Increasing Space System Capabilities – Increasing Military/Civil User Benefits

GPS Modernization – New Civil Signals

Second civil signal "L2C"

- Designed to meet commercial needs
- Higher accuracy through ionospheric correction
- Available since 2005 without data message
  - Currently, 7 IIR-Ms transmitting L2C
- Full capability: 24 satellites ~2016

Third civil signal "L5"

- Designed to meet demanding requirements for transportation safety-of-life
- Uses highly protected Aeronautical Radio Navigation Service (ARNS) band
- On orbit broadcast 10 APR 2009 on IIR-20(M) secured ITU frequency filing
  - Currently transmitting from 1 IIF satellite
- Full capability: 24 satellites ~2019

GPS Modernization – Fourth Civil Signal (L1C)

Under Trees

Urban Canyons

- Designed with international partners for interoperability
- Modernized civil signal at L1 frequency
  - More robust navigation across a broad range of user applications
  - Improved performance in challenged tracking environments
  - Original signal retained for backward compatibility
- Specification developed in cooperation with industry recently completed
- Launches with GPS III in 2014
- On 24 satellites by ~2021

Modernized Operational Control Segment (OCX)

- Architecture Evolution Plan (AEP)
  - Transitioned in 2007
  - Increased worldwide commanding capability
  - Increased capacity for monitoring of GPS signals
  - Modern distributed system replaced 1970s mainframes
- Next Generation Control Segment (OCX)
  - Controls more capable constellation, and monitors all GPS signals
  - $1.5B contract awarded 25 February 2010
  - Capability delivered incrementally to reduce risk
  - Preliminary Design Review scheduled for June 2011
  - Full Capability by ~2016

GPS Modernization – Semi-codeless Transition

- GPS receivers attain very high accuracy by using "codeless" or "semi-codeless" techniques that exploit the encrypted military GPS signals without actually decoding them
  - Techniques will no longer be necessary once the new civil GPS signals are fully operational
- U.S. Government published a notice for users to transition to GPS civil-coded signals by 31 December 2020
  - Provided time for an orderly and systematic transition
  - Based on launch schedule and projected budget
- U.S. Government led community-wide collaboration on this transition plan
- U.S. is committed to continually improving GPS services as users complete a timely transition to dual-coded civil GPS equipment

Public Interface Specifications

- Current versions of the public GPS Signal-in-Space (SIS) Interface Specifications:
  - IS-GPS-200 – L1 (P(Y) , C/A), L2 (P(Y), L2C)
  - IS-GPS-705 – L5
  - IS-GPS-800 – L1C

- These and other key IS/ICD documents available at:
  - http://www.navcen.uscg.gov/index.php?pageName=gpsReferenceInfo/
  - http://www.gps.gov/technical/icwg/

Future Performance Standard Updates

- Planning a draft update of the SPS PS in 2011
  - Addition of L2C signal to current L1 C/A signal
  - Same performance values
  - Update to be approved before Initial Operational Capability (IOC) declaration for L2C
- Planning subsequent draft updates for L5 & L1C signals
  - Prior to each subsequent IOC declaration
- Developing an updated set of performance metrics
  - Include different user applications and terrain environments

U.S. Augmentation Systems

U.S. GPS Augmentation Programs Designed for Aviation

Wide Area Augmentation System (WAAS) Architecture

38 Reference Stations

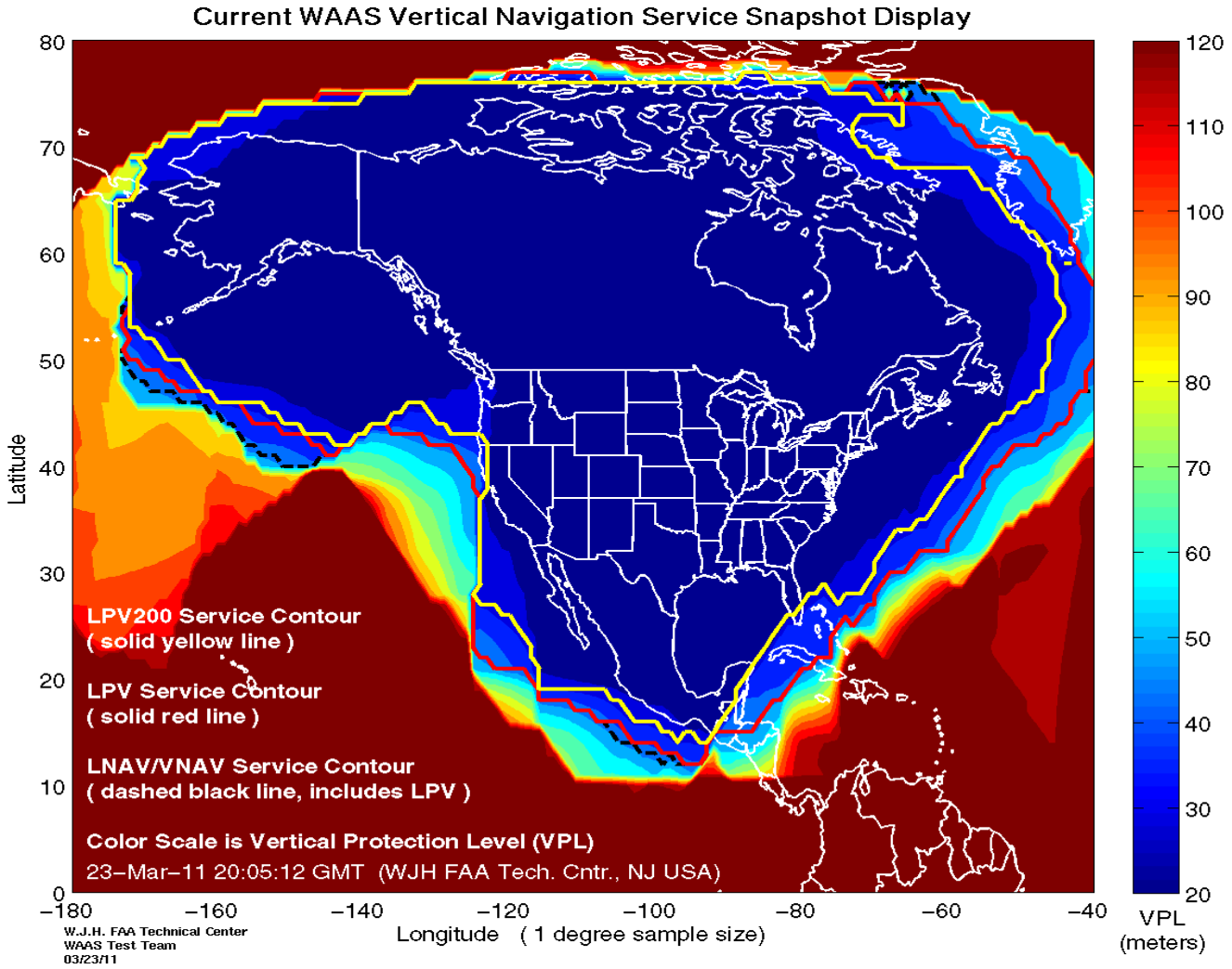
3 Master Stations

6 Ground Earth Stations

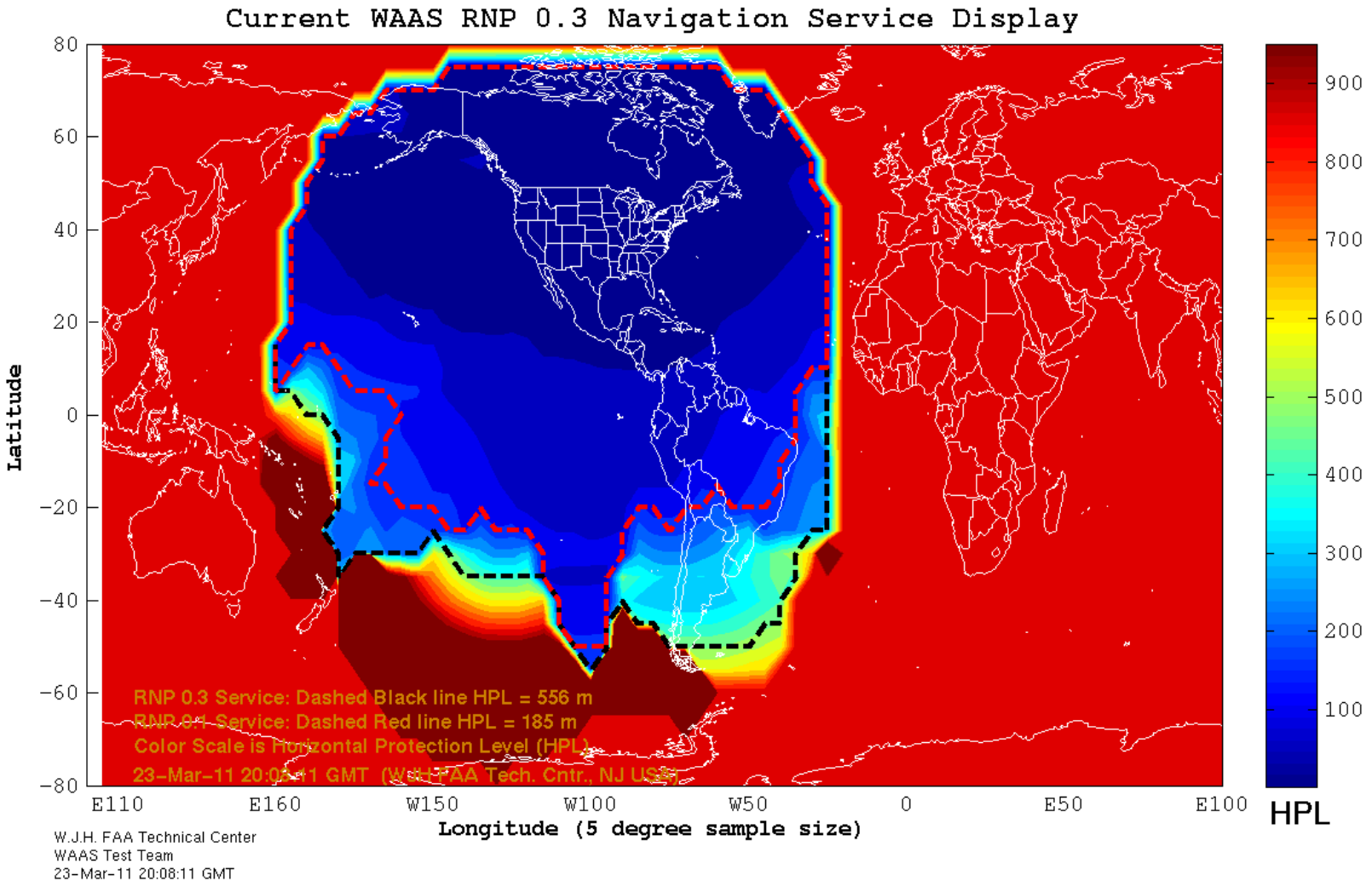
3 Geostationary Satellite Links

2 Operational Control Centers

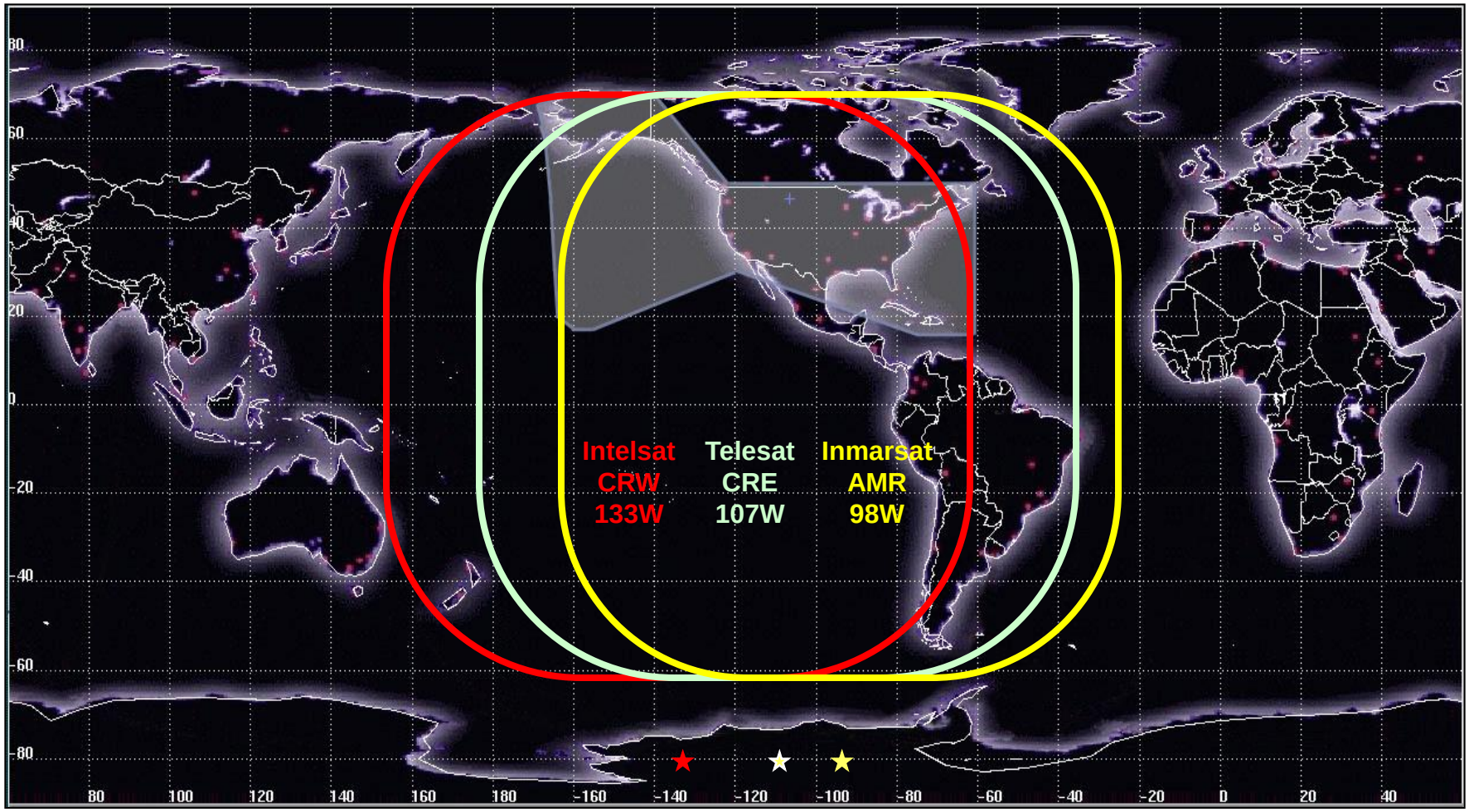
Current WAAS Availability



Current WAAS RNP 0.3 Performance



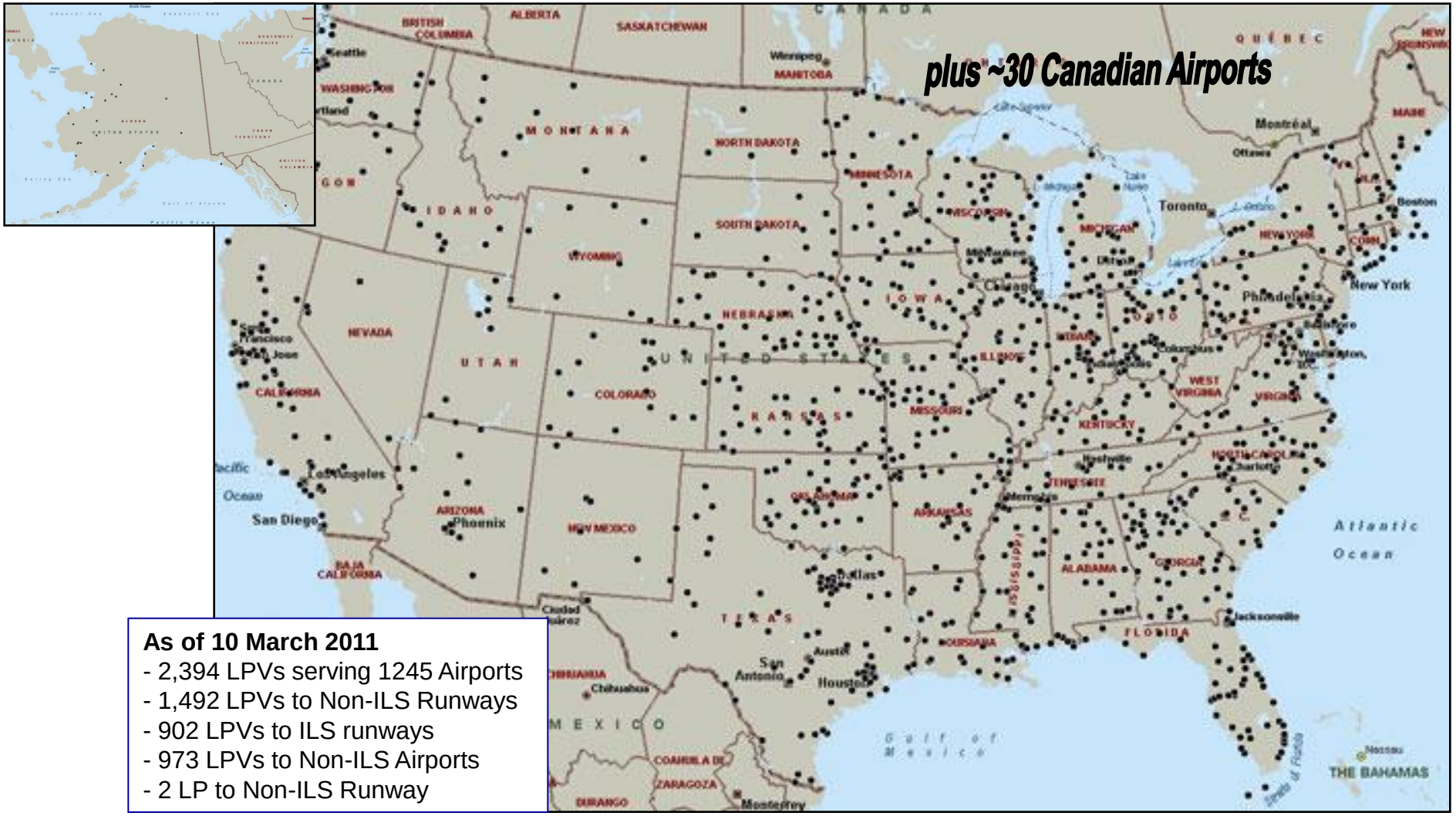
Current WAAS Geo Coverage



WAAS Phased Upgrades

- Phase I: IOC (July 2003) Completed
  - Provided LNAV/VNAV/Limited LPV Capability
- Phase II: Full LPV (FLP) (2003 – 2008) Completed
  - Improved LPV availability in CONUS and Alaska
  - Expanded WAAS coverage to Mexico and Canada
- Phase III: Full LPV-200 Performance (2009 – 2013)
  - Software enhancements, hardware upgrades
  - Steady state operations and maintenance
  - Transition to FAA performed 2nd level engineering support
  - Begin GPS L5 transition activities
- Phase IV: Dual Frequency (L1,L5) Operations (2014 – 2028)
  - Complete GPS L5 transition
  - Will significantly improve availability and continuity during severe solar activity
  - Steady state operations and maintenance
  - Will continue to support single frequency users

Airports with WAAS LPV Approaches



As of 10 March 2011
- 2,394 LPVs serving 1245 Airports
- 1,492 LPVs to Non-ILS Runways
- 902 LPVs to ILS runways
- 973 LPVs to Non-ILS Airports
- 2 LP to Non-ILS Runway

WAAS/SBAS Aviation Benefits

- Increased Runway Access
- More direct en route flight paths
- New precision approach services
- Reduced and simplified equipment on board aircraft
- Potential elimination of some ground-based navigation aids (NDB, VOR, ILS) can provide a cost saving to air navigation service provider

GPS/WAAS Aviation Performance

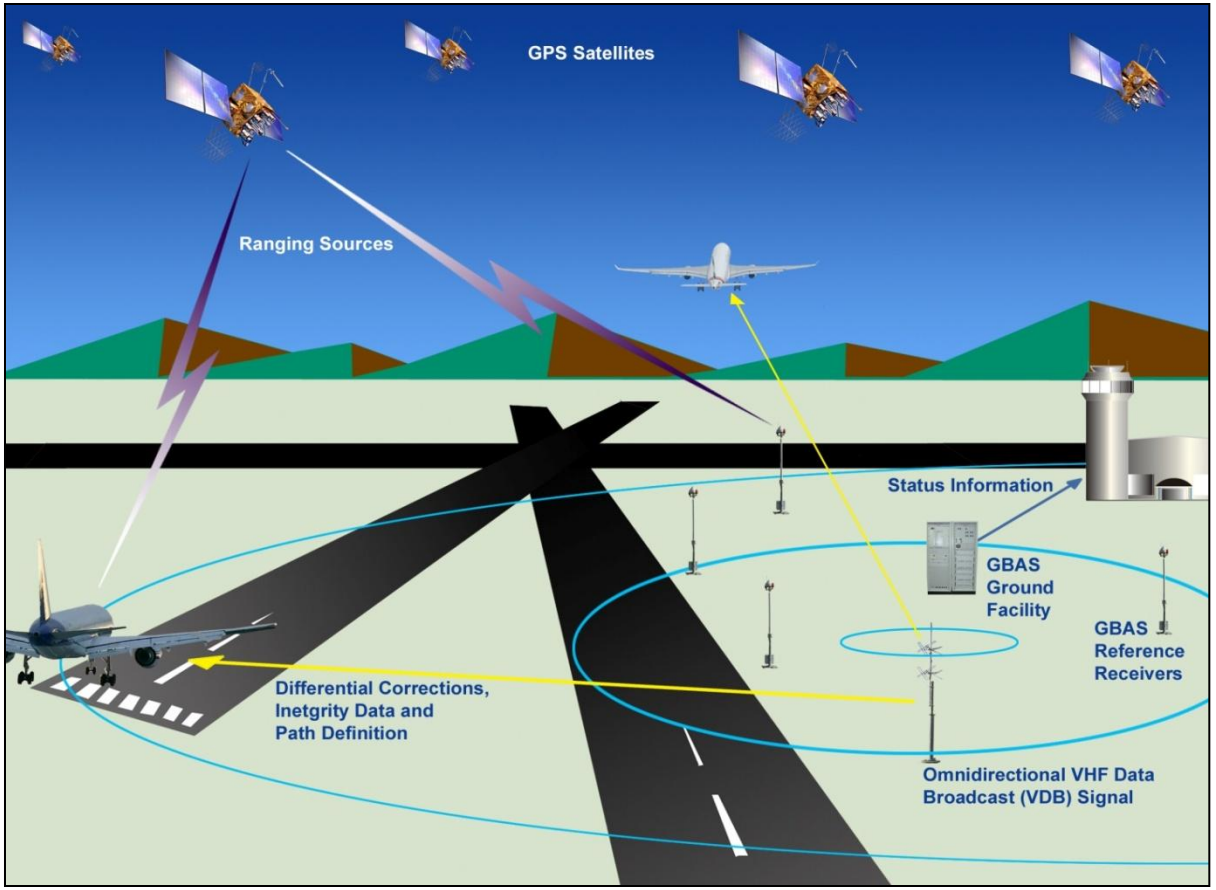
	GPS Standard	GPS Actual	WAAS LPV-200 Standard	WAAS Actual
Horizontal 95%	36 m	2.74 m	16 m	1.08 m
Vertical 95%	77 m	*3.89 m	4 m	1.26 m

** Use of GPS vertical not authorized for aviation without augmentation (SBAS or GBAS)*

WAAS Performance evaluated based on a total of 1,761 million samples (or 20,389 user days)

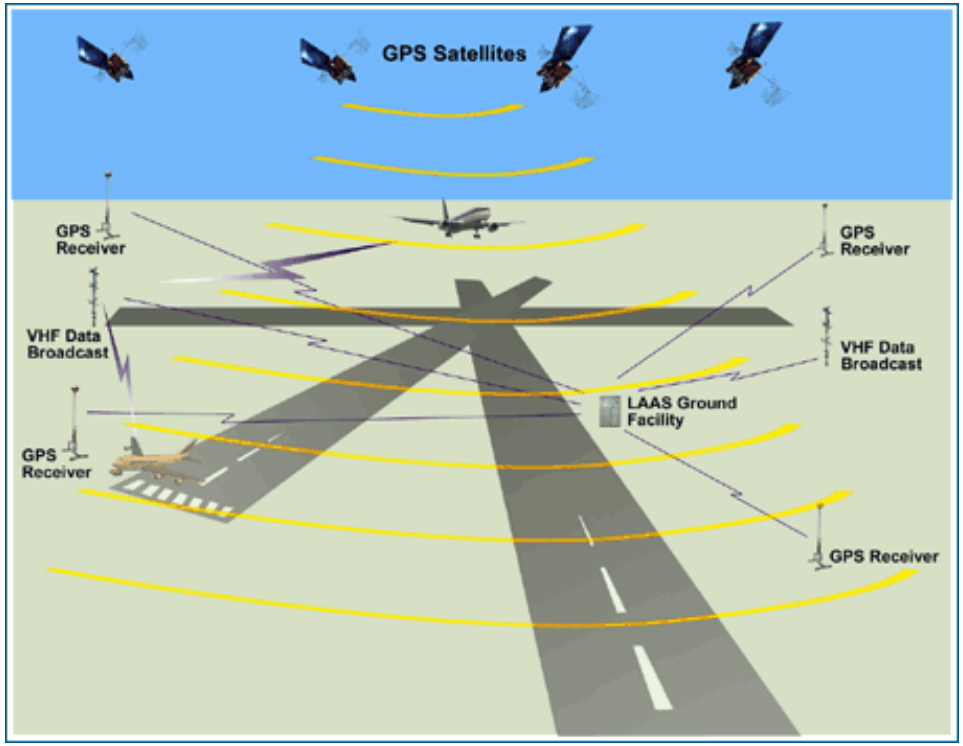
Ground Based Augmentation System (GBAS)

- Architecture
  - Ground Station/Processing Unit/Power Supply (one shelter on airport property)
  - 4 Reference Receivers/Antennas
  - VHF Data Link Antenna
- Specifications
  - Supports Category I approach with growth to Category III
  - Single facility can provide service up to 23 mile radius



Ground Based Augmentation System (GBAS)

- Designed for aviation use



Current & Future Aviation Capabilities

- Precision approach for ILS Category - I, II, III approaches
- Multiple runway coverage at an airport
- 3D RNP procedures (can be supported by multiple navigation sources)
- Continuous Descent Arrivals (CDA)
- Navigation for closely spaced parallel runways

GBAS Category I Implementation

- CAT I Engineering Activities
  - System Design Approval Support
    - Honeywell SLS-4000 Block I changes (Improve Availability, Maintainability)
  - Monitor SLS-4000 performance
    - FAATC Monitors in Newark, Atlantic City, Memphis
    - Planned: Houston / TBD: Boeing - Moses Lake
- GBAS CAT I implementation at Newark
  - Airspace Simulations for multiple scenarios
  - Flight Inspection completed / First Flight late summer 2011
  - Continental taking delivery of GBAS capable 737NG (30 total by February)
- GBAS implementation Houston
  - CAT I GBAS implementation 2011
  - Establish city pair Newark-Houston for Continental

GBAS Category II/III Acquisition Planning

- CAT III Acquisition documents according to FAA Acquisition Management System (AMS)
  - Final Investment Decision – September 2013
- CAT II/III Engineering Activities
  - Prototyping and Validation
    - Develop CAT-III prototype LGF and avionics by ~2011/12
    - Validate implementation of the integrity design and allocations ~2013
  - ICAO standards
    - Technical validation of proposed CAT III standards completed May 2010
    - "Operational Validation" (Ground/avionics prototypes support this)
- FAA-Boeing – Memorandum of Agreement
  - Agreement on cooperation and coordination of GBAS CAT III requirements development, validation, prototyping

GBAS International Activities

- International GBAS Working Group (IGWG)
  - Service providers starting transition from research to implementation of GBAS
  - Major topics of interest/cooperation
    - Coordination of worldwide Ionospheric activities
    - Post Implementation activities
    - Future applications/CAT II/III CONOPS
    - Korea Aerospace Research Institute (KARI) a major contributor
- GBAS in SESAR (Single European Sky ATM Research)
  - SESAR budget includes substantial budgets for GBAS R&D
- FAA supporting international ANSP requests for GBAS technical support
  - Australia, Brazil, Germany, Spain, Chile, India

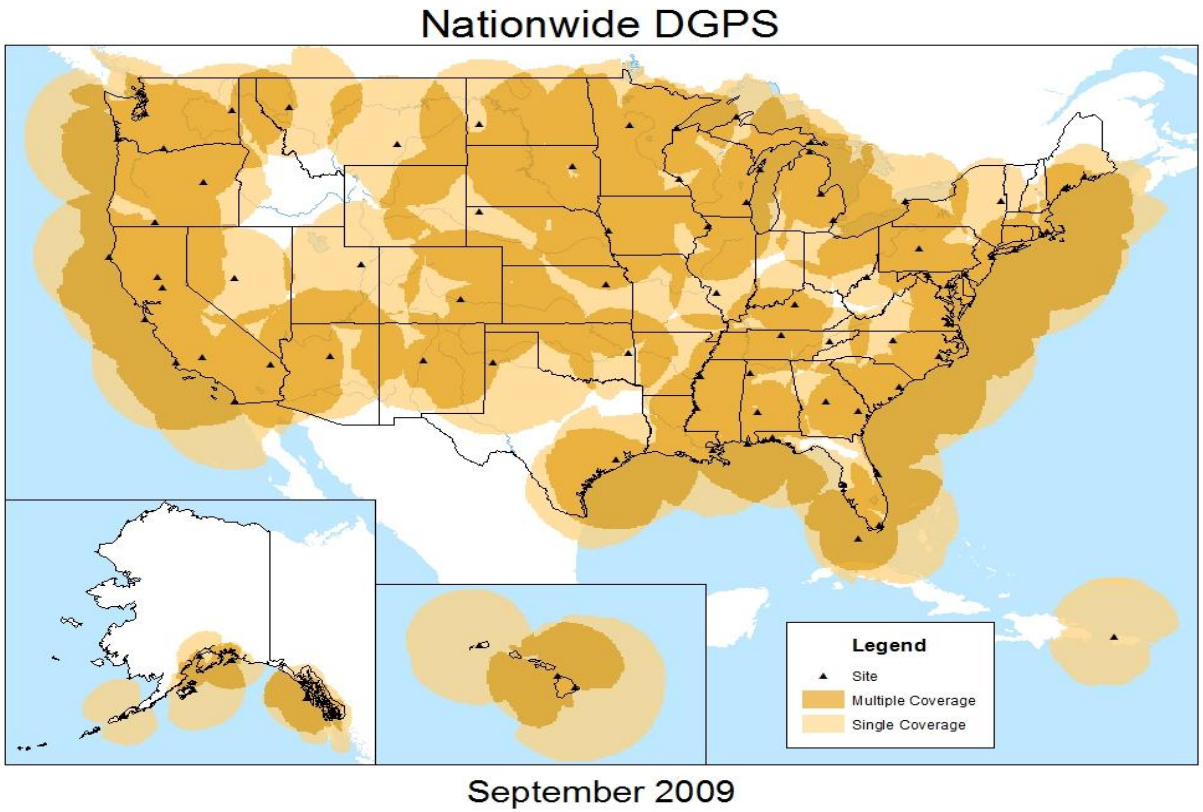
GBAS Usage Worldwide

- ANSPs with implementation / certification plans (2010-11)
  - USA, Australia, Germany, Spain, Brazil, Chile, India, Russia
- ANSPs with R&D activities
  - Japan/ENRI, Korea/Kari, Italy, Spain, France, Portugal
- Ground System Manufacturers
  - Established: Honeywell, Thales, NPPF Spectr,
  - New/prototypes: NEC, Indra, Selex,

Nationwide Differential GPS (NDGPS)

- Operated/managed by U.S. Coast Guard as a Combined NDGPS
  - Includes Maritime + Department of Transportation + Army Corps of Engineers sites
- System Specifications
  - Corrections broadcast at 285 and 325 kHz using Minimum Shift Keying (MSK) modulation
  - Real-time differential GPS corrections provided in Radio Technical Commission for Maritime Services (RTCM) SC-104 format
  - No data encryption
  - Real-time differential corrections for mobile and static applications
- More than 92% of Continental U.S. has single coverage
- More than 65% of Continental U.S. has dual coverage

Nationwide Differential GPS



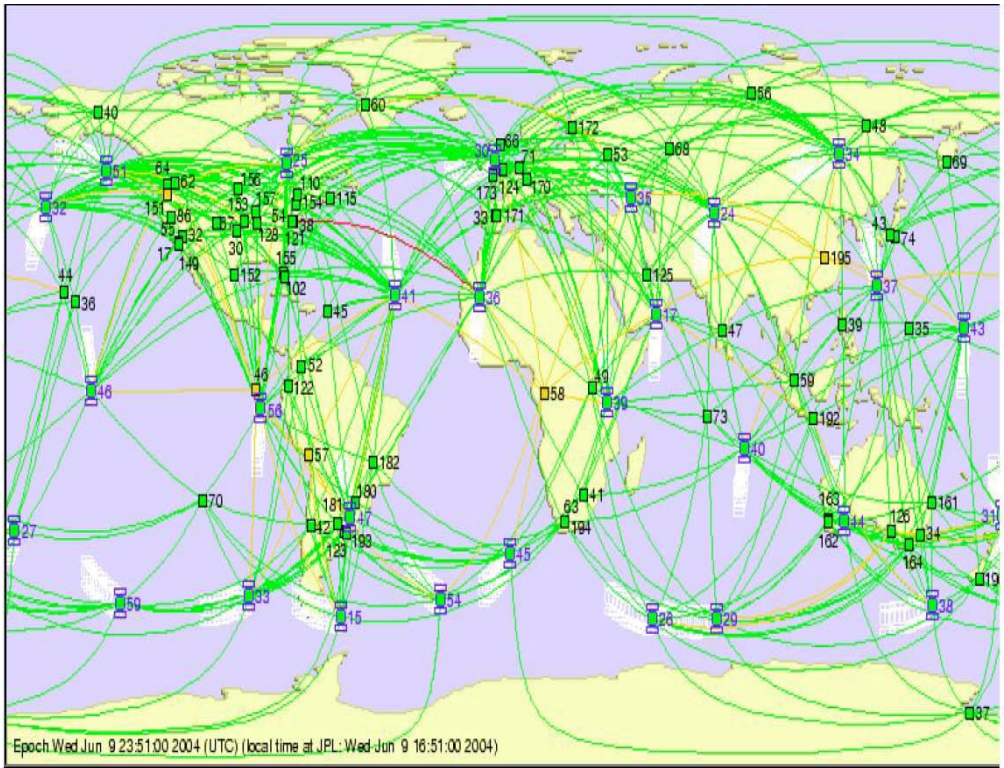
- Expansion of maritime differential GPS (DGPS) network to cover terrestrial United States
- Built to international standard adopted in 50+ countries

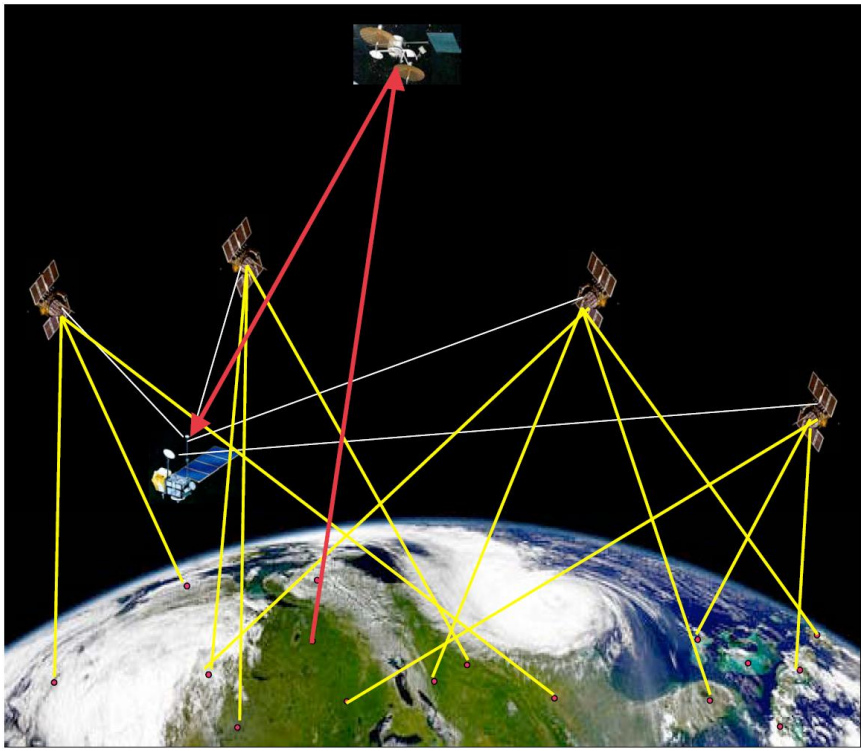
Global Differential GPS (GDGPS) and TDRSS Augmentation Service for Satellites (TASS)

Sponsor: NASA

GDGPS: More than 100 real-time tracking sites
- Real-Time Positioning, Timing, and Orbit-Determination

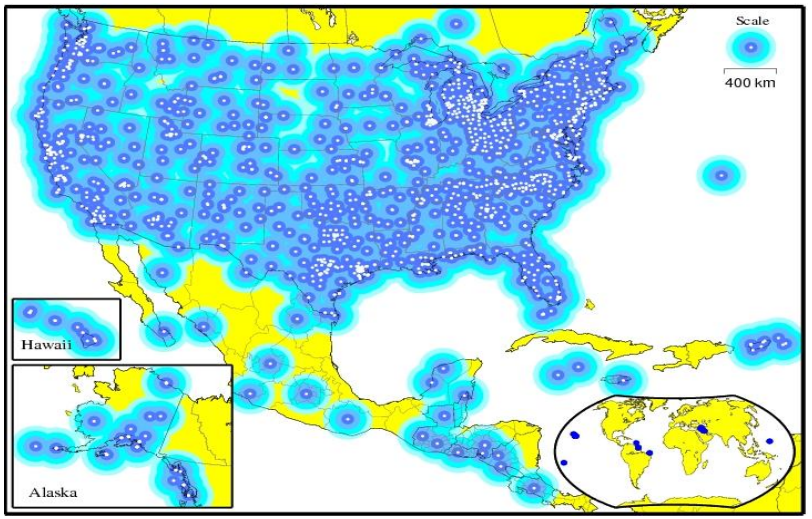
TASS: Future plans to disseminate GDGPS corrections to satellites for autonomous orbit determination and science missions





National Continuously Operating Reference Stations (CORS)

- Enables highly accurate, 3-D positioning
  - Centimeter level accuracy via post processing
  - Tied to National Spatial Reference System
- 1,450+ sites operated by 200+ public, private, academic organizations



- NOAA's Online Positioning User Service (OPUS) automatically processes coordinates submitted via the web from around the world
- OPUS-RS (Rapid Static) declared operational in 2007
- NOAA considering support for real-time networks

Summary

- U.S. policy encourages worldwide use of civil GPS and augmentations
- International cooperation at all levels is a priority
- GPS continues to meet or exceed our performance commitments to worldwide users
- WAAS upgrades/system improvements occurring in phases
- GBAS continues progress toward providing advanced aviation capabilities

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http://www.pnt.gov/