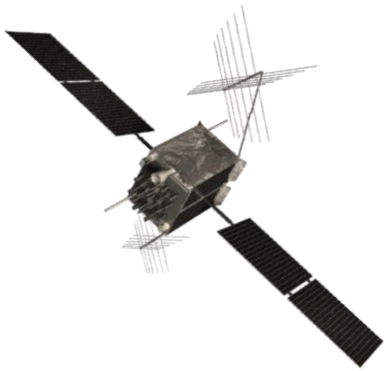
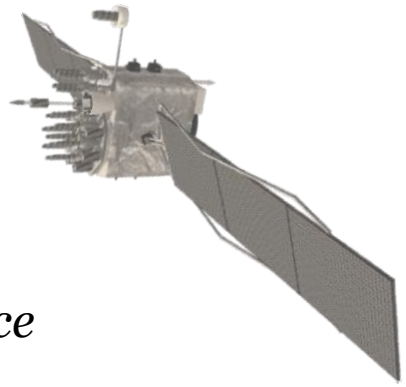


U.S. Space-Based Positioning, Navigation and Timing Policy and Program Update

9th Meeting of the International Committee on GNSS

Prague, Czech Republic

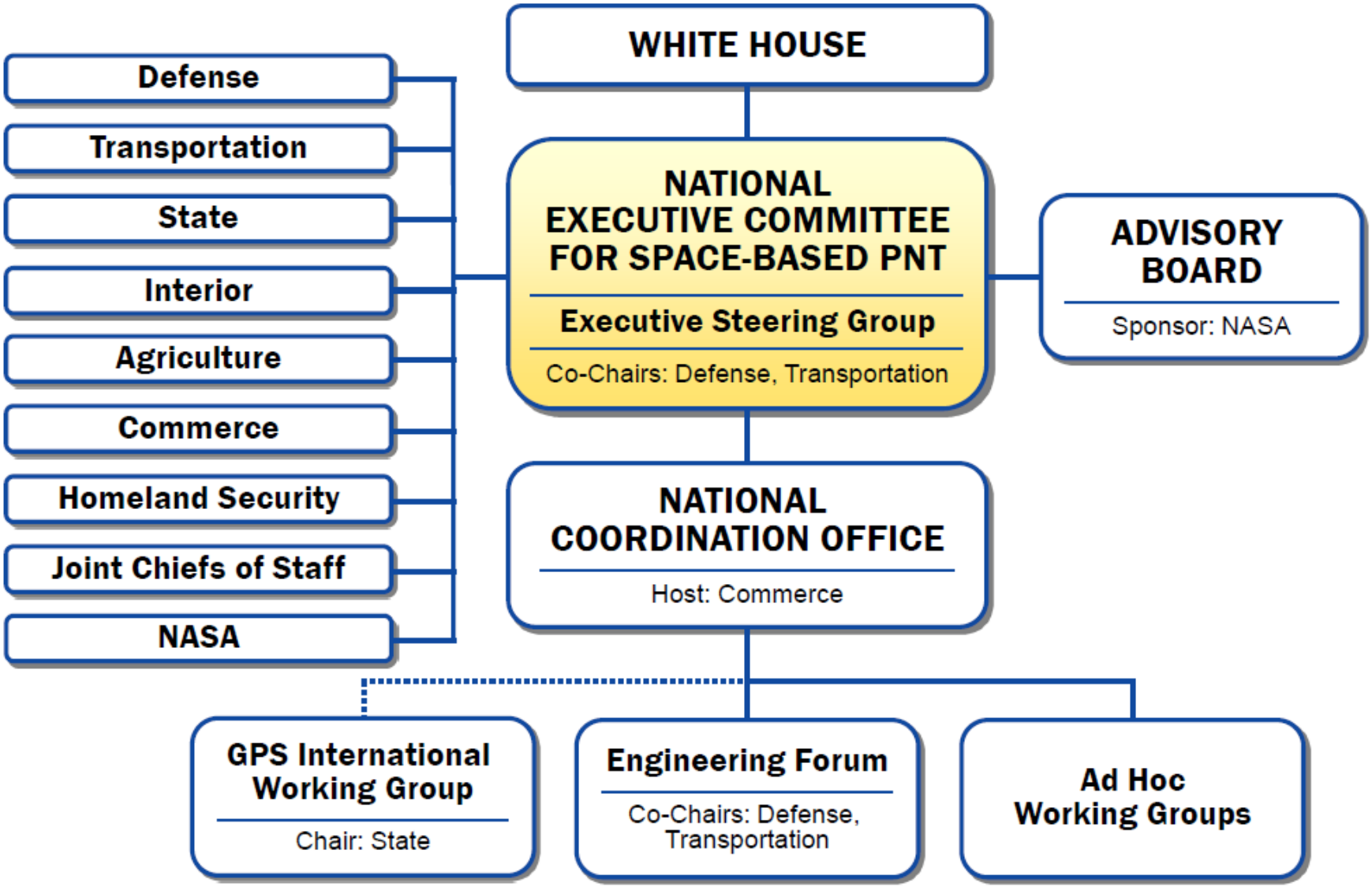
10 November 2014



Harold W. Martin III

Director, National Coordination Office
United States of America

National Space-Based PNT Organization



U.S. Policy

- Provide continuous worldwide access for peaceful uses, free of direct user charges
- Encourage compatibility and interoperability with foreign GNSS services and promote transparency in civil service provisioning
- Operate and maintain constellation to satisfy civil and national security needs
  - *Foreign PNT services may be used to complement services from GPS*
- Invest in domestic capabilities and support international activities to detect, mitigate and increase resiliency to harmful interference

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
- Ensure a level playing field in the global marketplace

Pursue through Bilateral and Multilateral Cooperation

Keys to Successful U.S. Program

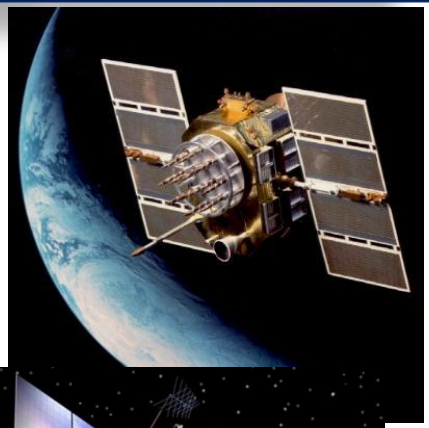
- Policy Stability
- Transparency
- Program Stability
- Sustained Performance and Credibility
- Continuous Improvement

Policy stability and transparency improve industry confidence and investment

GPS Constellation Status

30 Operational Satellites (Baseline Constellation: 24+3)

- Robust constellation
  - 4 GPS IIA, 12 GPS IIR, 7 GPS IIR-M, 7 GPS IIF
  - 8 Additional satellites in residual/test status, and 1 in early orbit test (IIF-8)
- Global GPS civil service performance commitment met continuously since December 1993
  - Best performance 46.6 cm User Range Error (URE) 8 Jun 2013; best weekly average 58.7 cm URE 18 Aug 14
  - Performance improving as new satellites replace older satellites



GPS IIF Launches in 2014

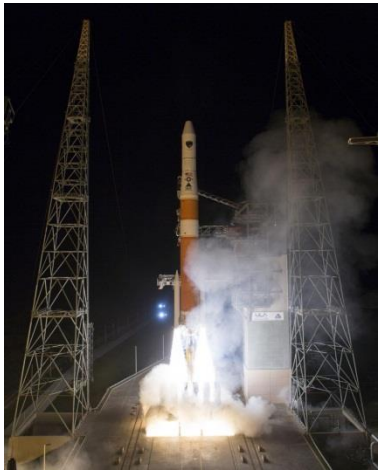
- IIF-8 Successfully Launched on 29 October 2014
  - Satellite Vehicle Number 69
  - PRN 03

- SVN 64 launched 20 Feb 2014
- SVN 67 launched 16 May 2014
- SVN 68 launched 01 August 2014

Most GPS launches in a single year since 1993

GPS IIF Status

- 8 total GPS IIFs on orbit
- 4 more GPS IIFs in the pipeline
  - SVs 10, 11, and 12 are in storage
  - SV-9 is in production testing



20 Feb: IIF-5

16 May: IIF-6

1 Aug: IIF-7

29 Oct: IIF-8

GPS Modernization Program

Legacy GPS IIA/IIR

- Single Frequency (L1)
- Coarse acquisition (C/A) code
- Y-Code (L1Y & L2Y)

GPS IIR-M

- 2nd Civil Signal (L2C)
- M-Code (L1M & L2M)

GPS IIF

- 3rd civil signal (L5)
- 2 Rb + 1 Cs Clocks
- 12 year design life

GPS III

- 4th civil signal (L1C)
- 4x better User Range Error than IIF
- Increased availability
- Increased integrity
- 15 year design life

Legacy OCS

- Mainframe system
- Command & Control
- Signal monitoring

AEP

- Distributed architecture
- Increased signal monitoring
- Security
- Accuracy
- Launch and disposal ops

OCX Block 0

- Launch & On-Orbit Checkout of GPS III

OCX Block 1

- Transition to OCX for all GPS command and control operations

Increasing System Capabilities - Increasing User Benefit

GPS III and OCX Status

- GPS III
  - L1 C/A, L1C, L2C, L5; L1/L2 P(Y), L1/L2M
  - SV07/08 contract awarded 31 Mar 14
  - SV01 navigation payload panel began space environment testing at Lockheed Martin's Colorado facility Sep 14
  - SV01 available for launch starting 2016
- Next Generation Operational Control System (OCX)
  - Modernized command & control system with M-Code and modern civil signal monitoring
  - OCX Block 0 supports launch & checkout for GPS III and is in integration & test
  - OCX Block 1 will support transition from OCS in 2018
  - Successfully completed 4 GPS III launch exercises


Monitor Station


Ground Antenna

Modernized Civil GPS Capabilities

- Second civil signal "L2C
  - Designed to meet commercial needs
  - Available since 2005 without data message
  - Currently 14 satellites broadcasting L2c

Third civil signal "L5"

- Designed to meet transportation safety of life requirements
- Uses Aeronautical Radio Navigation Service band
- Currently 7 satellites broadcasting L5

- Fourth civil signal "L1C"
  - Designed for GNSS interoperability
  - Specification developed in cooperation with industry
  - Improved tracking performance

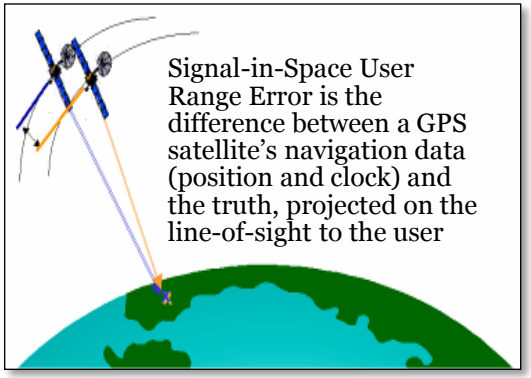
Urban Canyons

Improved performance in challenged environments

GPS Signal-in-Space Performance

2001 Standard Positioning Service (SPS) Performance Standard (PS)

(RMS over all SPS SIS URE)



2008 Standard Positioning Service (SPS) Performance Standard (PS)

(Worst of any SPS SIS URE)

Root Mean Square (RMS) Signal-in-Space (SIS) User Range Error (URE) in meters

Decreasing range error = Increasing accuracy

2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
1.6	1.4	1.2	1.2	1.1	1.1	1.0	1.0	0.9	0.9	0.9	0.8	0.8

Better Performance

System accuracy better than published standard

CNAV Implementation

- First-Ever pre-operational Civil Navigation (CNAV) message broadcast on L2C began 28 April 2014
  - Signal set Healthy, but use at own risk
  - Part of GPS modernization program announced in 1999
- CNAV message also broadcast since 28 Apr on L5
  - L5 message set 'unhealthy' until sufficient monitoring capability established (signal verification)

Civil signal messages on-line now

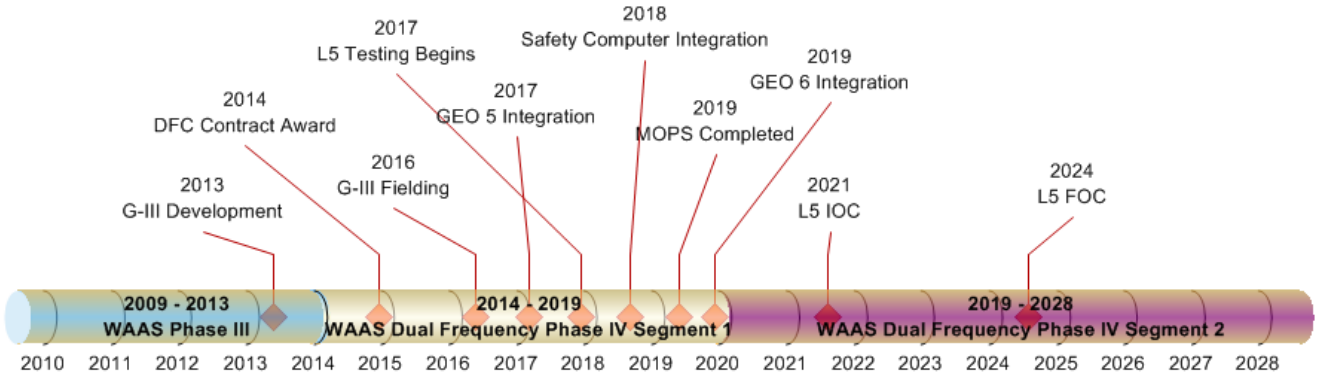
Wide Area Augmentation System (WAAS) Architecture

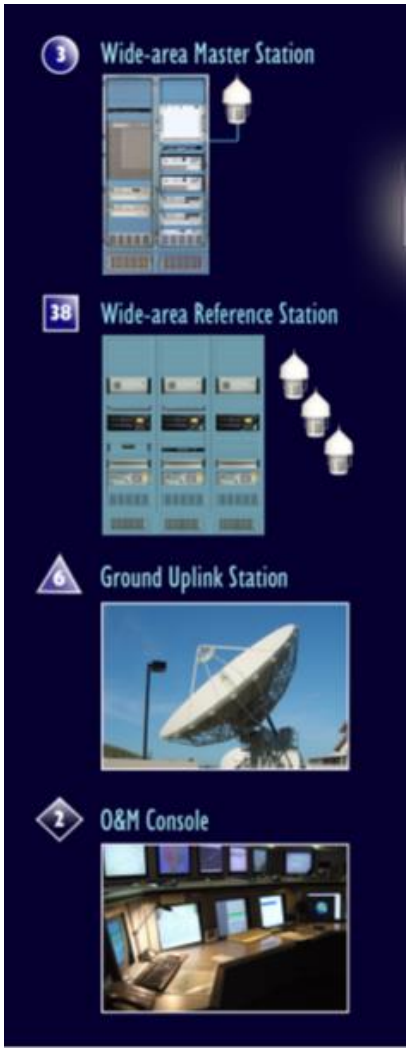
- A combination of ground-based and space-based systems that augment the GPS Standard Positioning Service (SPS)
- Provides the capability for increased availability and accuracy in position reporting, allowing more time for uniform and high quality air traffic management.
- Provides navigation service for all classes of aircraft during all phases of flight - including en route navigation, departures, arrival and landing

Sponsor: Federal Aviation Administration

WAAS Status

- Phase IV: Dual Frequency (L1, L5) Operations (2014 – 2044)
  - Improved availability/continuity during severe solar activity
  - Transition from use of L2 to L5 in WAAS reference stations
  - Support sustainment of WAAS GEOs
  - Infrastructure modifications to support L1/L5 users
  - Continue to support single frequency users
  - Evaluate Multi-Constellation utility

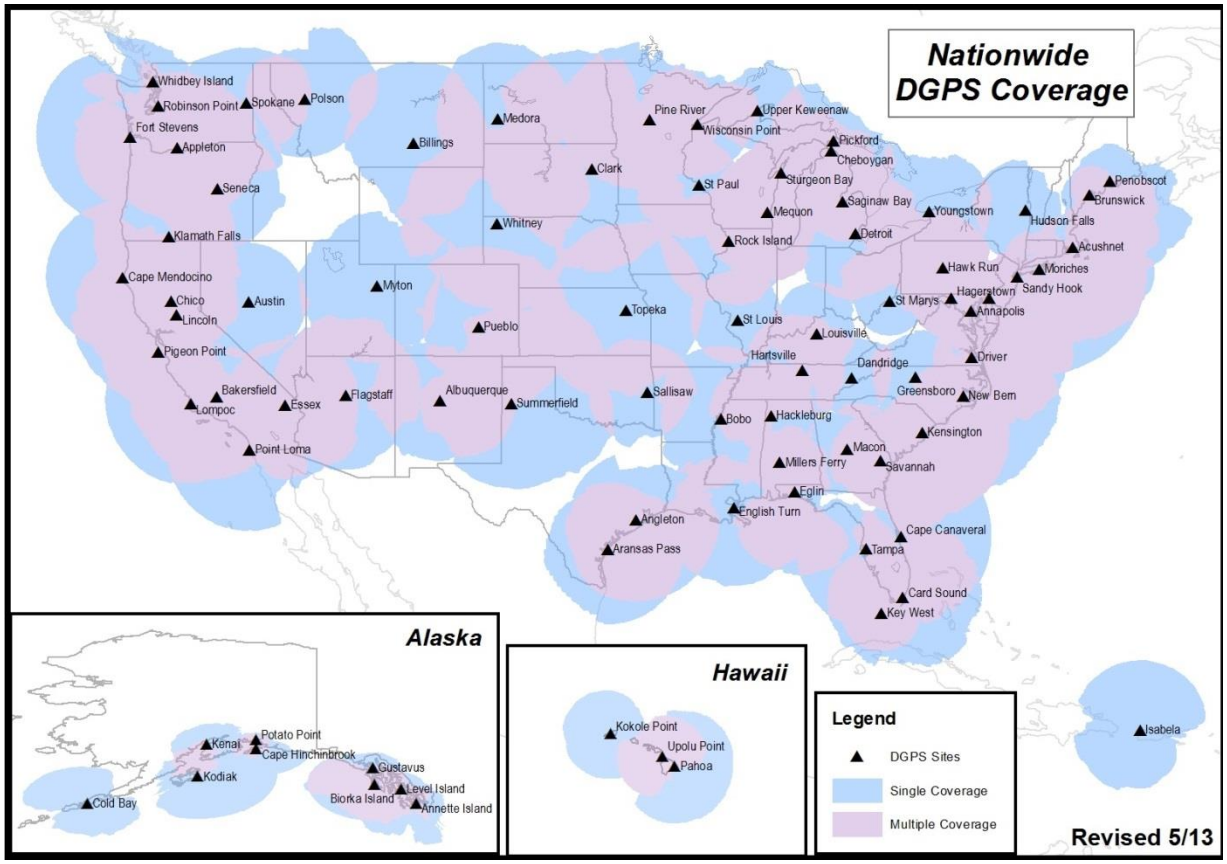




Nationwide Differential GPS (NDGPS)

Sponsors: U.S. Coast Guard & Department of Transportation

- 80+ sites
- Broadcasts GPS correction signals
- Improved accuracy & integrity



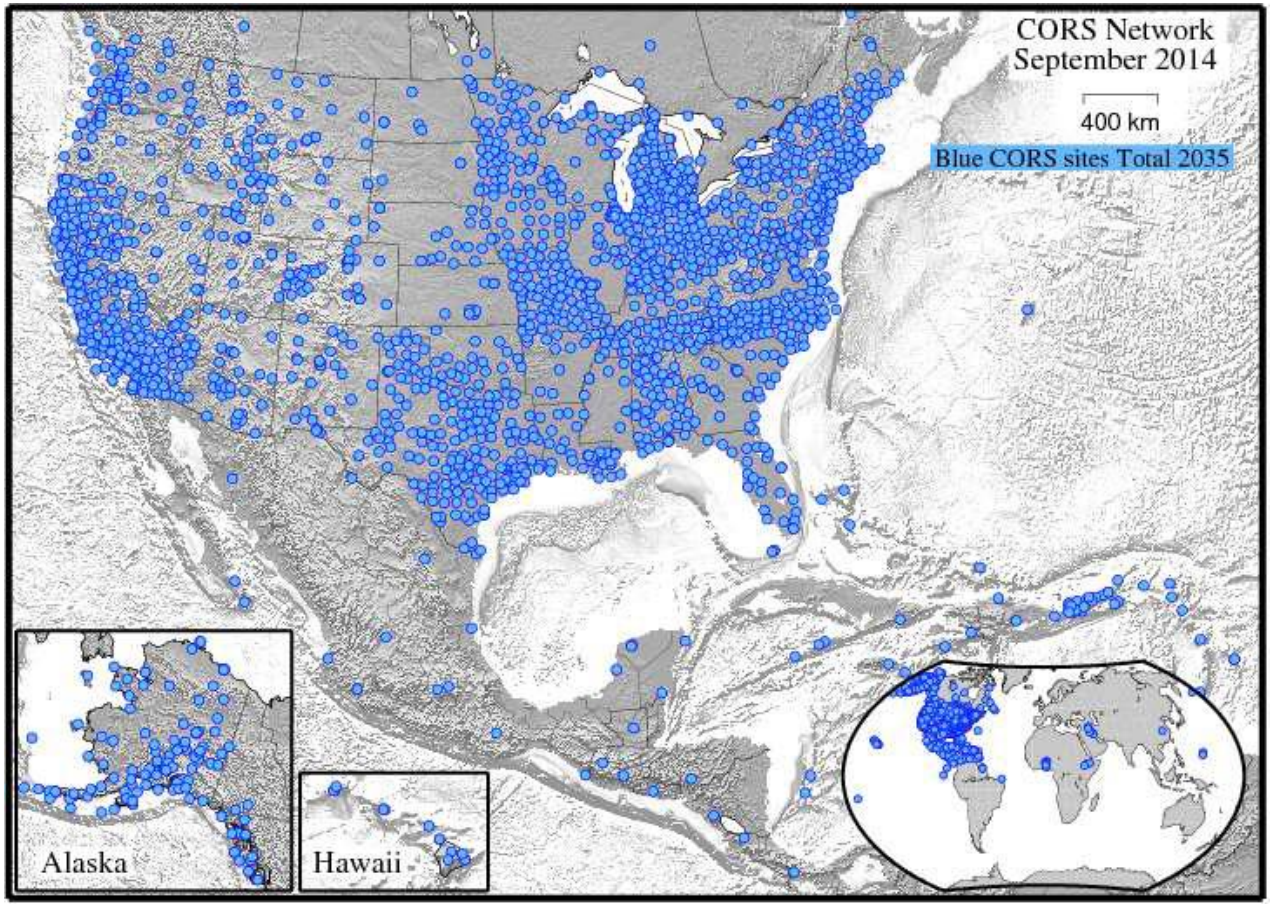
Assessment of Future of NDGPS

- Joint U.S. Coast Guard & Department of Transportation Federal Register Notice 16 April 2013
  - Assessment driven by many factors: from policy to technology
  - Asked how NDGPS is used, impact/alternatives if discontinued
  - Responses have been reviewed
- Current Activity: Identify and assess alternatives
  - Continuation/partial decommission/transfer/hybrid
- Decision timeline: No earlier than fall/winter 2014
  - Supports investment decisions in 2017
- Continue uninterrupted NDGPS service to users as currently provided until future decision reached
- Public/user community information/ involvement in decision processes and next steps

National Continuously Operating Reference Stations (CORS)

Sponsor: National Oceanic and Atmospheric Administration

- 2,030+ sites
- Operated by 200+ Fed, State, City, Private, Educ. organizations
- Enables highly accurate, post processed 3-D positioning



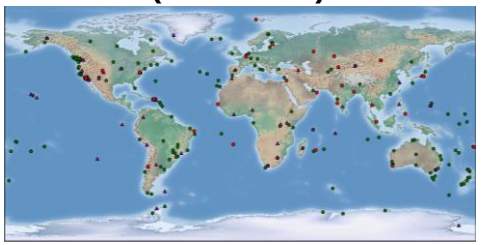
The Global Differential GPS (GDGPS) System

Providing mission-critical, global real-time services, 24/7, since 2000

Sub-10 cm positioning accuracy globally

Customer-supported by industry, NASA, and DoD

Real-Time Tracking Network (200+ sites)



Measurements

Triple Hot Redundant Operation Centers

Products, Services

GNSS performance Monitoring

Precision Industrial Positioning

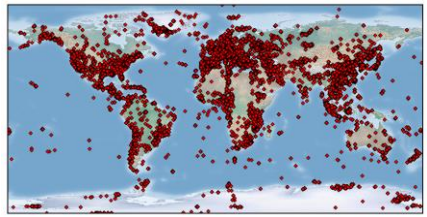
Personal Geolocation

Core software for WAAS (U.S.), MSAS (Japan), GAGAN (India)

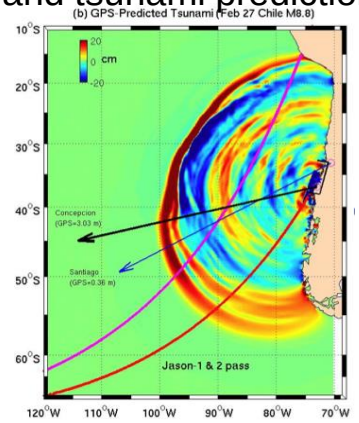
Software and testbed for Next Generation GPS Control Segment (OCX)

Multiple societal services

Public positioning Service

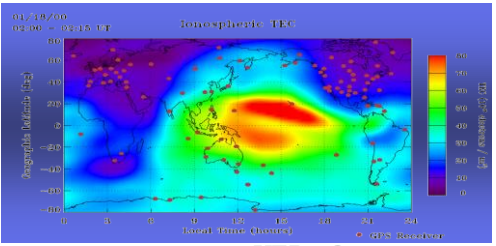


Earthquake monitoring and tsunami prediction



Repeat path interferometry with UAV-SAR

Space weather monitoring



Summary

- The U.S. supports free access to civilian GNSS signals and all necessary public domain documentation
- GPS is a critical component of the global information infrastructure
  - Compatible with other satellite navigation systems and interoperable at the user level
  - Guided at a national level as multi-use asset
  - Acquired and operated by the Air Force on behalf of the USG
- The U.S. policy promotes open competition and market growth for commercial GNSS
- Modernization milestones: Multiple launches and new Civil Navigation messages broadcast

GPS continues to provide continuously improving, predictable, dependable performance

Thank You !

Contact Information:

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1401 Constitution Ave, NW – Room 2518

Washington, DC 20230

Phone: (202) 482-5809

www.gps.gov

Official public resource for U.S. Government information about GPS and related topics

Harold.Martin@gps.gov

Introduction

Bradford Parkinson, Ph.D.

U.S. National Space-Based PNT Advisory Board

Acting Chairman

Protect, Toughen, Augment (PTA) GNSS/PNT Services

- U.S./National Space-based PNT Advisory Board (the "**PNTAB**")
  - 'Citizen-based user group' - US non-governmental plus international experts
  - Balanced to include members from all Major User Groups
  - Promotes transparency and fosters communications amongst all stakeholders – gives users a voice!
  - Provides Independent Recommendations to USG decision makers with a

Fundamental Purpose: *Assured PNT*

- 'Current PNTAB activities :
  - Quantify ***Economic Benefits*** of GNSS and Inform Decision Makers
  - Make Recommendations to further Protect, Toughen and Augment GNSS (PTA). More details in ***Applications and Experts Seminar*** later today…

Recommendation to ICG-9: *Other Global PNT service providers establish Advisory Boards with international participation to further understanding and collaboration.*