United States Global Positioning System (GPS) and Augmentation Systems Update

Ad Hoc Provider's Forum of the International Committee on GNSS

Bangalore, India

4 September 2007

Contents

NATIONAL SPACE-BASED
POSITIONING, NAVIGATION, AND TIMING
EXECUTIVE COMMITTEE

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

Michael Shaw, Director
U.S. National Coordination Office for Space-Based Positioning, Navigation, and Timing

Overview

- Service Provision Policies
- U.S. Law and Policy
- Satellite Navigation Trade and Business Practices

Introduction

- Over the past decade, GPS has grown into a global utility providing space-based positioning, navigation and timing (PNT)
  - Consistent, predictable, dependable policy and performance
  - Augmentations improve performance even further

- Like the Internet, GPS has become a critical component of the global information infrastructure
  - Scalable applications enabling broad new capabilities
  - Facilitating innovations in efficiency, safety, environmental, public security, and science

GPS: Global Public Service

- Global GPS civil service performance commitment continuously met/exceeded since 1993
  – SPS Performance Standard (2001)
- Access to civilian GPS service is free of direct user charges
  – As well as USG augmentation services (e.g. NDGPS, WAAS, etc.)
- Public domain documentation
  – Free and equal availability to all users and industry
  – Equal opportunity to develop user equipment and compete on the world market
- Owned and operated by the U.S. Government
  – Acquired and operated by U.S. Air Force on behalf of USG
  – Managed at national level as multi-use asset

United States Policy History

- 1983: President Reagan offers free civilian access to GPS
- 1996: President Clinton issues first U.S. GPS policy
  - Designates GPS a dual-use system under joint civil/military management
- 1997: Congress passes law requiring civil GPS to be provided free of direct user fees
- 2004: President Bush issues U.S. policy on Space-Based PNT

U.S. Law – 10 U.S. Code §2281

The Secretary of Defense:

- Shall provide for the sustainment of GPS, and the operation of basic GPS services, that are beneficial for the national security interests of the U.S.
- Shall provide for the sustainment and operation of the GPS Standard Positioning Service for peaceful civil, commercial, and scientific uses
  - Continuous worldwide basis free of direct user fees

Policy and Law establish dual-service operation and sustainment of GPS

U.S. Policy Promotes Commercial Markets/Applications Growth

- Provide civil GPS and augmentations **free of direct user fees** on a continuous, worldwide basis
- Provide open, **free access to information** needed to use civil GPS and augmentations
- **Improve performance** of GPS and augmentations
- Seek to ensure that international space-based PNT systems are **interoperable** with civil GPS and augmentations or, at a minimum, are compatible

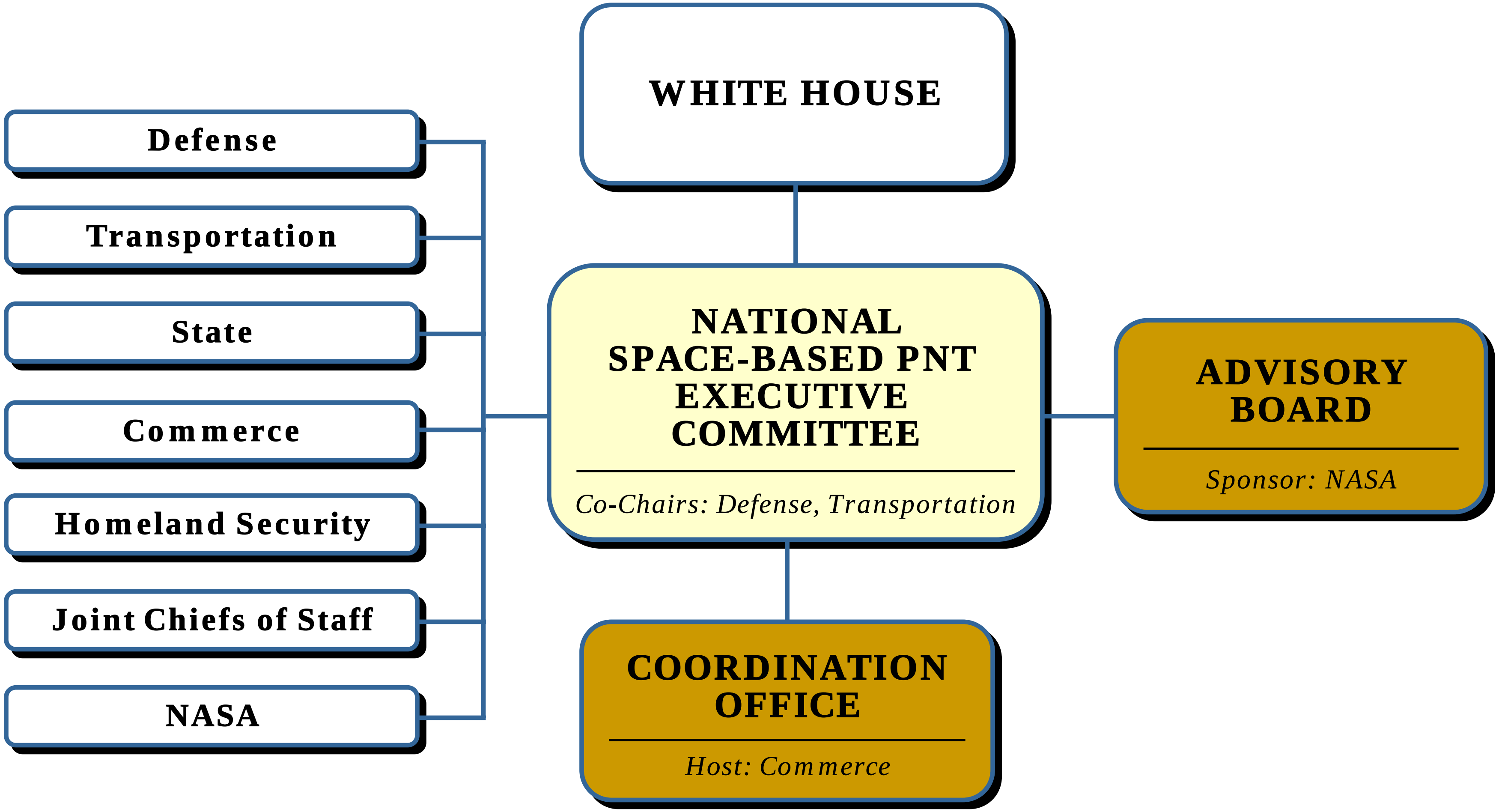
Policy stability and transparency improve industry confidence and investment

2004 U.S. Space-Based PNT Policy

Updated policy retains 1996 principles

- Recognizes the changing international scene
  - Other nations implementing space-based systems that provide PNT services
- National Space-Based PNT Executive Committee
  - Chaired by Deputy Secretaries of Defense and Transportation
  - Membership includes: State, Commerce, Homeland Security, JCS and NASA
- Established National Coordination Office (NCO) a with staff from each member agency

U.S. Organizational Structure



National Coordination Office

- Facilitates information sharing, coordination, and issue resolution regarding space-based PNT across all Departments
- Evaluates plans to modernize U.S. space-based PNT infrastructure
- Conducts or oversees space-based PNT studies, analyses, and projects that have broad U.S. Government participation
- Represents the Executive Committee in discussion with federal, state, local, and foreign governments

National Space-Based PNT Advisory Board

- Conducts assessments, makes recommendations to accomplish national policy goals and objectives
- Twenty-four members; six international members
- First meeting held March 2007
- Next meeting in October 2007

U.S. International Cooperation

Outlined in 2004 U.S. National Policy on Space-Based Positioning, Navigation, and Timing (PNT)

- Provide civil GPS and augmentations free of direct user fees on a continuous, worldwide basis
- Seek to ensure international systems are interoperable, or at a minimum, are compatible, with civil GPS and augmentations
- Improve performance of civil GPS and augmentations to meet or exceed that of international systems
- Provide open, free access to information needed to develop equipment
- Encourage international development of PNT systems based on GPS

Bilateral GPS Cooperation

- **U.S.-Japan**: Policy and technical consultations on GPS cooperation since 1996
  - QZSS/MSAS to be compatible, interoperable with GPS
- **U.S.-EU** GPS-Galileo Cooperation Agreement since 2004
  - July 2007 accord on improved civil signal (MBOC)
- **U.S.-India**: Policy and technical consultations on GPS cooperation since 2005
  - Research into ionospheric distortion/solutions
  - Joint Statement on GNSS Cooperation, February 2007
- **U.S.-Russia** negotiating GPS-GLONASS Cooperation Agreement since 2005
  - Discussing greater interoperability of civil GPS-GLONASS signals
- **U.S.-Australia**: Joint Delegation Statement on Civil GPS cooperation signed April 2007
  - Developing enhanced mechanisms for notification of GPS satellite operational changes

Summary

- The U.S. supports free access to civilian GNSS signals with public domain documentation necessary to develop user equipment
- 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
- U.S. Government policy promotes open competition and market growth for commercial GNSS

GPS is a Global Public Service providing consistent, predictable, dependable performance

The Global Positioning System (GPS)

Jules McNeff

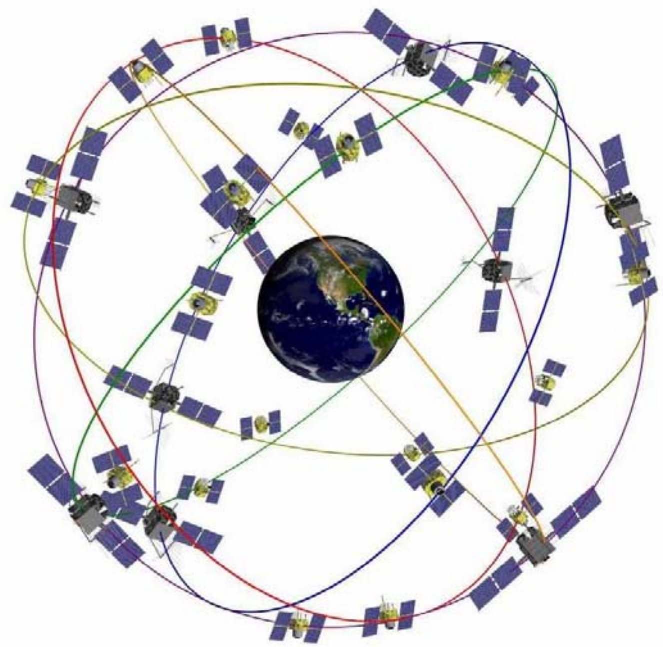
representing
Office of the Assistant Secretary of Defense
Networks and Information Integration
U.S. Department of Defense

Overview

- Global Positioning System Description
- System Improvements & Modernization
  - GPS Constellation Status
  - Next Steps for Space and Control Segments
- System Performance

The Global Positioning System

- Baseline 24 satellite constellation in medium earth orbit
- Global coverage, 24 hours a day, all weather conditions
- Satellites broadcast precise time and orbit information on L-band radio frequencies
- Two types of signals:
  - Standard (free of direct user fees)
  - Precise (U.S. and Allied military)
- Three segments:
  - Space
  - Ground control
  - User equipment



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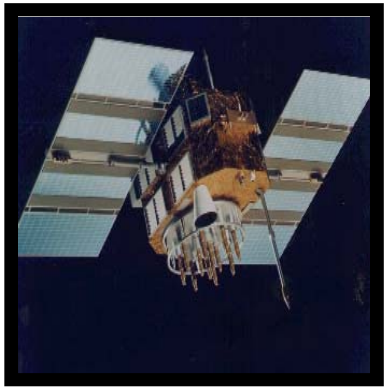
Current Constellation

30 Operational Satellites
(Baseline Constellation: 24)

- 15 Block IIA satellites operational
- 12 Block IIR satellites operational
  - 5 remaining Block IIR satellites are modernized
- 3 Block IIR-M satellites operational
  - Transmitting new civil signal (L2C)
- U.S. Government continuously assessing constellation health to determine launch need
  - New IIR-M satellites launched
    - Sep 05, Sep 06, Nov 06
  - Next launch: Oct 07
- Global GPS civil service performance commitment met continuously since Dec 1993



IIR-15(M) Launch & Aerial View
25 September 2006

Overview

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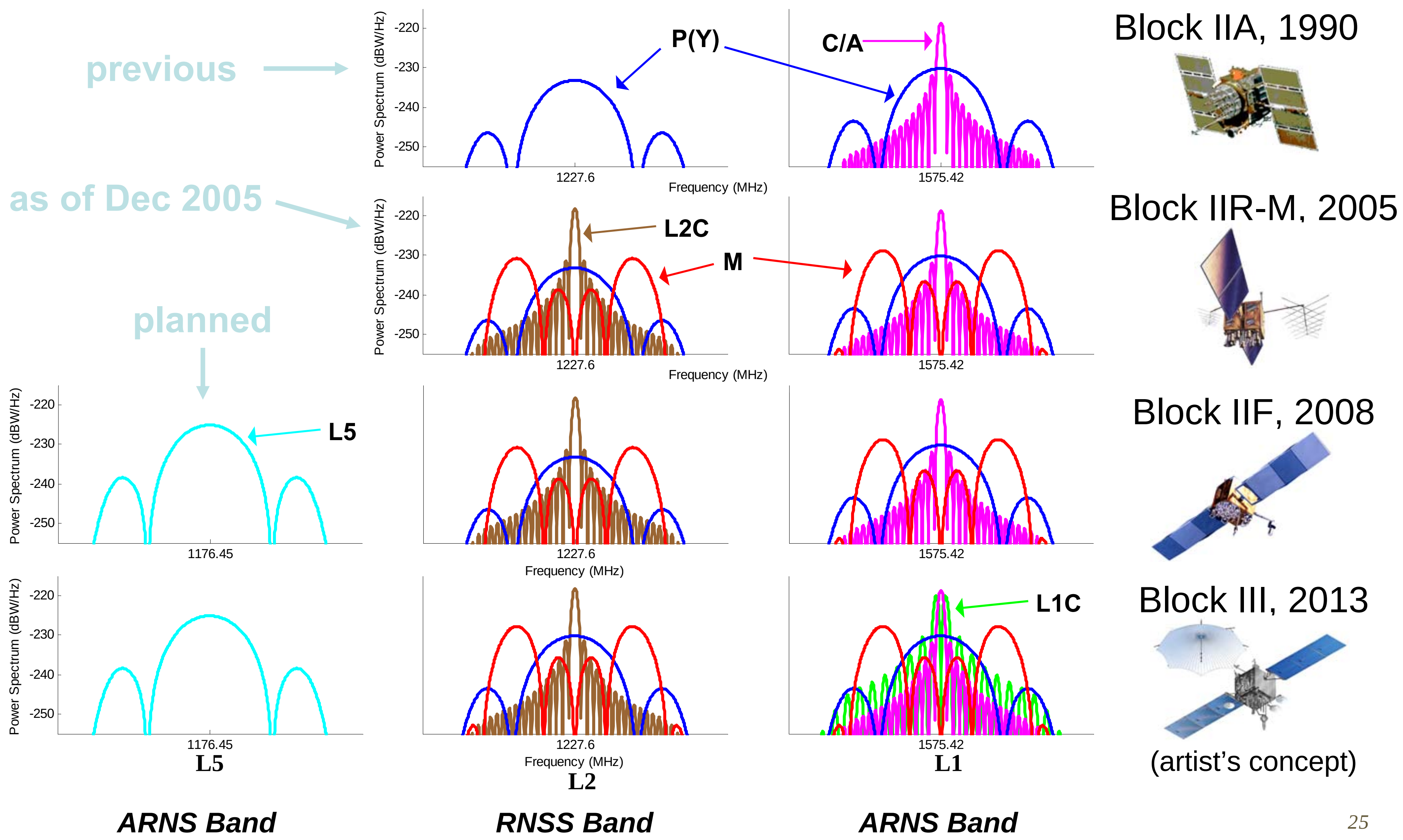
Modernized GPS – Civil Signals

- Second civil signal ("L2C")
  - Designed to meet commercial needs
    - Higher accuracy through ionospheric correction
    - Higher effective power and improved data structure reduce interference, speed up signal acquisition, enable miniaturization of receivers, may enable indoor use
  - Began with GPS Block IIR-M in Sep 2005; 24 satellites: ~2014

- Third civil signal ("L5")
  - Designed to meet demanding requirements for transportation safety (safety-of-life)
    - Uses highly protected Aeronautical Radio Navigation Service (ARNS) band
  - Begins with GPS Block IIF
  - First launch: ~2008; 24 satellites: ~2016

- Fourth civil signal ("L1C")
  - Designed with international partners to enable GNSS interoperability
  - Begins with GPS Block III
  - First launch: ~2013; 24 satellites: ~2021

GPS Modernization – Spectrum



GPS Evolutionary “System-of-Systems” Programs

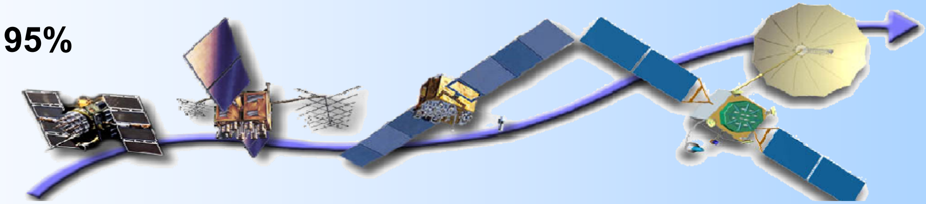
Space Segment

Legacy (Block IIA/IIR)
- Std Service (≤ 6 meters RMS SIS SPS URE)
  - Single frequency (L1)
  - Coarse acquisition (C/A) code navigation
- Precise Service (≤ 2.6 m 95% URE PPS at Zero AOD)
  - Y-Code (L1Y & L2Y)
  - Y-Code navigation

Modernized (Block IIR-M)
- 2nd civil signal (L2C)
- M-Code signals (L1M, L2M)
- Anti-jam flex power

Modernized (Block IIF)
- 3rd civil signal (L5)

GPS III (Block III)
- Increased accuracy
- Increased A/J power
- Signal integrity
- Search and Rescue
- L1C civil signal common w/Galileo, QZSS, & possibly GLONASS



Ground Segment

Legacy
- TT&C
- L1 & L2 monitoring

Upgraded (AEP)
- IIR-M IIF TT&C
- WAGE, AII, LADO
- NMCS/AMCS

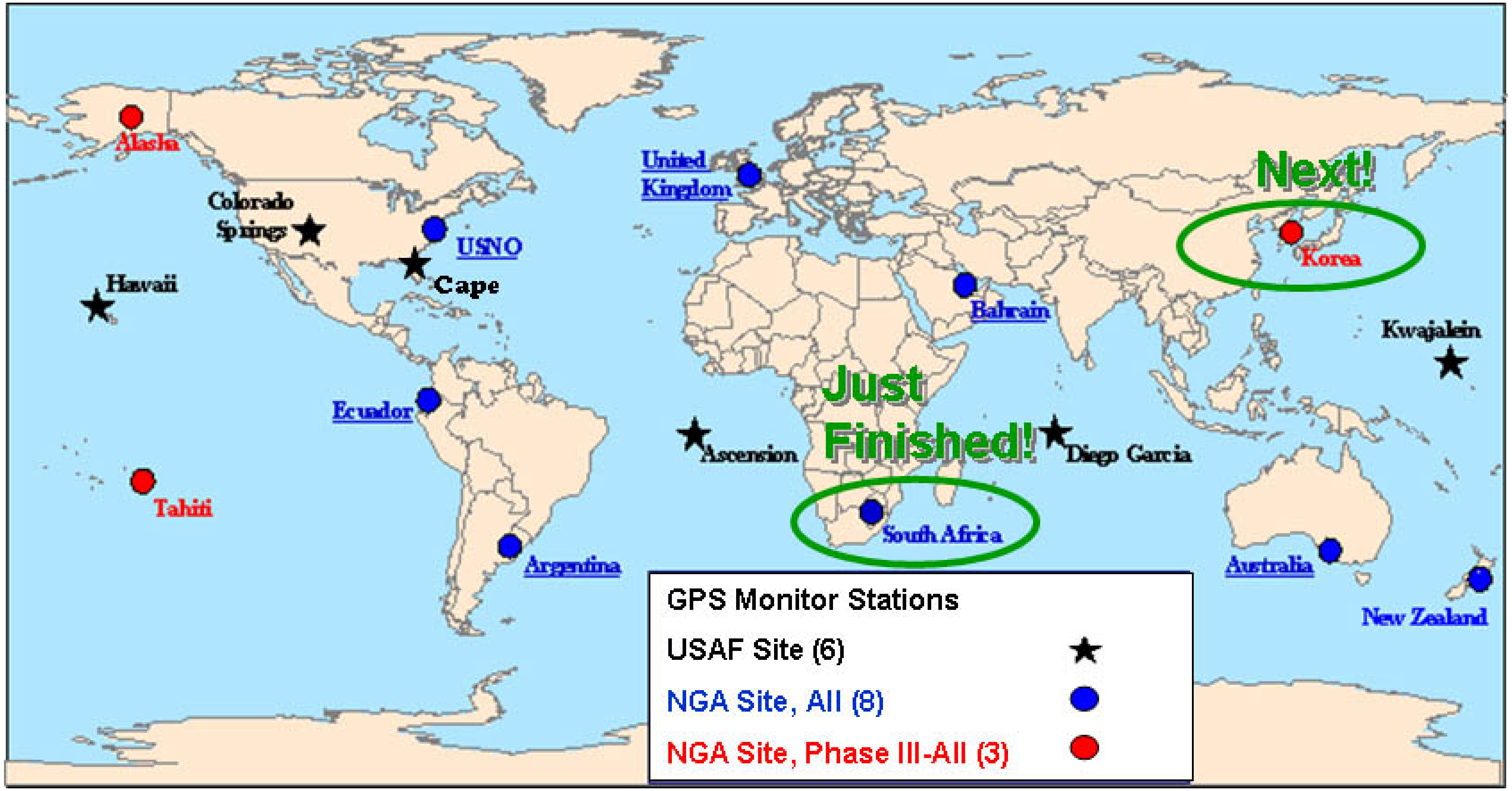
Modernized (OCX V1)
- New Architecture
- Signal Monitoring

GPS III (OCX V2)
- GPS III TT&C
- Real-Time C2

GPS OCS Modernization Status

- Transitioning to new ground segment - September 2007
- OCS Modernization impacts every element of OCS architecture
- Architecture Evolution Plan (AEP) migrates OCS from mainframe to distributed architecture -- makes OCS easier to operate/maintain
  - Two new control stations:
    - New Module at Schriever AFB
    - New Alternate MCS (AMCS) at VAFB
- AEP provides flexibility to incorporate future requirements
  - Command and Control for IIF (1st launch scheduled for 2008)

Modernizing the operational control segment (OCS)



- **Each SV tracked by three or more monitor stations over 99% of time**

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Constellation Performance

January 1-December 31, 2004

Specification values from the Standard Positioning Service Performance Standard, October, 2001

PDOP (Geometry) Availability

Specification - PDOP of 6 or Less, 98% of the time

Actual - 99.98798%

Horizontal Service Availability

Specification - 95% Threshold of 36 meters, 99% of the Time

Actual – 2.74 meters

Vertical Service Availability

Specification - 95% Threshold of 77 meters, 99% of the Time or Better

Actual – 3.89 meters

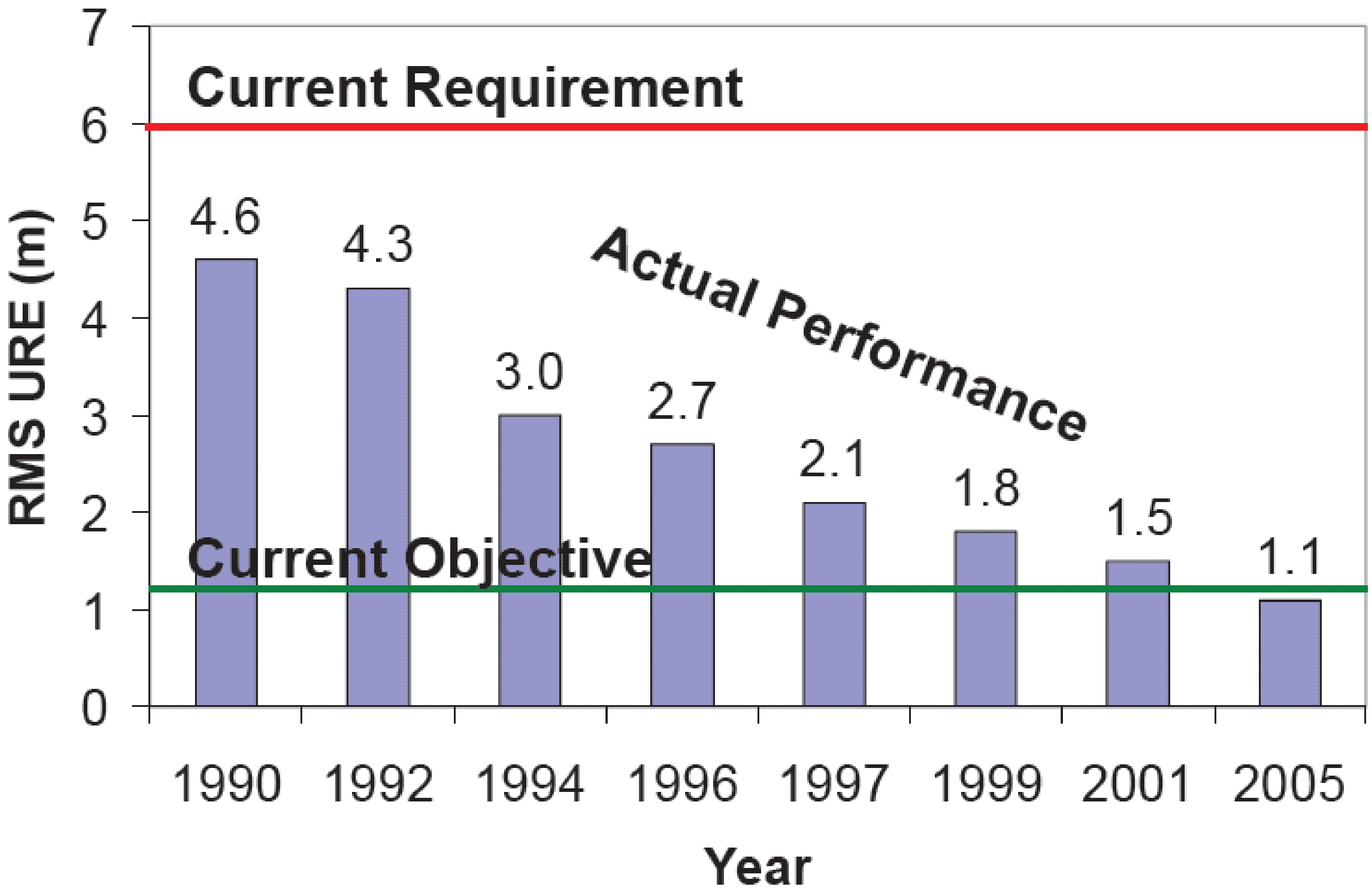
User Range Error

Specification - 6 meters or Less, Constellation Average

Actual – see next chart

System accuracy and availability far exceed current specifications

GPS constellation – Delivering excellent performance



Summary

- GPS has been operational and has met its civil service performance commitment continuously since Dec 2003
  - Performance continues to exceed standards
- GPS modernization is underway
  - New civil signals being launched
  - Modernized control capabilities being implemented

Wide Area Augmentation System (WAAS) and Local Area Augmentation System (LAAS) Update

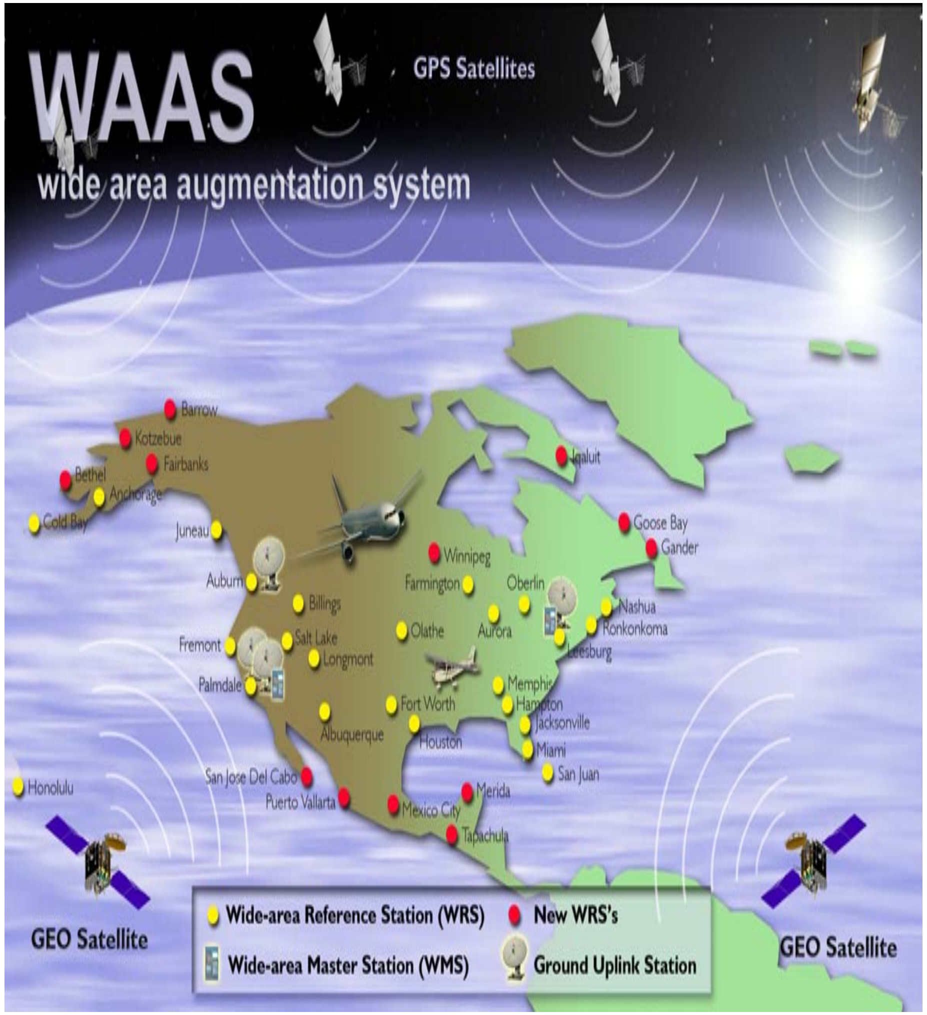
Carlos Rodriguez, FAA

Dr. Navin G. Mathur, AMTI

Agenda

- WAAS Architecture
- WAAS Ground and Space Segment Update
  - Phase II – Full LPV Performance (FLP)
  - Phase III – Full LPV-200 Performance (FLP)
  - Phase IV – Dual frequency Operations
- WAAS User Segment Update
- SBAS Interoperability Efforts
- LAAS Architecture
- GBAS Activity Update

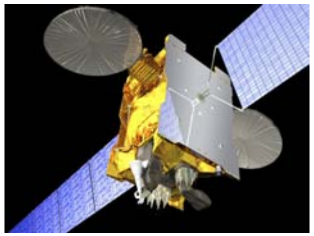
WAAS Architecture



38 Reference Stations

3 Master Stations

4 Signal Generator System/ Ground Earth Stations

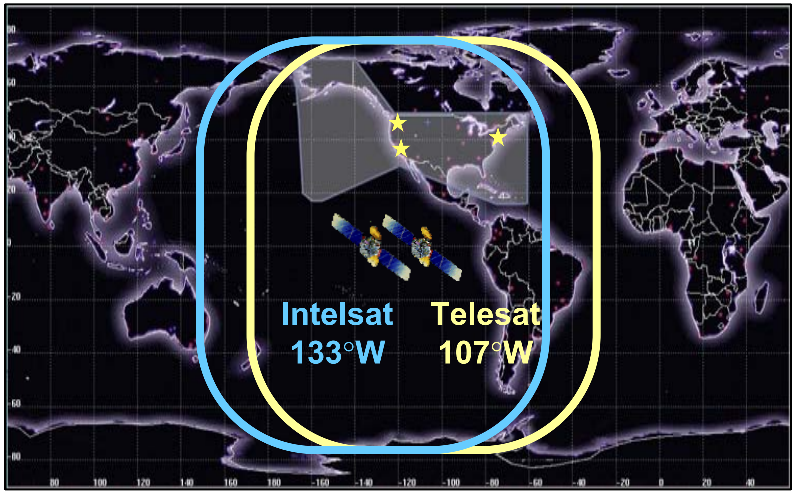


2 Geostationary Satellite Links

2 Operational Control Centers

GEO Satellite Improvements

- IOC WAAS (Commissioned system) utilized two Inmarsat satellites
  - Provided single satellite coverage over the majority of the U.S.
  - Inmarsat satellites removed from operational WAAS July 2007
- Two replacement satellites launched in 2005
- Intelsat (Galaxy XV)
  - Operational November 2006 (Datalink Only)
  - Ranging scheduled operational mid 2008
- Telesat Canada (Anik F1R)
  - Operational July 2007, for corrections & ranging



WAAS Ground and Space segment Update

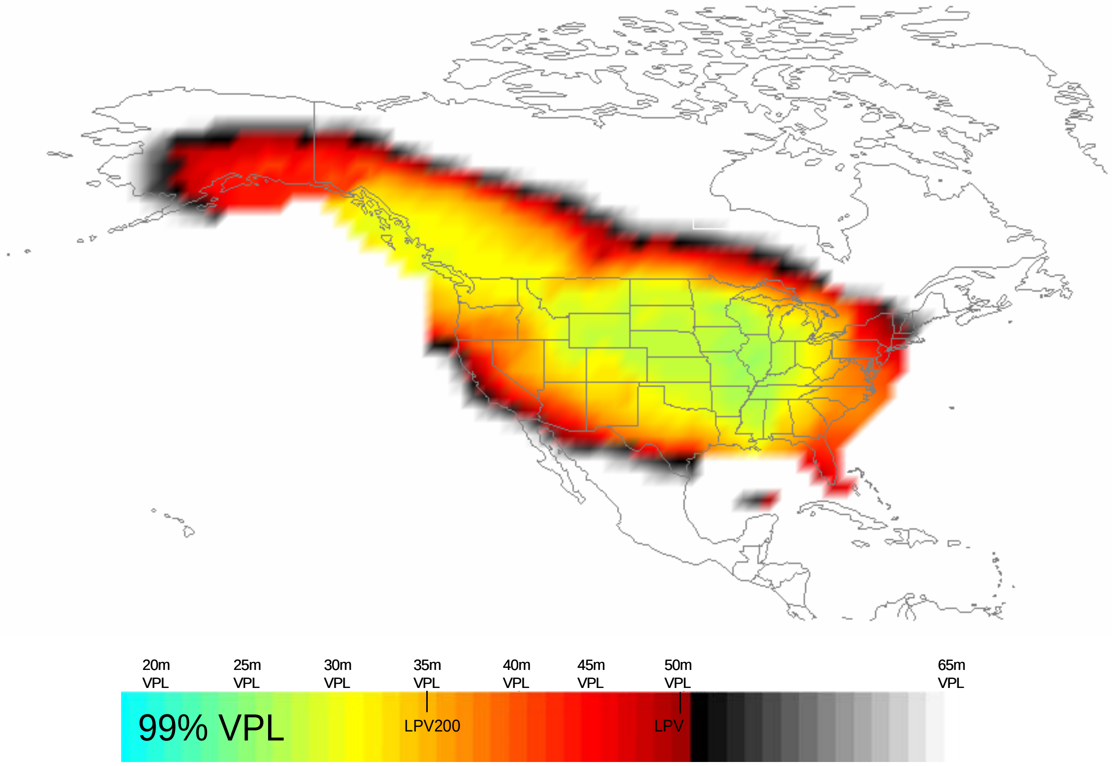
- WAAS Acquisition Phases
  - WAAS Commissioned – IOC – Phase I
    2003
  - Full LPV Performance – Phase II
    2003-2008
  - Full LPV-200 Performance – Phase III
    2009-2013
  - Dual Frequency Operations – Phase IV
    2014-2028
- Procedure Development ~300/year
  2004-2028

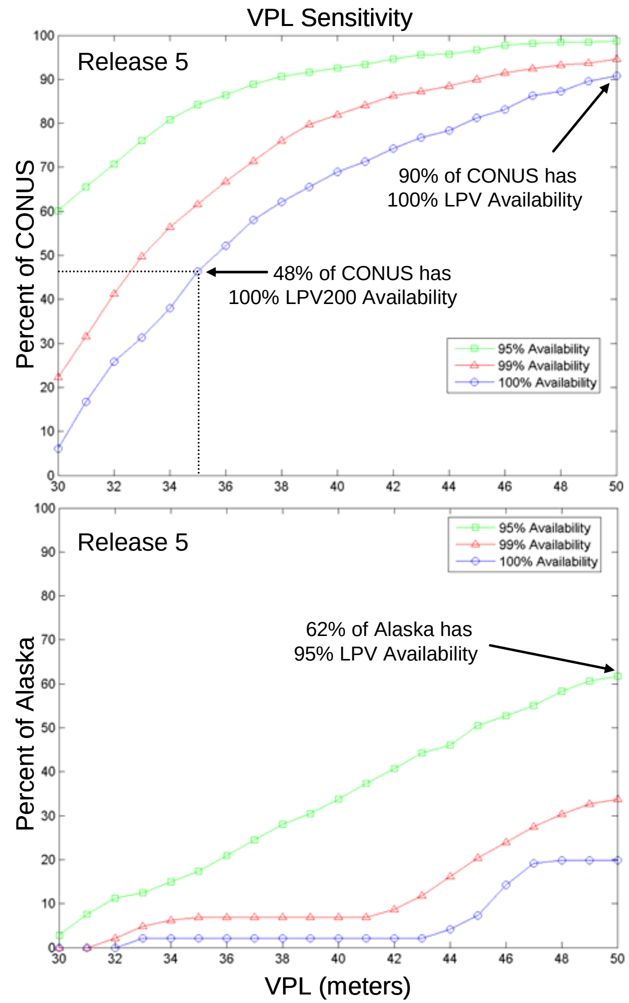
WAAS Program Status – Phase II

Full LPV Performance (FLP)

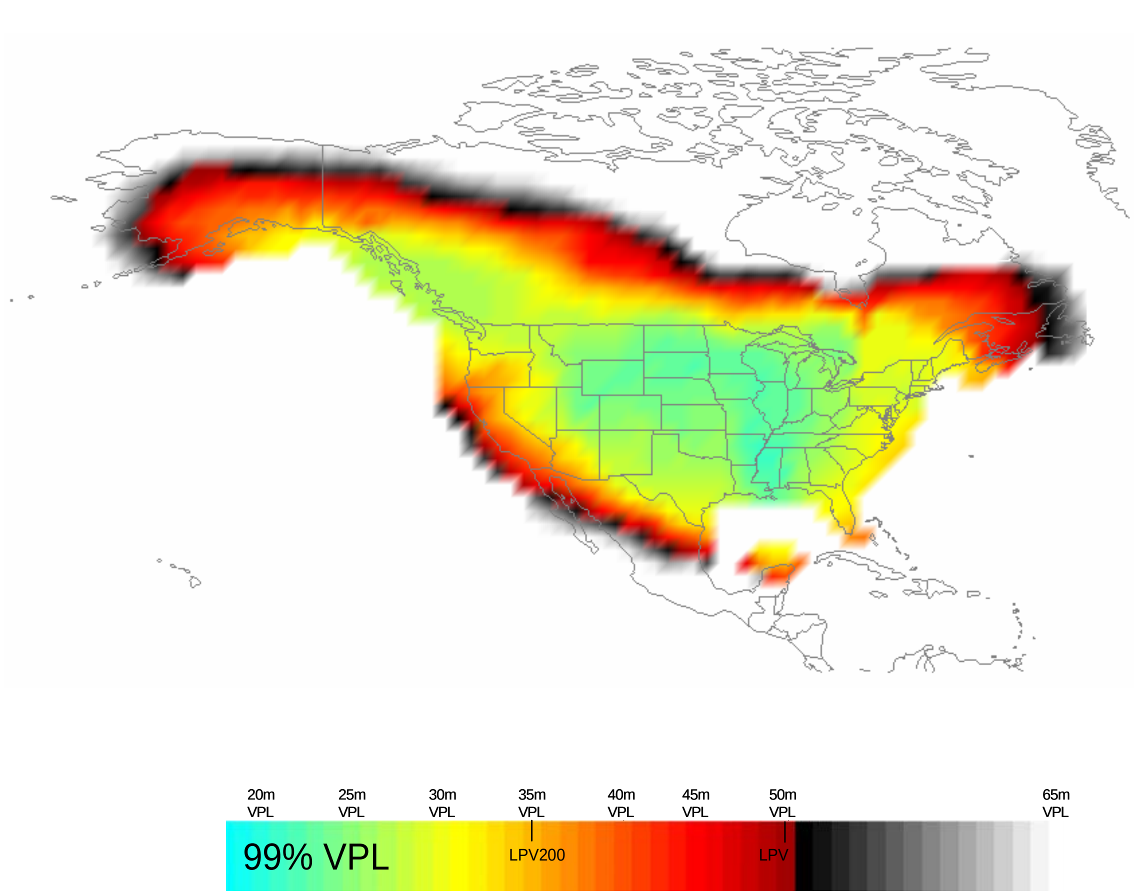
- Localizer Performance with Vertical Guidance to 250'
  - Provide Full LPV service with a limited LPV-200 approach service availability and coverage within the CONUS
  - LPV approach service extended to Alaska and portions of Canada and Mexico
- Highlights include:
  - Two new leased GEO satellites that provide the WAAS broadcast SIS,
  - An additional master station,
  - Enhancements to the broadcast corrections, and
  - Additional wide area reference stations (5 Mexico and 4 Canada)

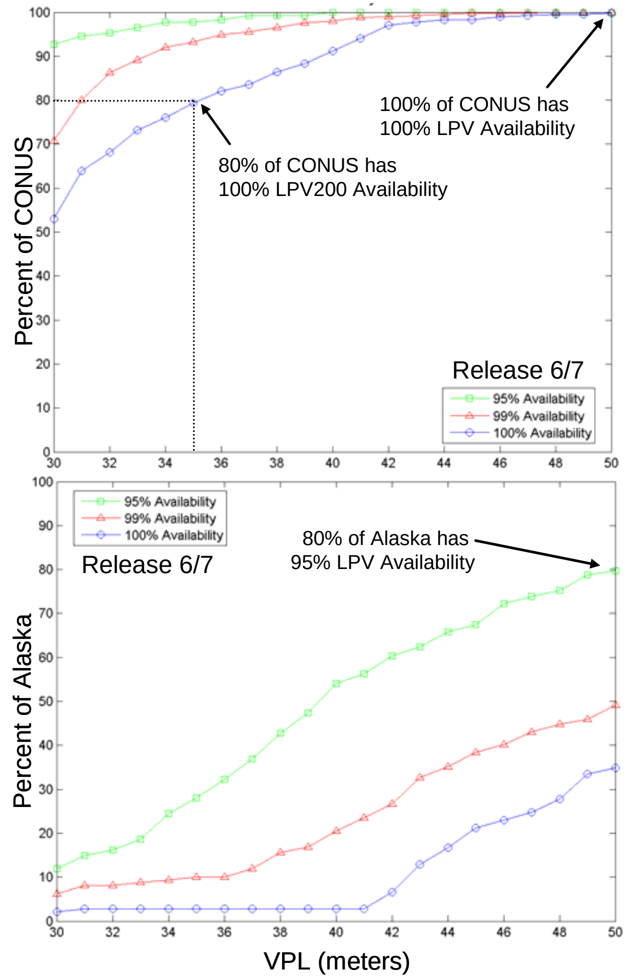
WAAS Release 5



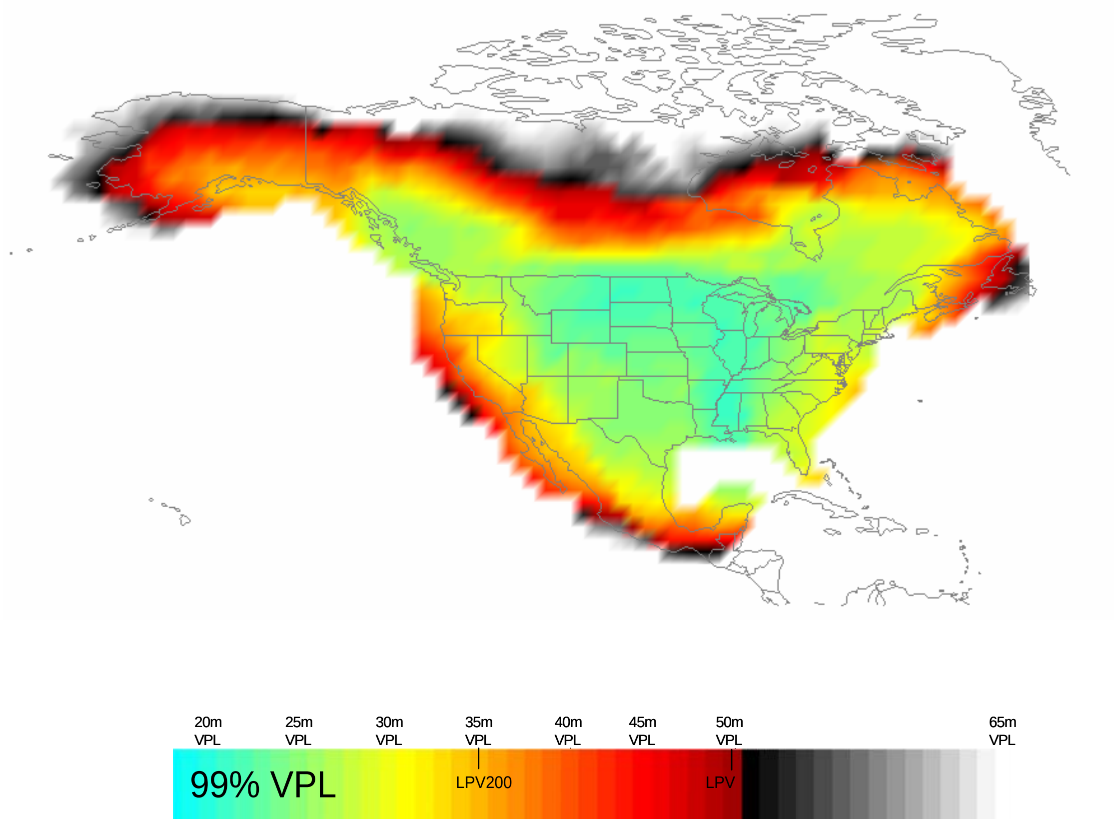


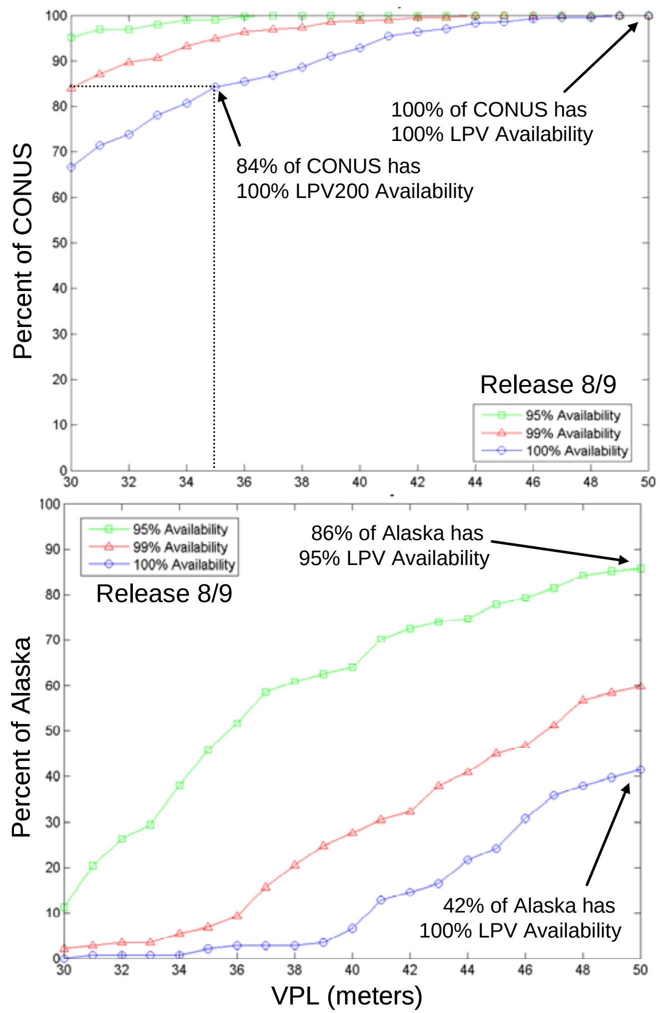
WAAS Release 6/7



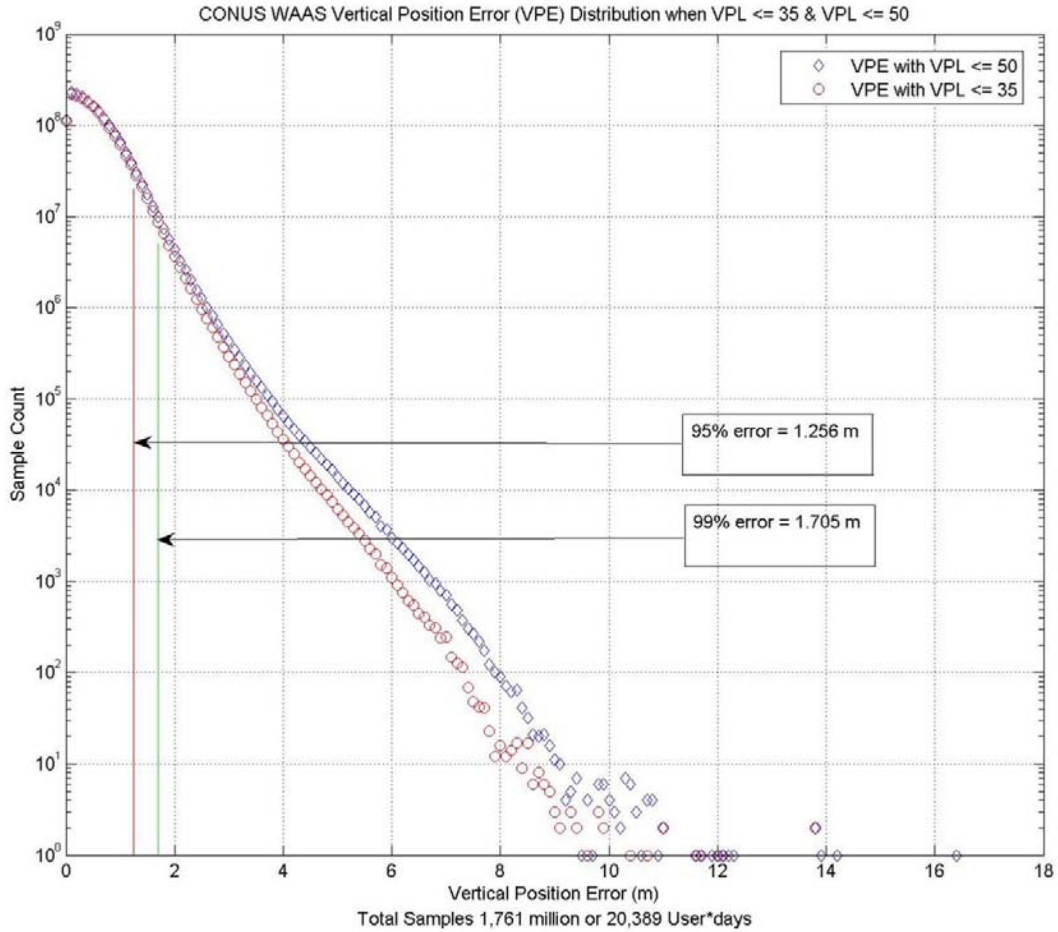


WAAS Release 8/9





WAAS Vertical Error Performance



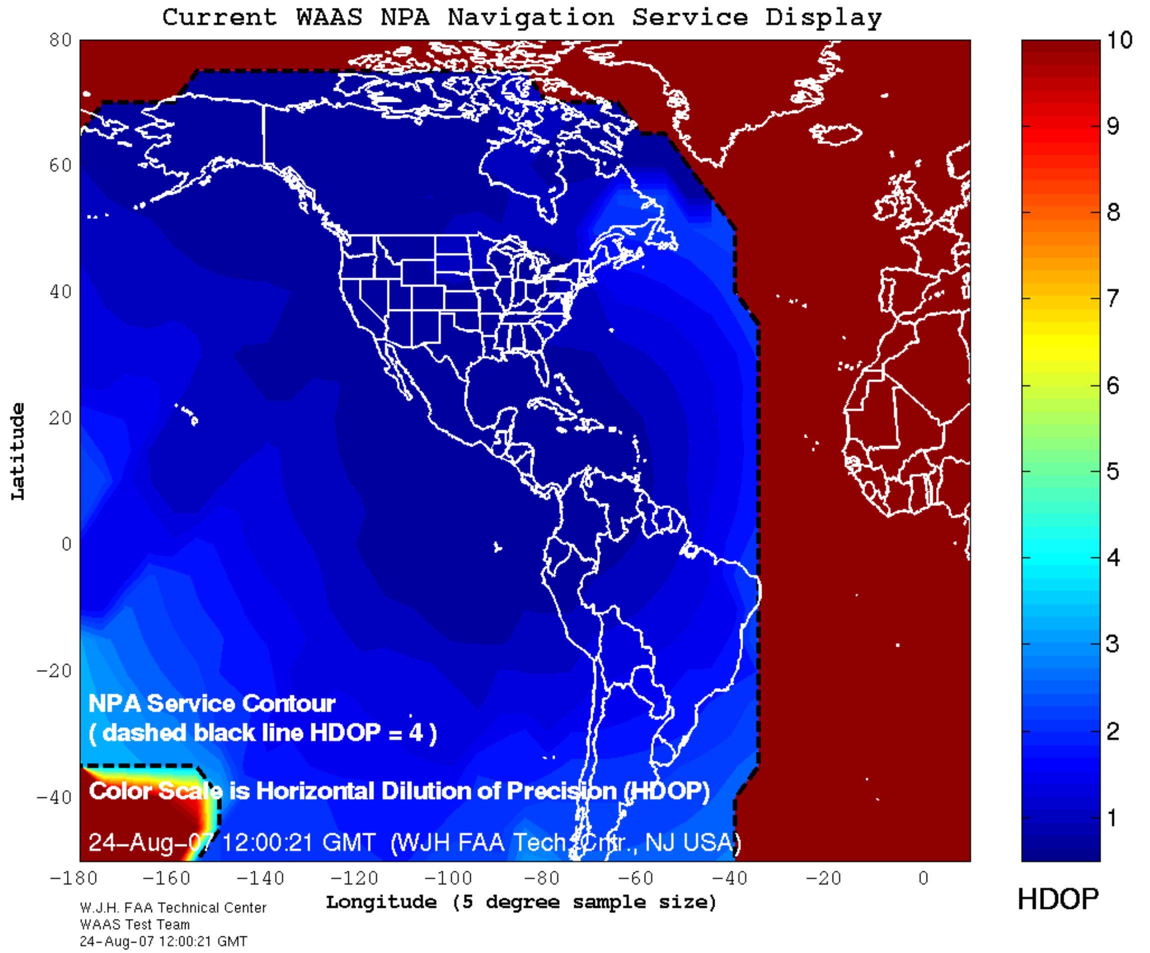
GPS Performance with WAAS and LAAS

	GPS Standard	WAAS LPV Standard	WAAS LPV Actual	LAAS Cat-I Standard	LAAS Cat-I Actual
Horizontal 95% (Worst Location)	36 meters	16 meters	1.08 meters	16 meters	0.68 meters
Vertical 95% (Worst Location)	77 meters	20 meters	1.26 meters	4 meters	1.17 meters

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

LAAS Performance is based on the 104 LAAS approaches at Memphis Airport

WAAS LNAV (NPA) Performance



WAAS Program Status – Phase III

Full LPV-200 Performance

- Provides for a robust, reliable, and sustainable LPV-200 capability
- Support transition of WAAS maintenance and development capabilities to the FAA
- Planned WAAS Algorithm Updates for Phase III
  - Acquisition of additional GEO satellite
  - WIPP Participation for continual GIVE Algorithm Tuning (especially during the approaching Solar max)
- A contract award for the WAAS Phase III Transition efforts (WAAS Follow-on) is anticipated in Summer 2008

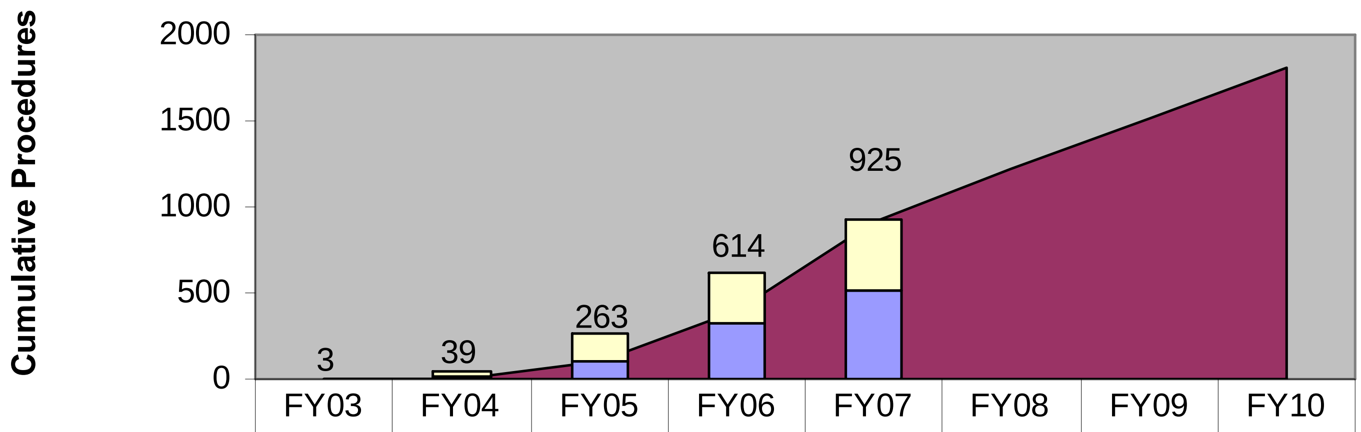
WAAS Program Status – Phase IV

- Dual Frequency Operations
  - Maintain a robust, reliable, and sustainable LPV-200 capability
    - Support Single frequency WAAS users through end of Phase IV (2028)
  - Support User Equipage of dual frequency (L1/L5) avionics
- GPS Evolutionary Architecture Study (GEAS) Group formed – Fall 2006
  - Goal of GEAS is to identify, evaluate, and recommend GNSS-based architecture (s) for robust LPV-200 service worldwide (circa 2025-30)

WAAS Avionics Status

- Total WAAS equipped users ~15,000
- Approximately 40% of est. 140,000 GA aircraft are equipped with Garmin receivers
  - GNS-400/500 series:
    - 75,000 non-WAAS capable receivers sold
      - 18,000 owners have registered for WAAS upgrade
      - Plan to upgrade 300 units a month, currently far exceeding that rate
        - » Over 6,800 units upgraded to date
    - New production receivers are WAAS capable
      - 3,800 units shipped
- Rockwell-Collins: Challenger aircraft approval – August 2007
- CMC: FAA contract to integrate CMC WAAS sensor into Honeywell Primus 2000 FMS in FAATC Global 5000 aircraft, expected in 2008
- Universal Avionics: Developing WAAS-enabled capability in dual thread UNS-1 FMS TSO in Summer '07

WAAS Procedure Production



	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
CUMULATIVE LPV GOAL	0	0	100	400	914	1214	1514	1814
LPV to NON-ILS RWY ENDS	1	10	106	328	516			
LPV to ILS RWY ENDS	2	29	157	286	409			

Type of Approach	**Procedures To Date**
Total GNSS Approaches	**4225**
LNAV/VNAV	**1121**
LPV	**925**

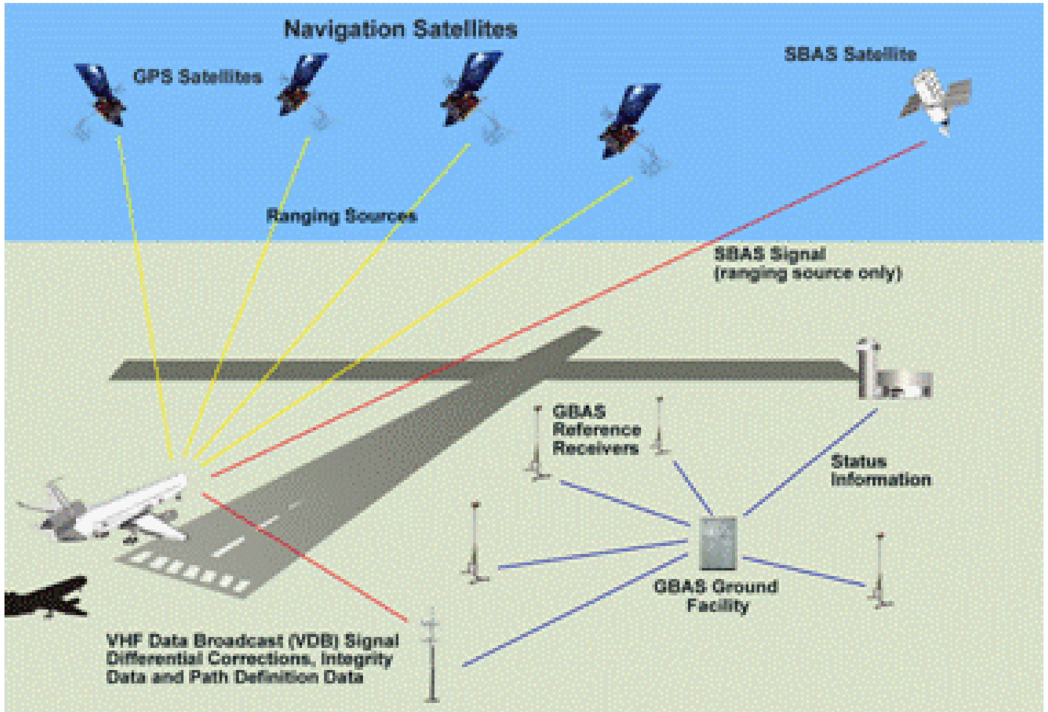
SBAS Interoperability Working Group (IWG)

- The FAA supports the mission of the IWG –Which is "*To perform adequate coordination and cooperation between SBAS Project Offices aiming at ensuring compatibility and interoperability of their respective SBAS Systems over lifetime for the benefit of the SBAS user communities*"
- *The 5 primary objectives of the IWG are:*
  - *Objective 1: Harmonize SBAS modernization plans*
  - *Objective 2: Forum for discussion on SBAS Technical issues*
  - *Objective 3: Harmonize technical improvements from Operation and users feedback*
  - *Objective 4: R&D cooperation on key SBAS technologies*
  - *Objective 5: Support joint SBAS promotion*

SBAS Ionospheric Working Group

- Chartered under the SBAS IWG to investigate ionospheric issues that jointly affect SBAS providers
  - FAA has supported the working group for the past 8 years
- Collaborated on development of white papers identifying Ionospheric threats
- Supported development of ICAO papers on Ionospheric threats
- Made available WAAS supertruth data to all participants

Local Area Augmentation System (LAAS) Architecture



- Precision approach for Category I, II & III
- Multiple runway coverage at an airport
- Guided missed approaches and departure procedures
- Aircraft surface navigation

Current GBAS Activities

- Integrity Analysis and Prototype Development
  - FAA GBAS prototype work under Honeywell Contract
  - Hazardous Misleading Information (HMI) Analysis underway to validate GBAS architecture/design
- GBAS CAT I Approval Process
  - System Design Approval for Honeywell architecture (SLS 4000)in progress
  - Hazardous Misleading Information (HMI) Analysis underway to validate GBAS architecture/design
- GBAS Avionics
  - GBAS/LAAS avionics documents (MASPS / MOPS / TSO / SARPS) completed
  - Boeing 737-800 series GBAS equipped, Airbus A320, A380 certification planned for 2007 (Qantas, Continental, Hapag-Fly aircraft in service and GBAS capable)
- CAT-III Research & Development Activities
  - Continuing Work to Develop Requirements Compatible with Aircraft Operations and Approval Process
- International GBAS Cooperation
  - International GBAS Working Group
  - FAA Memorandum of Cooperation established with Australia, Brazil, Spain, Germany

GBAS - Next Steps

- Technical
  - Continuation of HMI Analysis
  - Encourage regional investigations of the ionosphere
  - Encourage rapid transition to ionospheric strategies proposed for GSL-D
- Operational
  - Facility and Service Approval at Memphis in 2008
  - Parallel Facility and Service Approval at Sydney International Airport.
- International
  - Coordination of development and approval activities with International community
- R&D to Develop and Validate CAT II/III Requirements

U.S. Perspective on GNSS Compatibility and Interoperability

Tom Stansell

representing
U.S. Air Force GPS Wing

Definition of Compatibility

- "Compatible" refers to the ability of U.S. and foreign space-based positioning, navigation, and timing services to be used separately or together without interfering with each individual service or signal

Radio Frequency Compatibility

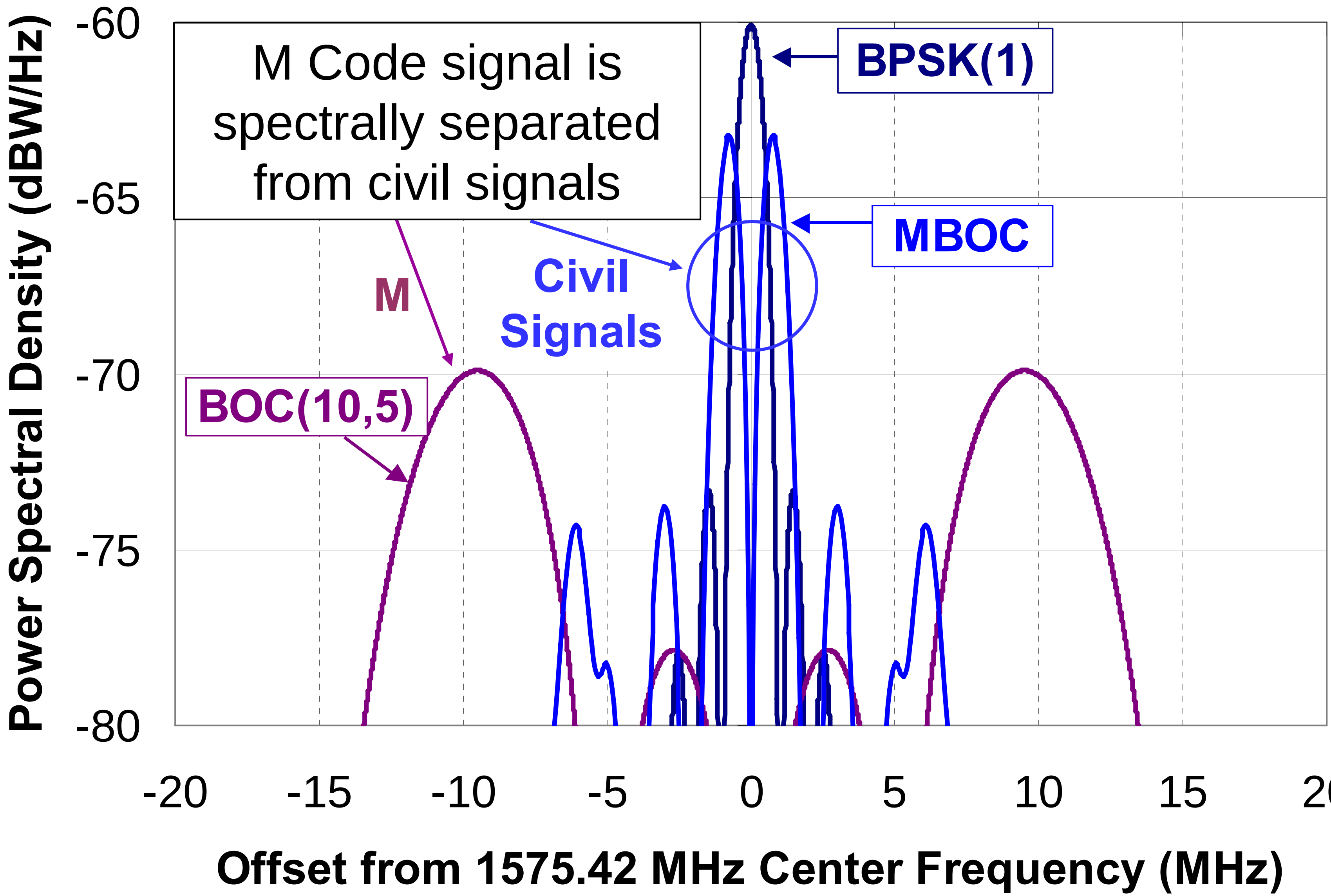
- Ensures that signals do not unacceptably interfere with use of other signals
- Requires thorough consideration of detailed technical factors, including
  - Effects on receiver noise floor
  - Crosscorrelation between interfering and desired signals
- International Telecommunications Union (ITU) provides framework
- Details are best worked bilaterally between providers

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

- Ensure compatibility
  - Radio frequency compatibility
  - Spectral separation between M code and other signals
    - See following example

- Achieve interoperability between GPS civil signals and other system's civil signals
  - Primary focus on the common L1C and L5 signals

Spectral Separation of GPS Civil and M-code Signals in L1

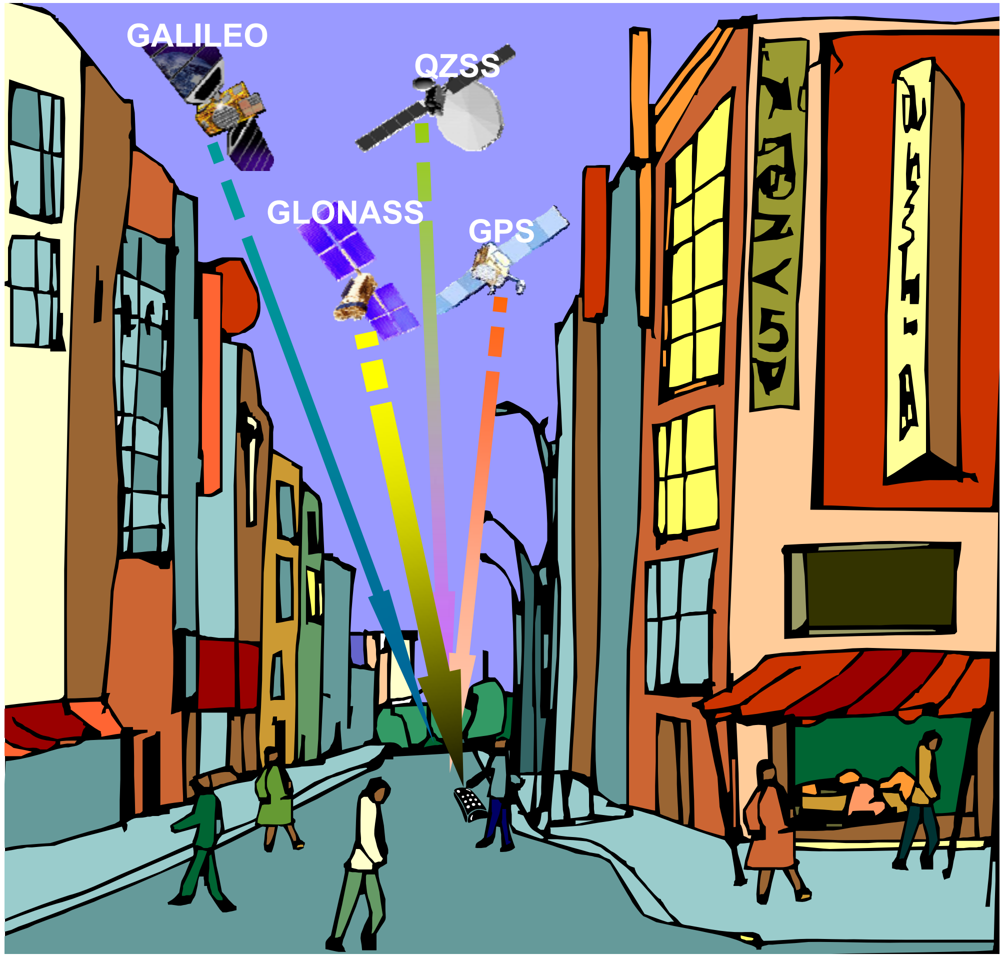


Definition of Interoperability

"Interoperable" refers to the ability of civil U.S. and foreign space-based positioning, navigation, and timing services to be used together to provide better capabilities at the user level than would be achieved by relying solely on one service or signal

Interoperable = Better Together than Separate

The Goal of RNSS Civil Interoperability



- Ideal interoperability allows navigation with one signal each from four different systems with no additional receiver cost or complexity

Main Benefit of Interoperability

Geometry

- More Satellites ➔ Better Geometry ➔ Improves:
  - **Satellite coverage** ➔ navigate where could not before
  - **Dilution of Precision** ➔ accuracy is better everywhere
    - Eliminates DOP holes (with open sky)
  - **RAIM*** ➔ integrity checked everywhere, all the time
    - Eliminates RAIM holes (with open sky)
  - **Phase ambiguity resolution** for survey and machine control applications

* Receiver Autonomous Integrity Monitoring

Important for Interoperability

- Common Center Frequency
  - Like L5 & E5a
- Same Antenna Polarization
- Common Signal Spectrum
  - Identical receiver time delay with common spectrum
- Same coherent integration period for acquisition
  - Usually related to symbol rate
  - Different symbol rates may require separate search correlators for acquiring signals

Essential (cost driver)

Important (no time bias or filter issues)

Desirable (ASIC gate count)

US-EU Coordination

- 26 June 2004 "U.S.-EU Agreement on GPS-Galileo Cooperation" called for improved compatibility and interoperability between GPS and Galileo
- Established bilateral Working Group A (WG-A) on Compatibility and Interoperability
  - Co-chaired by GPS Wing and European Commission
  - WG-A meetings:
    - 22–23 March 2005 in Brussels
    - 14–15 June 2005 in Los Angeles
    - 20–21 October 2005 in Rome
    - 20–21 March 2006 in Stockholm
    - 03–04 October 2006 in Los Angeles
    - 02–04 April 2007 in London

US-EU Coordination Successes

- Managed and agreed GPS-Galileo compatibility
  - RF compatibility of all signals
  - Spectral separation of GPS M code and Galileo PRS from each other and from other civil signals
- Achieved important levels of interoperability between GPS and Galileo civil signals at L1 and L5/E5a
- Coordinated development of new L1 civil signals
  - L1C on GPS and L1F (OS) on Galileo
  - New MBOC spreading modulation
    - Combines BOC(1,1) and BOC(6,1) components
    - Optimized for multipath mitigation and code accuracy

US-Japan Coordination

- Under the auspices of the 1998 “Joint Statement on Cooperation in the Use of the Global Positioning System”
  - The US and Japan have held Compatibility and Interoperability Expert Working Group (EWG) meetings on GPS and the Quasi-Zenith Satellite System (QZSS)
  - Co-chaired by GPS Wing and JAXA
  - The following meetings have been held:

21–22 January 2004 in Tokyo
19 November 2004 in Washington
19 July 2005 in Honolulu
06 September 2005 in Tokyo
24 January 2006 in Tokyo
04–05 April 2006 in Los Angeles
04 August 2006 in Kauai
23 May 2007 in Washington

US-Japan Coordination Successes

- Agreement on GPS-QZSS compatibility
- Achieved important levels of interoperability between GPS and QZSS signals on L1, L2, and L5
  - L1C, L2C, and L5 QZSS signal specifications derived from and referenced to GPS Interface Specifications

US-Russia Coordination

- Based on a United States – Russian Federation Joint Statement issued in December of 2004
  - A Working Group (WG1) on GPS-GLONASS Compatibility and Interoperability was formed
  - Co-chaired by GPS Wing and Roscosmos
  - The following meetings have been held:
    - 5 October 2005 in Moscow, Russia
    - 5 December 05 in Moscow, Russia
    - 7-8 June 2006 in Cocoa Beach, Florida
    - 13-14 December 2006 in Yaroslavl, Russia

US-Russia Coordination Results

- Sharing of system status, concepts, and plans has improved mutual understanding
- Compatibility and interoperability of GPS and GLONASS:
  - Both parties have made "significant progress" understanding benefits to users of a common approach

Summary

- GNSS compatibility is vital
- GNSS interoperability benefits civil users
- Bilateral GNSS working groups have been very effective
  - Both parties benefit from cooperation
  - Assuring compatibility between systems
  - Promoting interoperability of civil signals

United States GNSS Spectrum Protection Activities

David A. Turner

Supporting

U.S. Department of State

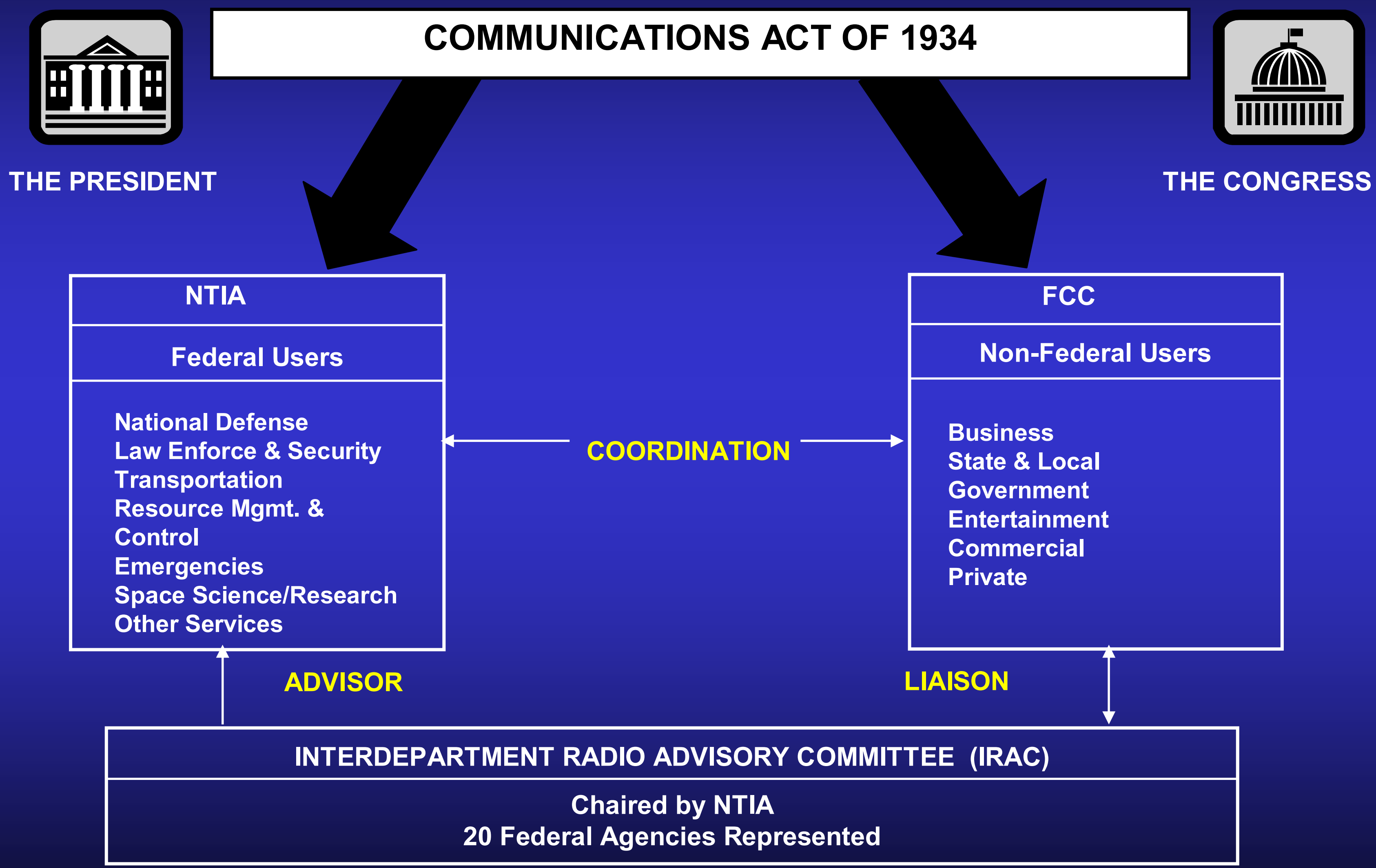
GNSS Spectrum Protection Activities

- **Domestic RNSS spectrum regulation/management procedures**
- **GNSS Spectrum Concerns**
- **Views on ITU RNSS spectrum issues and WRC Agenda Items**

Domestic Spectrum Management Process

- In the United States, responsibility for spectrum management including frequency allocations is divided between Federal government uses and other uses
- The National Telecommunications and Information Administration (NTIA) is responsible for Federal government uses, while the Federal Communications Commission (FCC) for all other uses
- Where responsibilities overlap, the FCC and NTIA reach a consensus through coordination

United States Spectrum Management



Current GNSS Spectrum Concerns

- Ultra-Wideband (UWB)
- Mobile Satellite Service Ancillary Terrestrial Component (MSS ATC)
- Other potential interference sources
- For all three, the concern is In-Band, Spurious, and Out-of-Band Emissions (OOBE)

Goal:

Protect Sensitive RNSS Bands From Additional Electromagnetic "Noise" To Minimize Radio Frequency Interference (RFI)

International RNSS Spectrum Activities (1)

- Participation in ITU-R Working Party 8D
  - WP8D is developing several Recommendations that provide technical characteristics and protection criteria for RNSS systems
  - WP8D is also developing a Recommendation on estimating interference from non-RNSS services to RNSS and a Recommendation on coordination methodology for RNSS inter-system interference estimation
  - Participation by all system providers is encouraged

International RNSS Spectrum Activities (2)

- Resolution 609
  - The U.S. encourages continued participation in the Resolution 609 Consultation Meetings by all system providers
    - Next meeting is scheduled for April/May 2008
  - Timely receipt of information to meet the Res 609 deadlines outlined in the Res 609 Terms of Reference is important
- ITU-R Radio Regulation Article 9 Coordination Requirements
  - Coordination under Article 9 and Resolution 610 is a necessity
  - Coordination can be carried out using the Methodology being developed in Working Party 8D
- World Radio-communication Conference 2007
  - All parties are encouraged to participate and pursue the protection of GNSS

WRC-07 RNSS Goals

- WRC Agenda Item 1.1 - “Deletion of Country Footnotes”
  - In order to maintain worldwide radio frequency protections, nations must cease allowing interference sources in the primary GPS/GNSS band (1559 – 1610 MHz).
  - In about 40 countries, mainly European, Middle Eastern, and African, GNSS spectrum is also used for fixed links (microwave links)
  - At WRC-2000, these nations agreed to remove these fixed links, or use on a non-interfering basis, by 2015
  - The U.S. will continue to encourage countries to adopt spectrum controls in their respective nations to promote safe and reliable GPS/GNSS use worldwide

Domestic PNT Interference Detection and Mitigation

David A. Turner

on behalf of

US Coast Guard Navigation Center
System Management Division

Presentation Overview

- Current GPS Interference Detection and Mitigation Process
- Active Television Antenna Example
- Interference Detection and Mitigation (IDM) Plan

GPS SPS Outage Causes

- GPS Constellation anomalies
- User equipment anomalies
- GPS frequency interference
  - Intentional
  - Unintentional

Domestic GPS Outage Reporting

USAF GPSOC
(military)

USCG NAVCEN
(surface)

FAA NOCC
(aviation)

GPS Outage Detection

- Government managed systems that monitor and/or augment GPS
  - GPS Ground Segment Monitors (USAF)
  - WAAS (FAA)
  - NDGPS (USCG)
  - CORS (NOAA)
  - JPL DGPS Network (NASA)

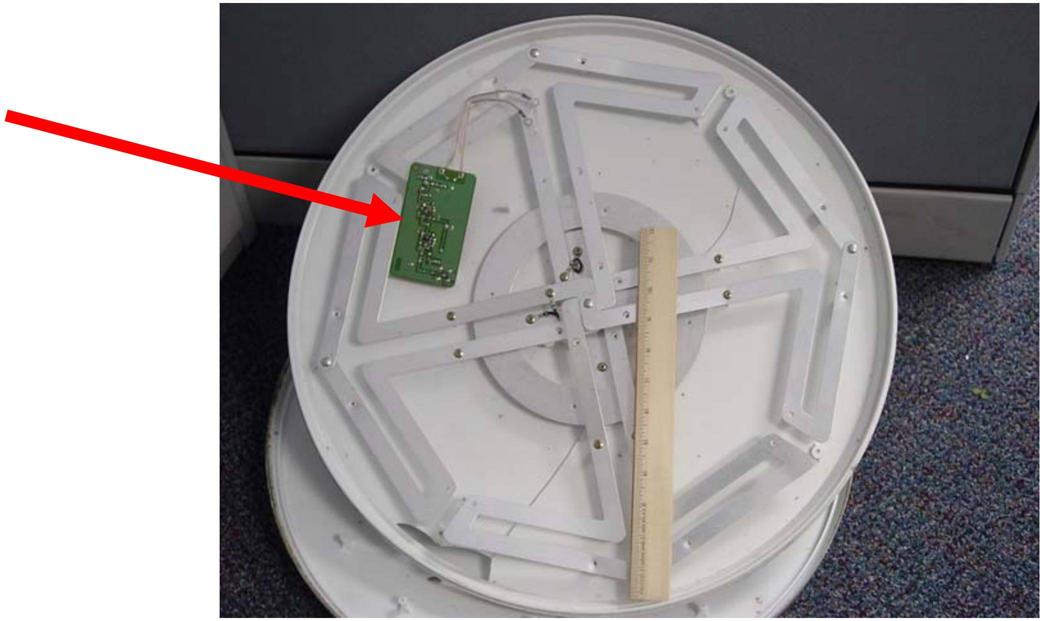
- User Reports (domestic and international)
  - Web-based
  - Phone calls
  - Emails

Domestic GPS Interference Example

In 1997 USCG first discovered a consumer market product could cause unintentional GPS interference up to a radius of 2000 feet or the equivalent of a small harbor.

Active TV Antenna

The product was an inexpensive television antenna with an active amplifier circuit. This circuit could generate GPS band interference due to poor design and low grade components



Disassembled TV Antenna

Domestic GPS Interference Example

In 2001 three of these TV antennas were found to be causing GPS interference in a small harbor and one mile seaward

Moss Landing, CA Harbor

Interference Mitigation

The following mitigation action has been taken for this GPS interference source:

- USCG has issued Notice to Mariners and Safety Advisory domestically on this product
- FCC has worked with manufacturers to issue voluntary recall of antennas
- FCC has stopped domestic production of the antenna's active circuit card
- Characteristics of this interference source can be readily recognized by trained personnel

Space-based PNT IDM Plan

- Coordinate domestic capabilities to identify, analyze, locate, attribute, and mitigate sources of interference to the GPS and its augmentations
- Collect, analyze, store, and disseminate interference reports from all sources to enable appropriate investigation, notification and enforcement action
- Develop and maintain capabilities, procedures and techniques, and routinely exercise civil contingency responses to ensure continuity of operations in the event that access to the GPS is disrupted or denied.

Space-based PNT IDM Plan Progress

- December 2004 - DHS assigned responsibility for domestic PNT IDM planning and coordination
- June 2005 – DHS began PNT IDM Plan development starting with existing processes in place for GPS outage reporting, tracking and resolution
- October 2006 – PNT IDM Plan completed coordination through the U. S. Space-Based PNT Executive Committee

Contents

Informational Websites

GPS.gov

PNT.gov

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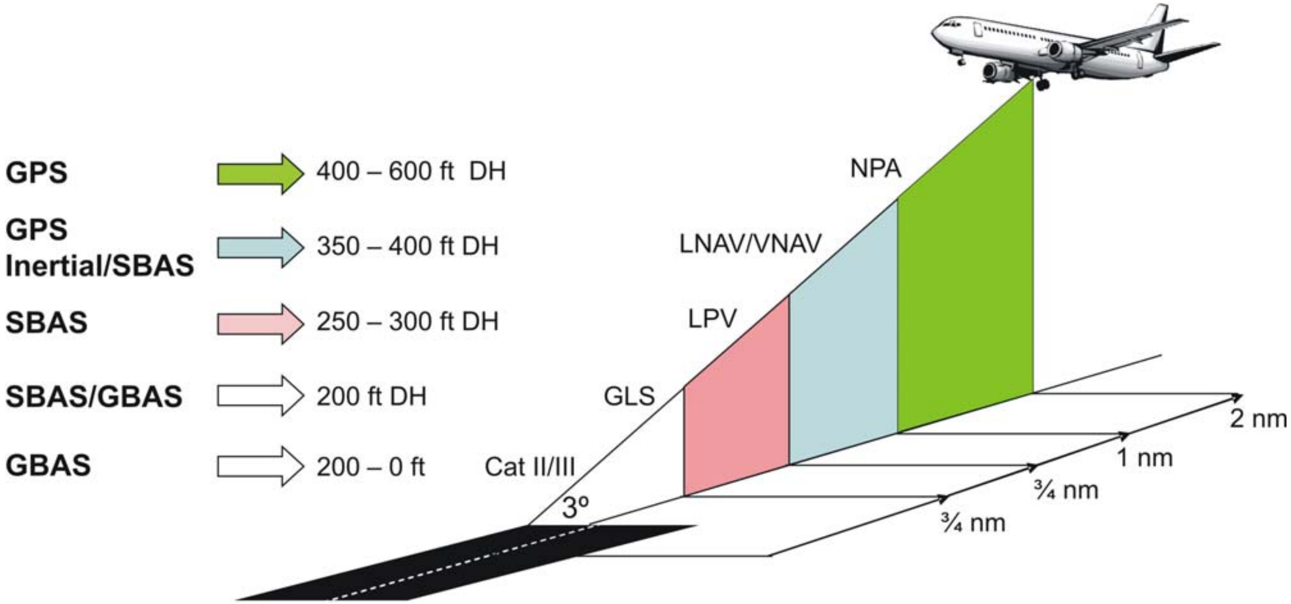
www.PNT.gov and www.GPS.gov

BACK-UP MATERIAL

WAAS/LAAS Update

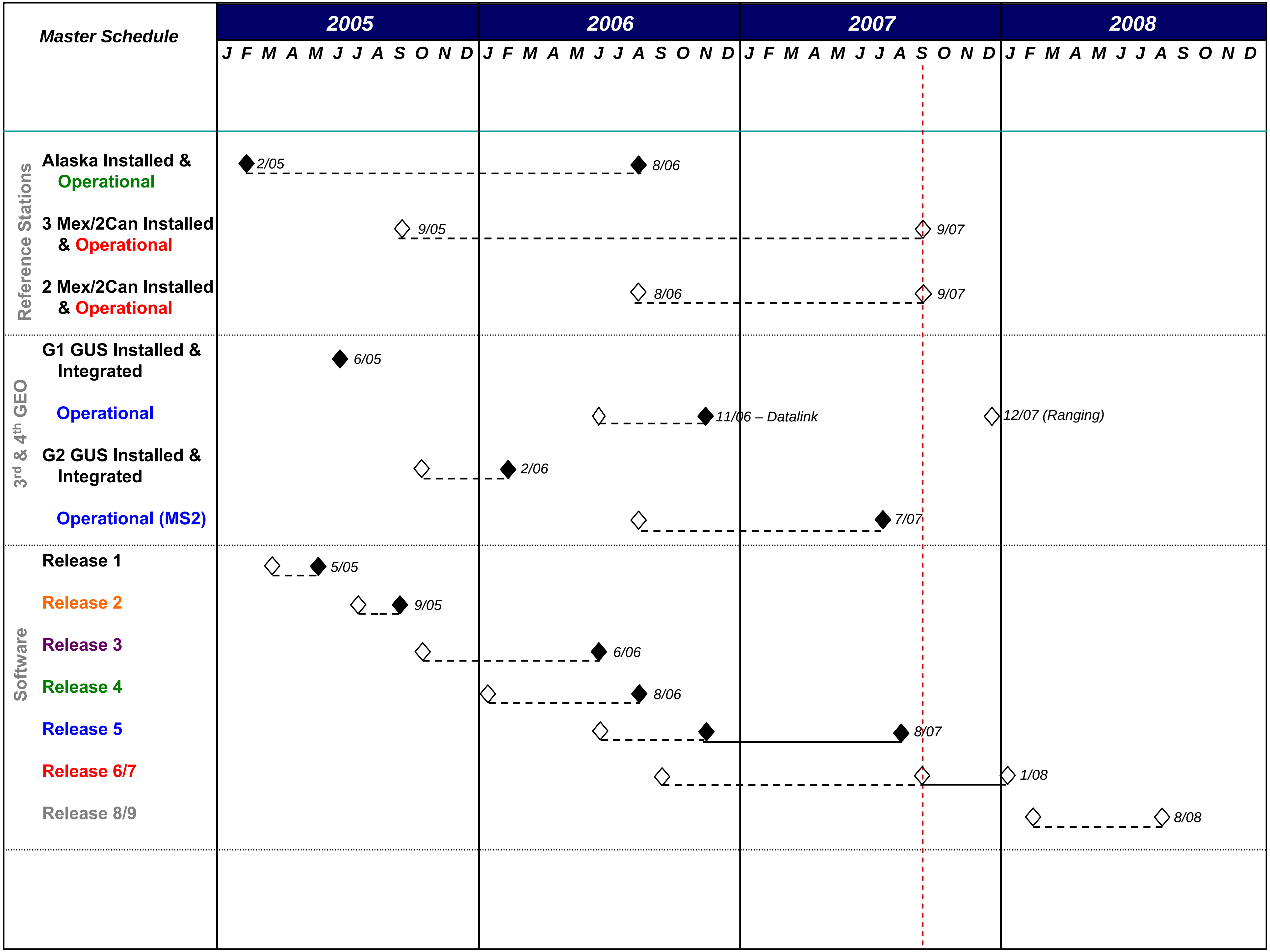
Approach Procedures



- Existing Procedures:
  - 4225 GNSS
  - 1,121 LNAV/VNAV
  - 925 LPVs

New WAAS Procedures

- LPV-200' Minimum
  - Minimum decision height of LPV approach lowered from 250' to 200'
  - First approach published in 2006
  - Safety Case Approved March 7, 2007
  - 10 LPV-200s published to date
- LP Approach
  - Acts like a Localizer approach utilizing WAAS horizontal Alert Limit (HAL) of 40 meters
  - Can be developed at approaches that fail to meet LPV criteria due to obstacle clearance surface (OCS) penetrations
  - Criteria development in formal coordination
  - Publication of LP procedures to start in 2008



Master Schedule
2005
2006
2007
2008
J F M A M J J A S O N D
Reference Stations
Alaska Installed & Operational
2/05
8/06
3 Mex/2Can Installed & Operational
9/05
9/07
2 Mex/2Can Installed & Operational
8/06
9/07
3rd & 4th GEO
G1 GUS Installed & Integrated
6/05
Operational
11/06 – Datalink
12/07 (Ranging)
G2 GUS Installed & Integrated
2/06
Operational (MS2)
7/07
Software
Release 1
5/05
Release 2
9/05
Release 3
6/06
Release 4
8/06
Release 5
8/07
Release 6/7
1/08
Release 8/9
8/08

Phase II System Improvements

- Release 5 (As compared to IOC)
  - Integrated 2 new GEO satellites with 4 new GEO Uplink Subsystem's
  - Installed 3rd Correction & Verification sub-system for improved continuity
  - Retired the original GEO satellites
- Release 6/7 (FY 07)
  - Implemented Extreme storm detector (ESD)
  - Added New IGP Mask (306 IGPs)
  - Added 5 Mexico WRSs and 4 Canada WRSs
  - Upgraded reference station with new G-II Receivers
- Release 8/9 (FY 08)
  - GIVE Algorithm Tuning – to maximize the region in which a user has a 50m VAL and to maximize the coverage region to include as many Mexico IPPs as possible without affecting the CONUS performance
  - Implement Signal Quality Monitor

GNSS Spectrum Protection Activities

- Part of the Department of Commerce
- Performs spectrum management and assignment for all Federal spectrum use
  - Regulations published in Manual of Regulations and Procedures for Federal Radio Frequency Management (NTIA Manual)
  - Authorized GPS frequency use and coordinates through ITU

www.ntia.doc.gov

Federal Communications Commission (FCC)

- An independent government agency, directly responsible to Congress
  - Established by the Communications Act of 1934
  - Charged with regulating communications by radio, television, wire, satellite and cable
- Directed by five Commissioners, appointed by the President and confirmed by the Senate for 5-year terms
- 7 bureaus responsible for:
  - Processing applications for licenses and other filings
  - Analyzing complaints and conducting investigations
  - Developing and implementing regulatory programs
- U.S. Table of Allocations for civil and U.S. Government uses is issued by the FCC and is found in the Code of Federal Regulations

www.fcc.gov