



GPS Augmentations and Applications

Workshop on the Applications of
Global Navigation Satellite Systems

Dubai, United Arab Emirates

16-20 January 2011

Jeffrey Auerbach

GNSS Policy Advisor

Office of Space and Advanced Technology

U.S. Department of State

New U.S. National Space Policy

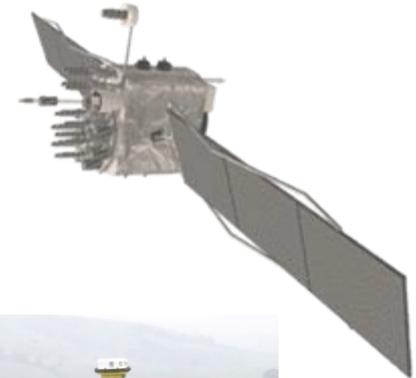
Space-Based PNT Guideline: Maintain leadership in the service, provision, and use of GNSS

- 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



Overview

- GPS Interface Specifications & Performance Standards
- U.S. Augmentations to GPS
 - NDGPS
 - CORS
 - GBAS
 - SBAS/WAAS
- Increased Accuracy with Augmentation





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

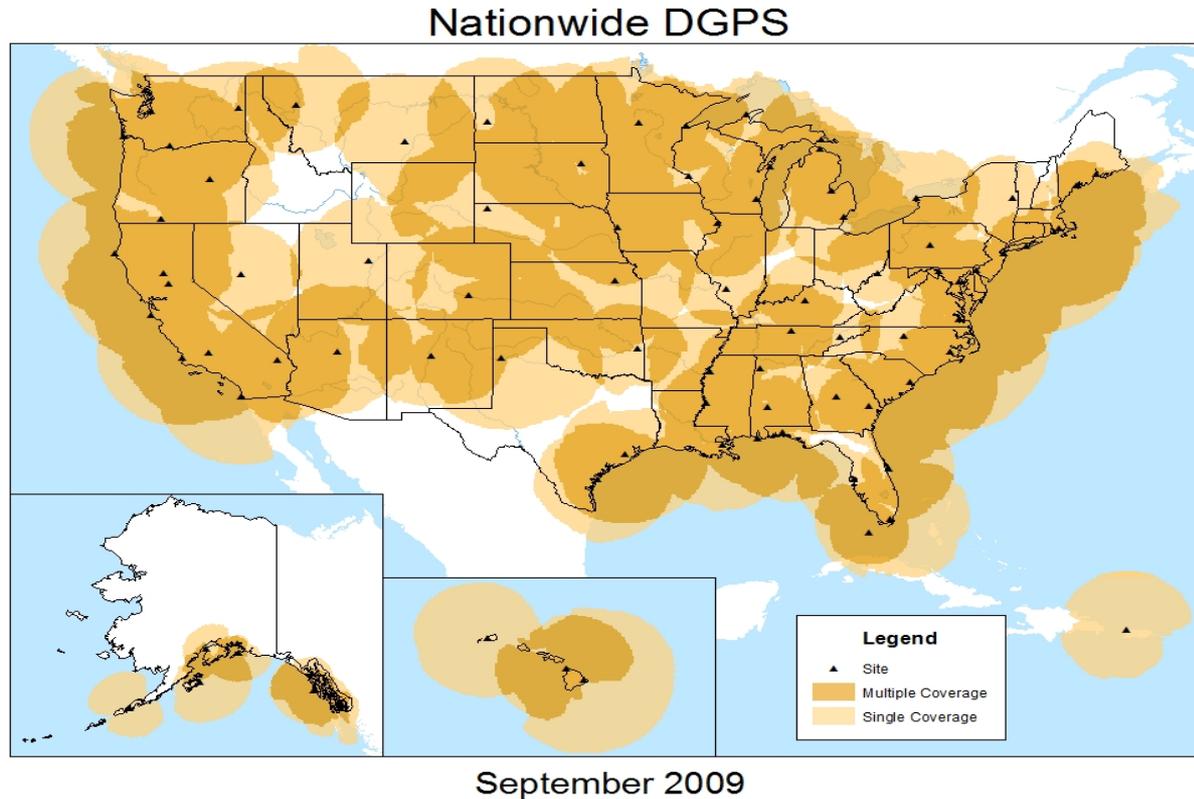


Nationwide Differential GPS (NDGPS)

- **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



NDGPS Capabilities and Uses

- **Transportation**

- Maritime
 - U.S. Coast Guard Aids to Navigation Positioning and maritime navigation
- Traffic congestion
- Baseline reference for railroads
- Used by U.S. Federal Highway Administration
 - Roadside management
 - Survey, construction, quality, asset management



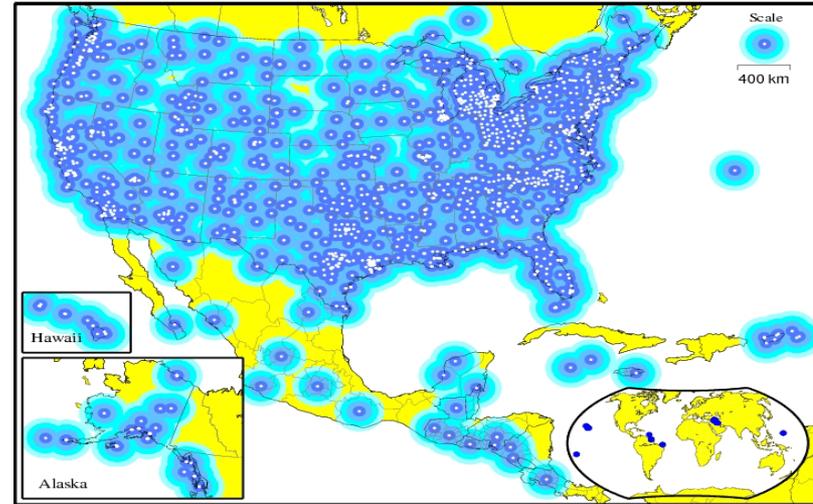
- **Other Uses**

- Federal-Aid Program
- Law Enforcement
- Resource Management
- Environmental and Geological Monitoring
- U.S. Army Corp of Engineers Surveying and Dredging operations



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





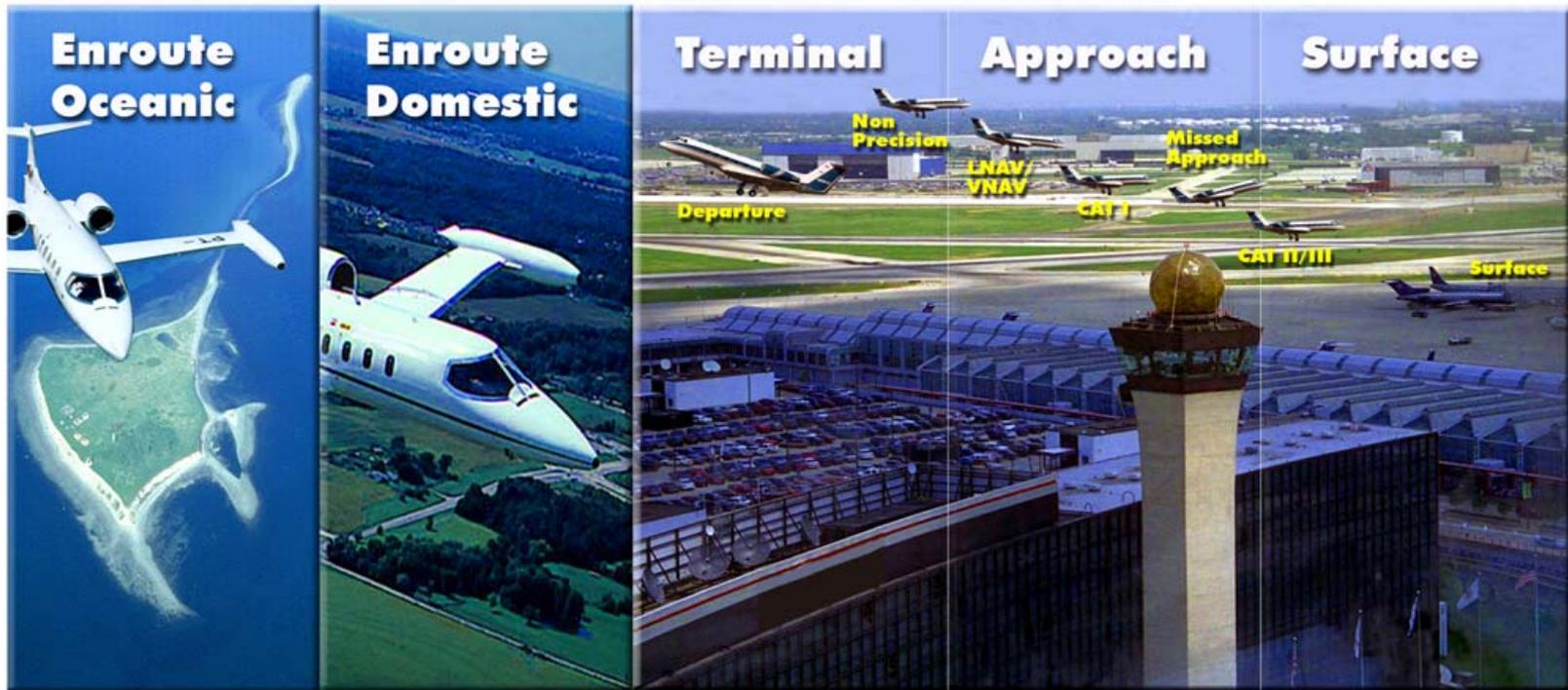
CORS Applications

- Primary application is to enable accurate positioning relative to the National Spatial Reference System
- Other applications include earth and scientific research
 - Monitoring earth tectonic motion
 - Sea level change
 - Atmospheric studies
 - Aerial mapping



U.S. GPS Augmentation Programs Designed for Aviation

WAAS

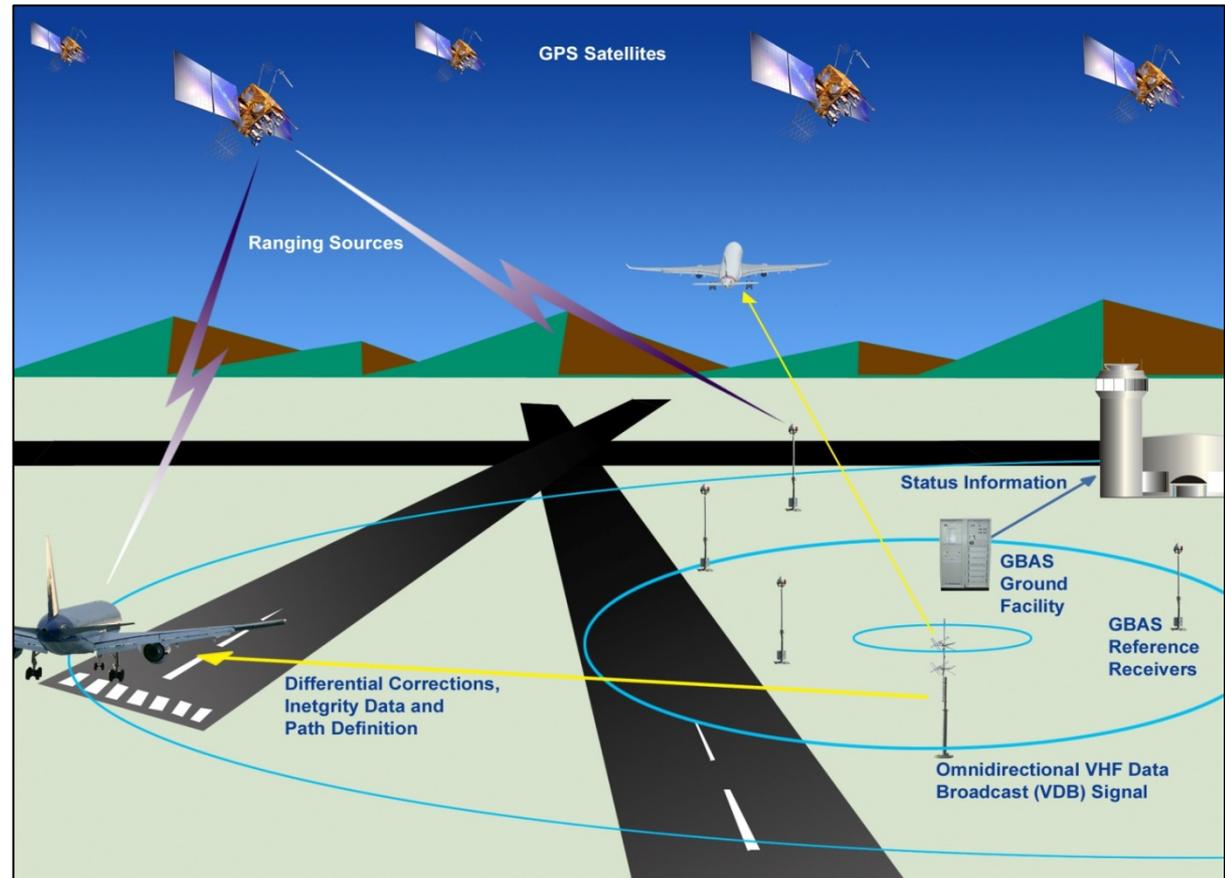


GBAS



Ground Based Augmentation System (GBAS)

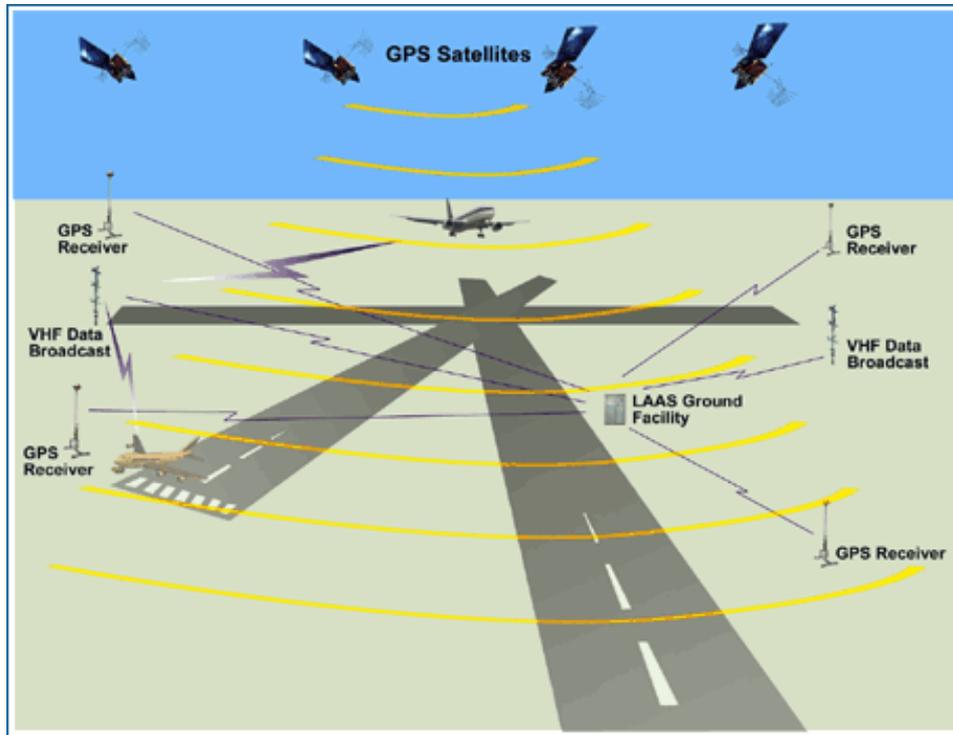
- Architecture
 - Ground Station/Processing Unit/Power Supply (one shelter on airport property)
 - 4 Reference Receivers/Antennas
 - VHF Data Link Antenna
- Specifications
 - Supports Category I approach with growth to Category III
 - Single facility can provide service up to 23 mile radius





Ground Based Augmentation System (GBAS)

- Designed for aviation use



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

- **Operational Implementation**
 - **GBAS implementation at Newark**
 - Straight in procedures developed
 - Airspace Simulations in progress for other scenarios
 - Flight Inspection 2010 / First Flight TBD
 - Continental Airlines taking delivery of GBAS capable 737NG
 - ISSUES
 - RFI issues on L1 – FAA Spectrum investigating
 - NOTAM to address non-availability
 - **GBAS implementation Houston**
 - Memphis GBAS will be relocated to Houston
 - Houston as an additional airport to establish city pair for Continental





GBAS Category II/III Acquisition Planning

- **Drafting/updating required documents according to FAA Acquisition Management System**
 - Single Competitive Contract Award for Development and Production options
 - CAT I/II/III GBAS ground facility
 - Low Rate Initial Production (LRIP) beginning around 2015 (IOC)
 - 10-12 installations per year, up to 90 installations
 - 20 year life-cycle ~2034
- **Next Milestones**
 - Investment Analysis Readiness Decision – September 2011
 - Initial Investment Decision – March 2012
 - Final Investment Decision – September 2012



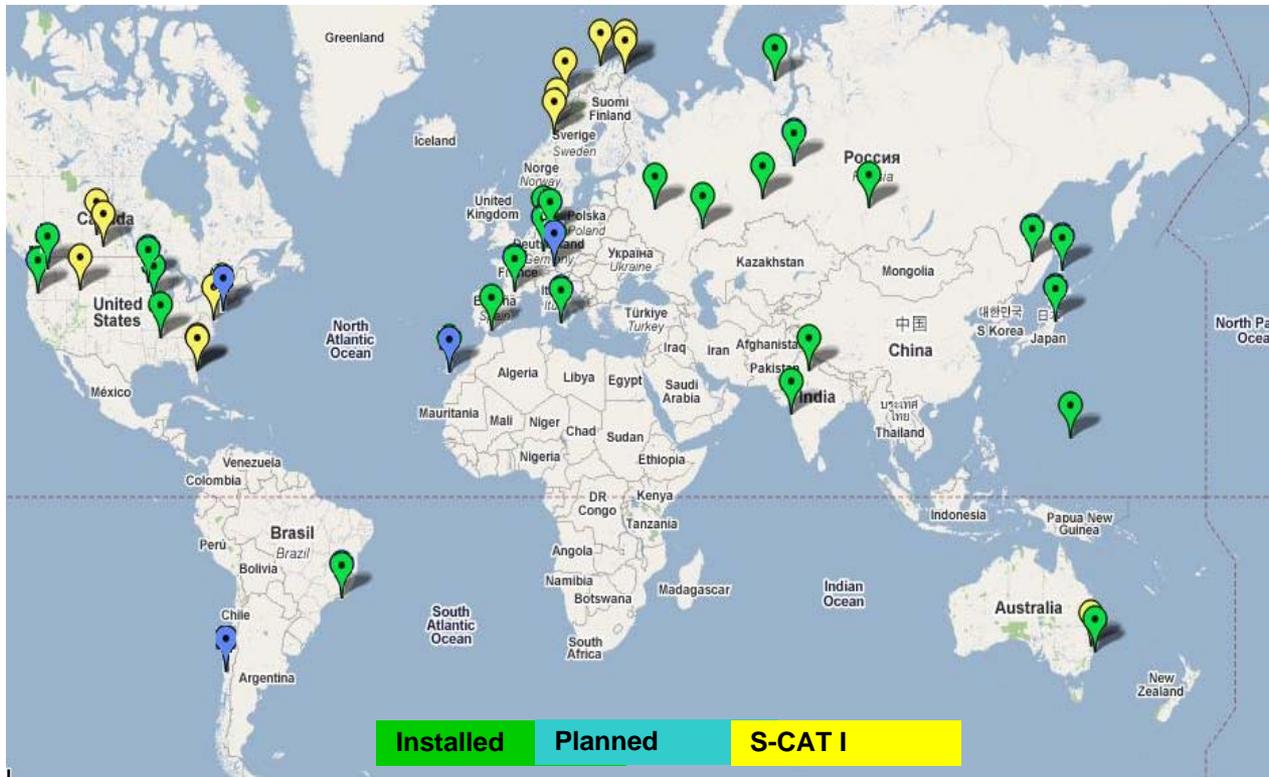
GBAS International Activities

- **International GBAS Working Group (IGWG)**
 - Last working group hosted by EUROCONTROL
June 3-6, 2010 in Brussels, Belgium
 - 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
- **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, China, Colombia



GBAS Usage

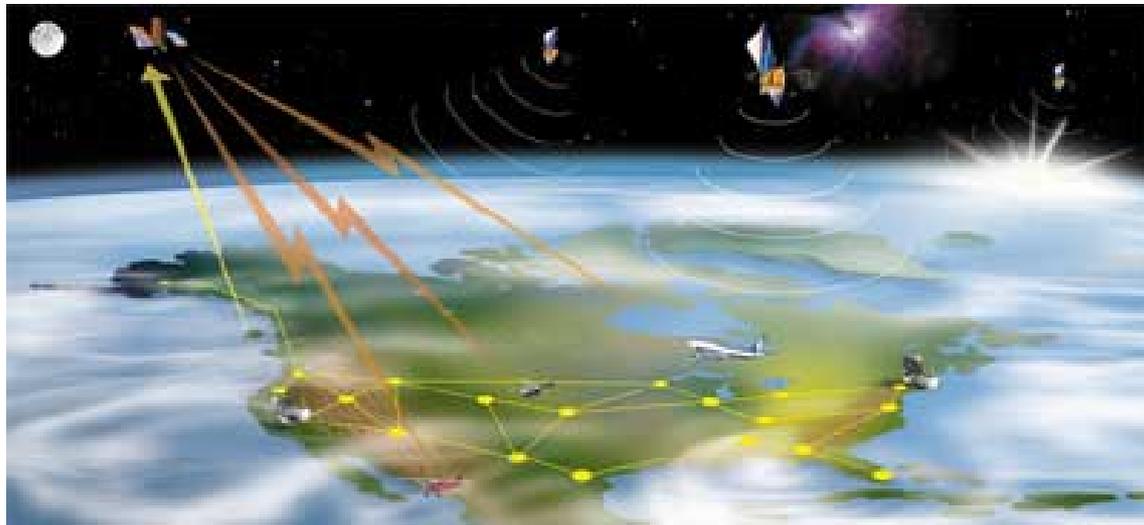
- Current airlines GBAS equipped
 - Continental, Delta Airlines, Qantas, Air Berlin, TuiFly, Sonair, Air Vanuatu, Emirates
- More than 15 countries have active GBAS programs





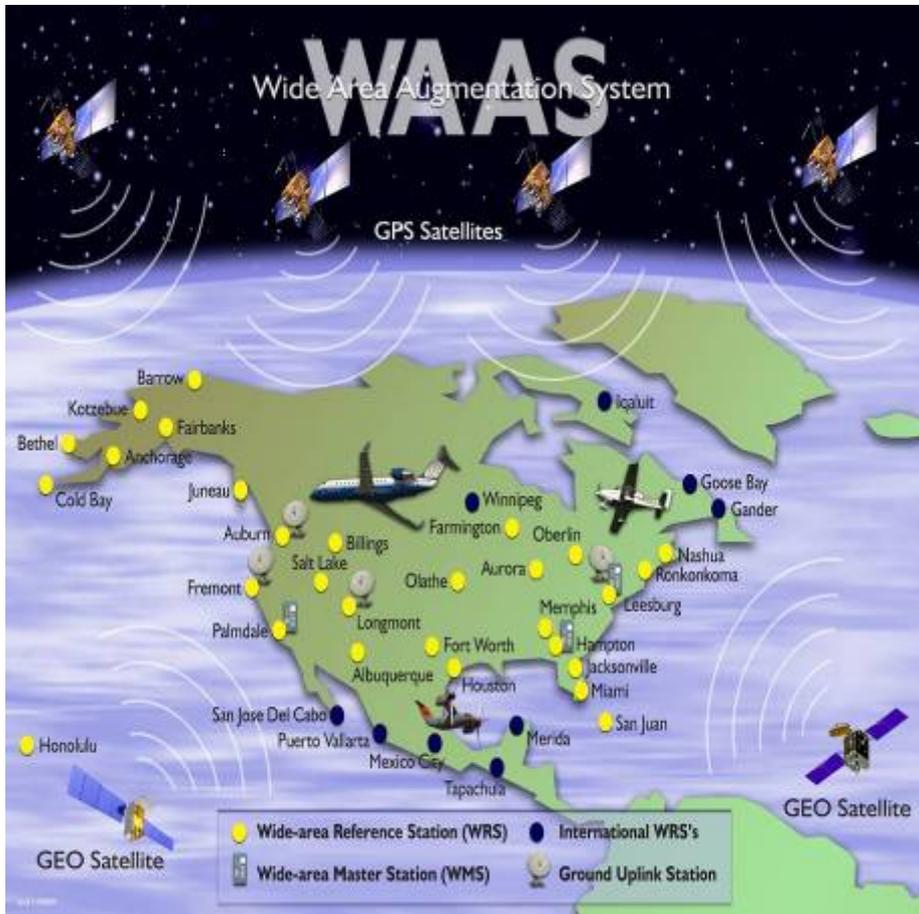
Wide Area Augmentation System (WAAS)

- Satellite Based Augmentation System (SBAS)
- Designed for aviation use, but available and used by many GPS users today
- Localizer Performance with Vertical Guidance (LPV)-200 approach is comparable to ILS Category I



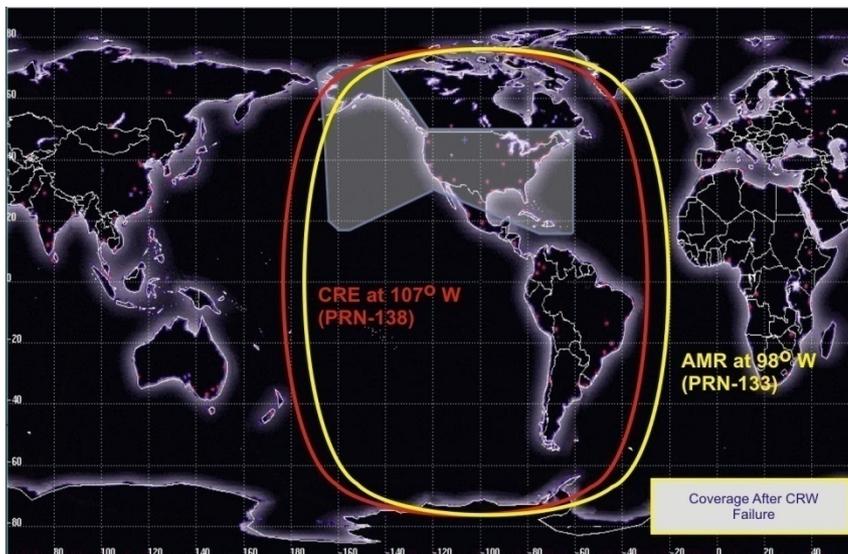
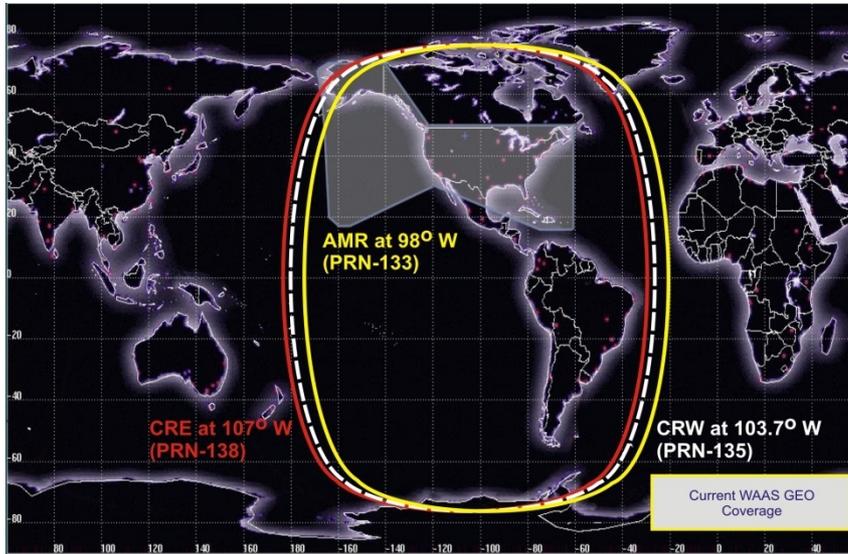


Wide Area Augmentation System (WAAS) Architecture

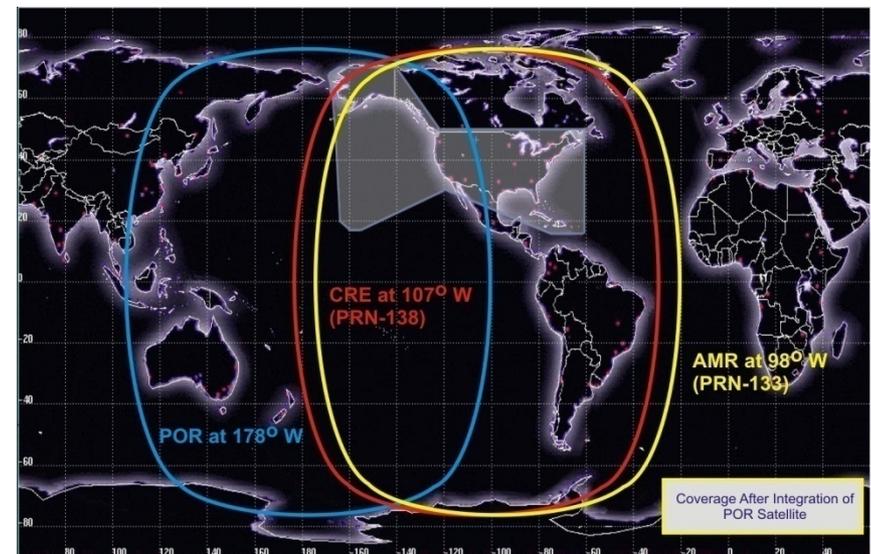




WAAS Geo Satellites



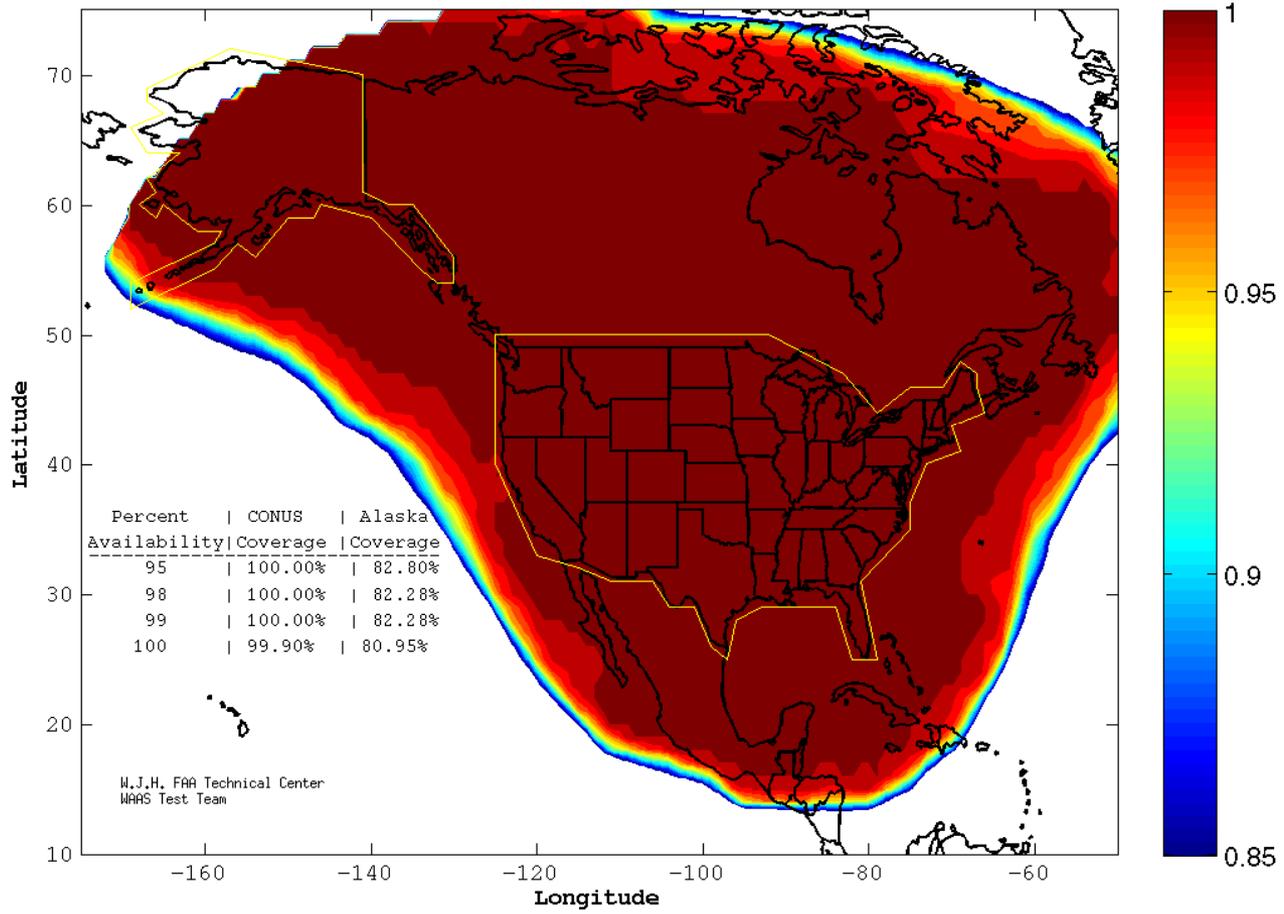
- WAAS GEOs (CRE and AMR) Currently Operating
- CRW turned OFF in December 2010
 - Performance deemed inadequate for WAAS service use
 - Total loss of T&C April 2010 resulted in uncontrolled easterly drift
- CRW recovery efforts initiated 24 December 2010
 - Satellite units undergoing test & evaluation
 - Projected possible return to WAAS service in Spring 2011
- *Potential* alternative would utilize former WAAS GEO (POR) to mitigate loss of service in Alaska





WAAS Availability

WAAS LPV Coverage Contours
12/05/10
Week 1613 Day 0



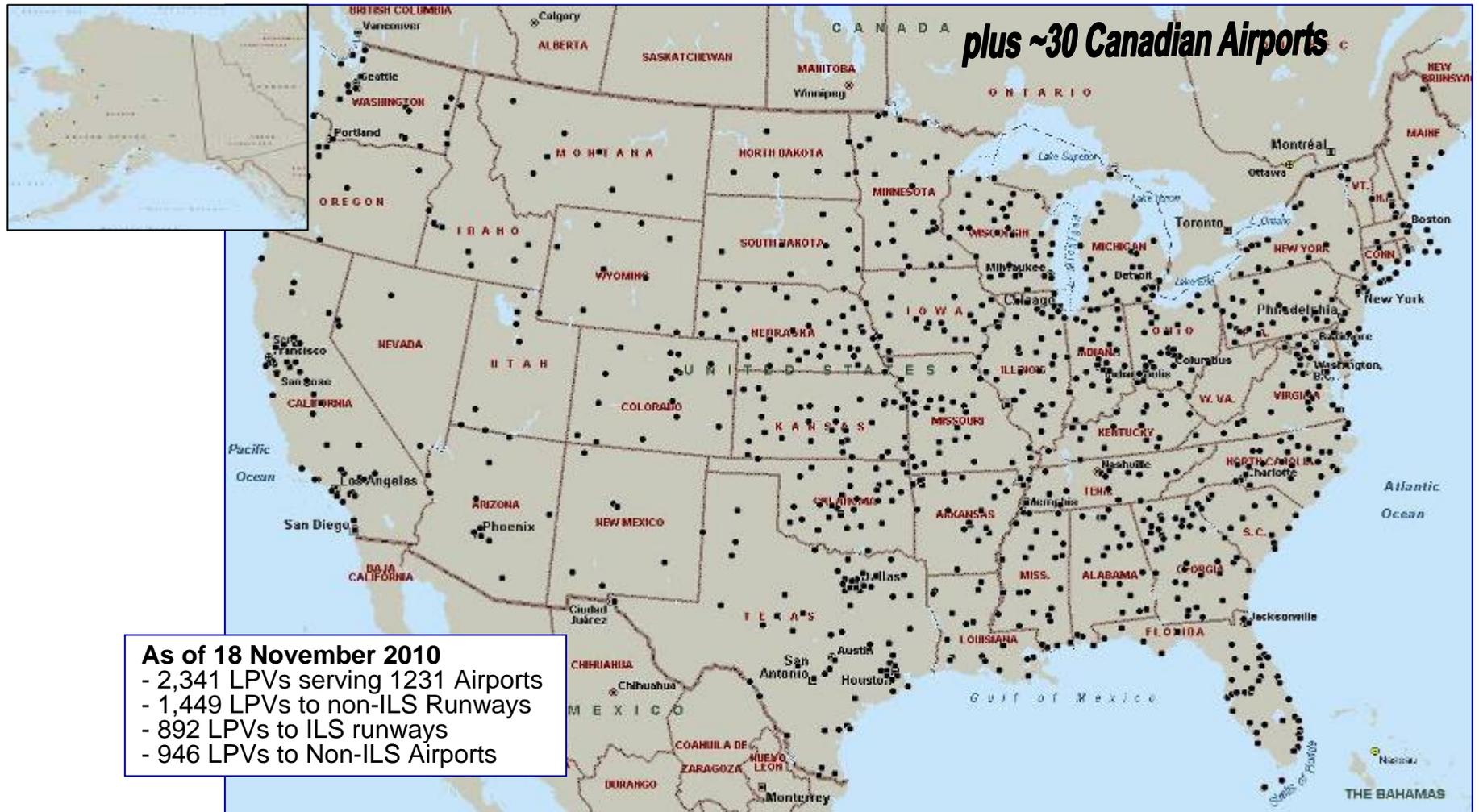


WAAS Phased Upgrades

- **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 (2013 – 2028)**
 - Complete GPS L5 transition
 - Will significantly improve availability and continuity during severe solar activity
 - Provide additional protection against GPS interference
 - Will continue to support single frequency users



Airports with WAAS LPV Approach





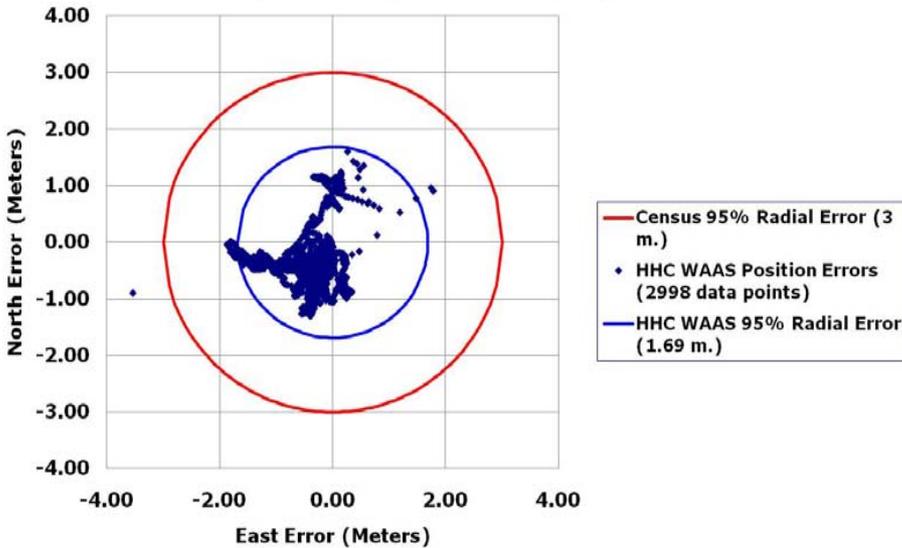
WAAS/SBAS Aviation Benefits

- 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

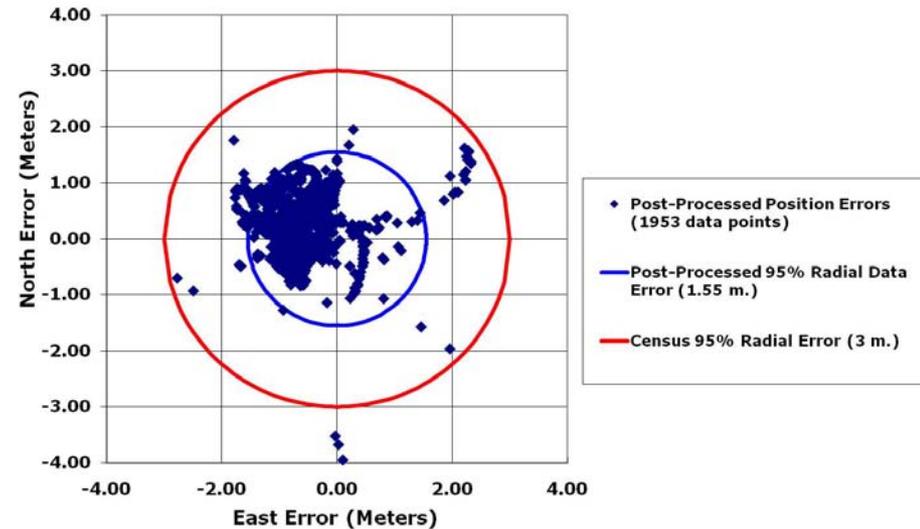


Accuracy with Augmentation

WAAS Position Errors
(NGS F304, Melbourne, FL)



CORS Post-Processed Position Errors
(NGS MARK F304, Melbourne, FL)





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)



Summary

- GPS Interface Documents are available on the Internet
- Plans in work for update to GPS Performance Standard
- NDGPS and CORS augmentation systems allow for a range of services free of charge to users throughout the service area
- GBAS continues progress toward providing advanced aviation capabilities
 - Ultimate goal is to provide Category III precision approach
- WAAS upgrades/system improvements occurring in phases
 - On schedule for Full LPV-200 Performance in 2013



Contact Information

Jeffrey Auerbach

GNSS Policy Advisor
Office of Space and Advanced Technology
U.S. Department of State
OES/SAT, SA-23, Suite 410
Washington, D.C. 20520
+1.202.663.2388 (office)
auerbachjm@state.gov

<http://www.state.gov/g/oes/sat/>

<http://gps.faa.gov/>

<http://www.pnt.gov/>