Navigation Services
and the
United States
National Airspace System

CGSIC
Toulouse, France
April 2008

Mitchell J. Narins
Chief Systems Engineer
Federal Aviation Administration
Navigation Services
Vision: To improve the safety and efficiency of aviation, while being responsive to our customers and accountable to the public

Air Traffic Organization


Leading Aviation Services into the Future
Int’l Cooperation… A Necessity

U.S. Assigned Airspace Equals ~77 Million Square Kilometers
Navigation Services Vision

Provide safe, cost effective position, navigation, and timing services to meet operational needs of aviation customers

– The Navigation Services vision serves the FAA Mission and ATO Corporate Principles
Navigation Service Roles & Responsibilities

- Provide safe, cost effective position, navigation, and timing services to meet the needs of aviation customers
- Provide precision approach and landing capability to runway ends in the National Airspace System
- Provide non-precision approach and landing capability to runway ends in the National Airspace System
- Provide missed approach capability to runway ends in the National Airspace System
- Provide navigation capability to aircraft flying in the National Airspace System
- Support the operational availability of navigation services/systems in the National Airspace System
Navigation Operational Benefits Hierarchy

- Operational Benefit
  - IMC Operations, Gate Management

- Navigation Services
  - Departure, Enroute, Approach, Surface

- Navigation Capability
  - Category I/II/III, RNAV SIDS, RNAV STARS, Q Routes

- Navigation Systems
  - DME, VOR, ILS, WAAS, GPS, MALSR
Today’s *ground based, human-centric* Air Transportation System is reaching its technological and capacity limits.
Navigation and Landing Facilities
(Terrestrial-Based)
Dallas-Fort Worth

- World’s 3rd Busiest Airport by Traffic
  ~ 700,000 Movements
- 14 Runway Ends
  - 2 Non Precision
  - 7 Cat I
  - 5 Cat II/III
Annual Ops and Maintenance Costs
DFW - 2005

Other Ops Costs
Lighting Ops Costs
Annual Ops and Maintenance Costs
DFW - 2005

Approach/Landing Facilities at DFW
- Non-Precision: 14%
- Cat I: 36%
- Cat II/III: 50%

Ops Costs by Facility Type
- Non-Precision: 2.4%
- Cat I: 55.1%
- Cat II/III: 42.5%

Ops Costs by Equipment Type
- Lighting Costs: 54%
- Other Costs: 46%
Daily Flight Traffic Over the U.S.
Daily Flight Traffic Over the U.S.

16626 planes in flight

2005 Mar 19-21:58 GST
NextGen Senior Policy Committee

- **Department of Transportation**
  - Mary E. Peters, Secretary of Transportation
  - Jeffrey N. Shane, Under Secretary for Policy

- **Department of Defense**
  - Michael W. Wynne, Secretary, United States Air Force

- **Department of Commerce**
  - Vacant, Deputy Secretary

- **Department of Homeland Security**
  - Paul A. Schneider, Acting Deputy Secretary

- **White House Office of Science and Technology Policy**
  - Dr. John Marburger, Director

- **NASA**
  - Dr. Michael Griffin, Administrator

- **FAA**
  - Robert Sturgell, Acting Administrator
Path to Performance-based NAS

- The Next Generation Air Transportation System (NextGen) Plan Defines A System That Can Meet Demands For The 21st Century
  - Precision Navigation is one of the 9 Key capabilities
- The Roadmap for Performance-Based Navigation v2 was published in 2006
- FAA Navigation Services has developed the Navigation Evolution Roadmap that defines the infrastructure now and in the future for implementation of RNAV, RNP and NextGen
What Is “Performance-Based Navigation?”

• An End-to-End Air Transportation System Based On Performance Standards Rather Than Specific Technologies Or Equipment
  – Area Navigation (RNAV)
  – Required Navigation Performance (RNP)

• Recognizes The Ability Of Modern Aircraft To Operate Safely And Efficiently Using A Variety Of On-Board Systems and External Signals
Performance-Based Navigation

- Complete Transition By 2025
- Consistent With ICAO Global Vision
- Operational Capability Based On GPS And Augmentations
- Enhance Safety, Capacity, Efficiency
- Reduce Cost For Legacy Navigation Systems
ICAO: Basic Elements of PBN Implementation (RNAV or RNP)

Possible Systems:
GNSS, DME/DME, DME/DME/IRU, ...

NAVAID INFRASTRUCTURE + NAVIGATION SPECIFICATION = NAVIGATION APPLICATION

Air Traffic System Airspace, Routes and Instrument Procedures

Airworthiness & Operator Requirements

Federal Aviation Administration
Air Traffic Organization
Navigation Services
The Next Generation Air Transportation System (NextGen) Plan Defines A System That Can Meet Demands For The 21st Century

Capabilities

- Trajectory-Based Operations
- Performance-Based Operations and Services
- Precision Navigation
- Weather Integration
- Network-Centric Information Sharing
- Surveillance Services
- Equivalent Visual Operations
- Super Density Operations
- Layered, Adaptive Security
Roadmap for Performance-Based Navigation

- The Roadmap for Performance-Based Navigation v2 was published in 2006
- FAA Navigation Services has developed the Navigation Evolution Roadmap that defines the infrastructure now and in the future for implementation of RNAV, RNP and NextGen
Navigation Evolution Roadmap

• In formal coordination for signature by FAA Administrator
• Provides a high-level framework for transition to performance-based navigation from navigation services primarily based on terrestrial-based systems
• Collaborative effort with aviation community
• Companion business plan
Navigation Evolution Roadmap

— An element of the FAA’s strategic planning
Navigation Roadmap

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<th>GNSS Domain</th>
<th>Galileo</th>
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<th>GPS III</th>
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<td>VOR</td>
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<td>DME</td>
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<td>SBAS(WAAS)</td>
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<th>Non-Precision Approach (NPA)</th>
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<td>VOR</td>
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<th>CAT I or Equivalent</th>
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<td>SBAS/LPV</td>
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<td>GBAS/GLS</td>
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<th>Precision Approach (PA)</th>
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<td>ILS (II/III)</td>
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<td>ALS</td>
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<td>GBAS/GLS</td>
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<td>ABAS</td>
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<th>Infra-Structure</th>
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Navigation Roadmap Decision Points

5  2007 - VOR decision for drawdown based on GNSS

6  2007 - Develop rightsizing DME Requirements, e.g., service volume, architecture, pathway

23  2008 - Decision on NextGen CAT I landing system

24  2008 - Decision on NextGen CAT II/III service, pending feasibility & schedule of potential ABAS/GBAS solutions and risk mitigation strategies

69  2012 - Begin ILS CAT I drawdown - limited backup at OEP airports

70  2012 - Determine if CAT II minima is the appropriate requirement at specific airports

81  2015 - VOR decision on complete drawdown

94  2020 - Decision on complete ILS CAT I drawdown
Navigation Roadmap Decisions (cont.)

- 2008 – NCIME Acquisition Decision
- 2009 – GPS Signal Monitoring Acquisition Decision
- 2014 – Signal Monitor Integration with GPS OCX Acquisition Decision
- 2019 – GPS Integrity Message Service ISD and WAAS Transition Decision
- 2009 - Develop phased approach for DME service to support RNAV/RNP
- 2007 – See Surveillance Roadmap
- 2007 - See Aircraft Roadmap
- 2008 – See Aircraft Roadmap
Automatic Dependent Surveillance (ADS-B)
ADS-B Program

• Benefits
  – Safety Improvements By Increasing Situational Awareness Both In-flight And On The Ground
  – Increased Operational Efficiency Through Higher Air Traffic Throughput

• Schedule
  – Final Rulemaking Issued 2010
  – Avionics Implementation 2010-2020
  – Ground Infrastructure Completion 2013

• FAA Lifecycle Costs to 2035: ~ $2.4B

**ADS-B is a Primary Building Block for NextGen**
Status of SBAS and GBAS Programs

Wide Area Augmentation System (WAAS)

Local Area Augmentation System (LAAS)
WAAS Architecture

Wide Area Augmentation System

2 Geostationary Satellite Links

3 Master Stations

4 Signal Generator System/ Ground Earth Stations

38 Reference Stations

2 Operational Control Centers

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WAAS Phases

- **Phase I: IOC (July 2003)**
  - Provided LNAV/VNAV/Limited LPV Capability
- **Phase II: Full LPV (2003 – 2008)**
  - Improved LPV availability in CONUS and Alaska
  - Consists of additional WRS, hardware updates, software optimization, improved human factors, and GEO replacement
- **Phase III: Full LPV-200 (Cat I Equivalent) Performance (2009 – 2013)**
  - Development, modifications, and enhancements to include tech refresh
  - Steady state operations and maintenance
- **Phase IV: Dual Frequency Operations (2013 – 2028)**
  - Originally scheduled for 2009
    - Delayed to align with DoD’s GPS Modernization Program (L5)
  - Will significantly improve availability and continuity during severe solar activity
  - Provide additional protection against unintentional GPS interference
  - Will continue to support single frequency users
  - Steady state operations and maintenance
GEO Satellite Improvements

- **IOC WAAS** (Commissioned system) utilized two Inmarsat satellites
  - Provided single satellite coverage over the majority of the U.S.
  - Relocated to the west by owner
    - Lost coverage in New England
  - Inmarsat satellites removed from operational WAAS July 2007

- **Two replacement satellites** launched in 2005, operational in July 2007
  - Intelsat (Galaxy XV)
  - Telesat Canada (Anik F1R)
New WAAS Procedures

• LPV-200’ Minimum
  – Minimum decision height of new LPV approaches lowered 250’ → 200’
  – First approach published in 2006
  – Will re-evaluate LPVs’ for lower decision height after flight inspection aircraft upgrade (2011)

• LP Approach
  – Flown like a Localizer approach
  – Can be developed at approaches that fail to meet LPV criteria due to obstacle clearance surface (OCS) penetrations (same TERPS for ILS)
  – Criteria development in formal coordination; Publication starting in 2008
  – Unlike an ILS, will have LPV or LP on approach chart, but not both.
  – If WAAS correction is lost, avionics defaults to LNAV procedure
• **Existing Procedures (as of 2/14/08 publication cycle):**
  - 4,411 GPS NPA (LNAV)
  - 1,251 LNAV/VNAV
  - 1028 LPVs (14 of which are below 250’

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**Approach Procedures**

- **GPS**
  - 400 – 600 ft MDA

- **GPS- Baro/ SBAS**
  - 350 – 400 ft DA

- **SBAS**
  - 200 – 300 ft DA

- **GBAS**
  - 200 – 0 ft

- **NPA**

- **LNAV/VNAV**

- **LPV**

- **GLS**

- **Cat II/III**

- **3°**

- **1 nm**

- **2 nm**

- **¾ nm**

- **¼ nm**
WAAS Avionics Status

• Total WAAS avionics receivers sold ~25,000
• Approximately 40% of est. 120,000 IFR equipped GA aircraft are equipped with Garmin receivers
  – New GNS-400/500 series WAAS equipped
  – Legacy GNS-400/500 series WAAS upgradable
  – G-1000 becoming WAAS upgradeable
• Flight Management System Interface more complicated, hence slower to the market
  – Rockwell-Collins: Providing both TSO WAAS enabled multimode receivers and WAAS FMS sensors. Expecting CRJ/Canadair 604 STC approval in FY’08
  – CMC: FAA Tech Center’s Global 5000 is contracted to integrate CMC WAAS sensor into Honeywell Primus 2000 FMS; expected in 2008. CMC WAAS sensor open architecture targets retro-fit aircraft
  – Universal Avionics: WAAS-enabled capability in dual thread UNS-1 FMS TSO. Supports: Helicopters, Turboprops, Business jets, regional aircraft, air transport aircraft retrofits, FAA’s two Citations XLs
  – Honeywell/Bendix King just announced their product line
WAAS Avionics Status (con’t)

• **Air Carrier & Cargo Aircraft**
  – **Southwest Airlines**
    • Equipping 200 Boeing 737 with Rockwell Collins' GPS-4000S for Required Navigational Performance (RNP) operations
  – **Federal Express (FEDEX)**
    • Equipped 253 Cessna Caravan Aircraft with Garmin GNS-530W WAAS avionics and GMX-200 multi-function displays
  – **Horizon Airlines**
    • Has begun to equip their Bombardier Q400 fleet for WAAS LPV capability

• **Helicopter Aircraft Implementing WAAS**
  – Sikorsky, Bell/Textron and Agusta all recently signed commitments to develop a WAAS STC for their Airframes
  – **Agusta**
    • Submitted their STC application to the New York ACO for implementation of Garmin GNS 480
  – **Sikorsky**
    • Working on Certification plan
    • Expected to submit to their ACO next week
  – **Bell/Textron**
    • Bell 429 expected to be certified in 2009
Expected RNP .3 Performance at the end of WAAS Phase II Development (Sept 2008)
Theoretical Coverage of RNP .3 with 13 South American Reference Stations
Instrument Flight Procedures Panel

• FAA adopted ICAO point-in-space (PinS) criteria
  – Pilot Information and Procedures Design

• March 2008
  – Coordinate Route departure criteria
  – Discuss the standardization of manuals between ICAO and FAA
  – Address further ICAO/FAA joint satellite based initiatives

- Doc 8168 Volume II proposals for PinS Route Departure criteria
- Doc 8168 Volume I proposals for PinS Route Departure criteria
- Standardization in Annex 4 and Charting manual of charting of PinS procedures
- Recognition of the Need for a Helicopter supplement to the ICAO Performance Based Navigation Manual
- Need for Navigation specification for reverse PinS Departure (consistent with Order 8260.42B Special Departure criteria)
- Reduction in existing Terminal Area Semi-widths to Meet Helicopter Reduced Flight Technical Error
Future Rotary Aircraft Actions

- Charting of Heliport Departure Procedures
- Special "En Route" Criteria with WAAS Equipage (Consistent with Appendix I to Order 8260.42B)
- LP PinS Procedure criteria
- LPV PinS Procedure criteria
LAAS

Antenna

GPS

Base Station Computes Differential Corrections, Provides Integrity Check & Provides Approach Coordinates

Transmitter Encoder

Broadcast Information

Differential Corrections, Integrity Status and Approach Coordinates

DATALINK

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LAAS Capabilities

• The Local Area Augmentation System (LAAS) Represents the U.S. Approach to the International Goal of an Interoperable GBAS Capability
• LAAS Provides a Navigation Signal That Supports the Most Demanding RNP Requirements
• LAAS is complementary to SBAS
• One LAAS Can Cover the Entire Terminal Area and Enables Precision Guidance
  – Precision approach for Category I, II, & III
  – Multiple runway coverage
  – Complex procedures Guided missed approaches and departure procedures
  – Aircraft surface navigation
Current Activities

- Integrity Analysis and Prototype Development
- GBAS Approval Process
- GBAS/LAAS Operational implementation
- International Cooperation
- CAT-III Research & Development Activities
GBAS Integrity

• Integrity Analysis and Prototype Development
  – FAA GBAS prototype work under Honeywell Contract
  – Hazardous Misleading Information (HMI) Analysis underway to validate GBAS architecture/design
  – **Responsibility for GBAS Integrity resides in the Ground Facility**
    • The user (aircraft) receives a set of integrity parameters from the LGF and applies those in a set of standardized equations to determine protection levels
    • The user must check the calculated result against the requirement
  – **The Service Provider is responsible for ensuring that the uplink integrity parameters are accurate and that they provide the required function**
    • When used in the specified equations, the protection level must always bound the user error
CAT II/III GBAS

- Requirements development underway in coordination with Boeing and FAA
  - Regular briefings to ICAO/NSP and RTCA/WG-4

- Target milestones
  - Draft MOPS and Non-fed Ground Facility (GF) specification September 2007
    - Ground rule: minimal changes to ground facility and transfer of some requirement responsibility to the aircraft
    - Develop requirements in line with current ILS auto-land criteria
  - Published MOPS and GF specification by Dec. 2008
  - SDA, airworthiness, and OPS approval to follow with close coordination to ensure success
LAAS Operational Implementation

- GBAS Implementation Activities in Memphis
  - Drafted GBAS Procedures for Memphis Airport (MEM)
  - Developed LAAS straight in procedures for all runway ends
  - Coordination with MEM Air Traffic Control
  - Developed GBAS Terminal Area Path (TAP) procedures
  - Developed new traffic flow concept based on GBAS terminal area capability
  - Performing flight test with FAA Technical Center Aircraft and FedEx B727 aircraft
LAAS International Efforts

Rio De Janeiro, Brazil
Agana, Guam
Malaga, Spain
Sydney, Australia
Frankfurt, Germany
Bremen, Germany
GBAS International Activities

• FAA Memorandum of Cooperation (MOC for GBAS) established with multiple countries
  – Australia, Brazil
  – Spain, Germany

• MOC
  – Scope
    • Engage in cooperative technical activities to support development and operational approval of GBAS capable of providing Category I approach services.
      – Technical Interchange of Local Area Augmentation System (LAAS) Data
      – Access to LAAS Information.
      – Type Acceptance and Commissioning Information.
      – Test and Evaluation Support.
Summary

• The U.S. is transitioning to a performance based CNS/ATM system

• GNSS is one of the cornerstones of NextGen

• RNAV/RNP is being implemented throughout the U.S. National Airspace

• SBAS (WAAS) will complete LPV development in September 2008

• GBAS (LAAS) will complete Cat-I development in December 2008

• The United States will continue its multilateral and bilateral efforts
Questions