Wide Area Augmentation System (WAAS) Status and History

By: Deane Bunce, WAAS Program Manager

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Agenda

- WAAS Status and History
- User Adoption
- Future Efforts
Wide Area Augmentation System

• WAAS is a combination of ground based and space based systems that augments the GPS Standard Positioning Service (SPS)

• WAAS provides the capability for increased availability and accuracy in position reporting, allowing more time for uniform and high quality worldwide air traffic management

• WAAS provides coverage over the entire National Airspace, with a precision approach capability at over 3,000 runway ends
GPS and WAAS Core Systems

GPS
- Approved for Aviation use in 1993
- Established as global leader and gold standard for satellite navigation
- Extensive modernization efforts underway that will make available additional civil signals (L1C, L2C, L5)

WAAS
- Commissioned for service in 2003
- Provided lessons learned in support of development of foreign SBAS in Japan, Europe and India
- Currently augments the GPS L1 signal providing improved accuracy and integrity
- WAAS modernization efforts tied directly to GPS modernization
WAAS Coverage Improvements

2003 IOC – LPV Coverage in lower 48 states only

2008 Coverage - Full LPV 200 Coverage in CONUS (2 Satellites)

2014 Coverage - Full LPV 200 Coverage in CONUS (3 Satellites)
WAAS Development Phases

• **Phase I: IOC (July 2003) Completed**
  – Included Development of a robust safety architecture
  – Included establishment of WAAS expert panel to evaluate potential integrity threats

  – Completed a Safety Risk Management Decision (SRMD) to support LPV-200 (VAL of 35m)
  – Expanded WAAS coverage to Mexico and Canada while modifying the System to address observed ionospheric threats

• **Phase III: Full LPV-200 Performance (2009 – 2013)**
  – Completed System updates to improve performance during moderate ionospheric activity
  – Supported continuous monitoring of system data that contributes to continued integrity assurance
  – Began transition of Second Level Engineering from contractor based to organic FAA capability

• **Phase IV: Dual Frequency (L1,L5) Operations (2014 – 2044)**
  – Includes the transition from use of L2 to L5 in WAAS reference stations
  – Infrastructure modifications to support future L1/L5 user capability
  – Support sustainment of WAAS GEOs
GEO Satellite Availability Improvements

- IOC WAAS (Commissioned system) utilized two Inmarsat satellites
  - Provided single satellite coverage over the majority of the U.S.
  - Removed from WAAS July 2007
- Replacement satellites launched in 2005
  - Intelsat (Galaxy XV) - Operational November 2006
  - Telesat Canada (Anik F1R) - Operational July 2007
- Implemented Gap-filler GEO
  - Inmarsat I4F3 (AMR) - Operational December 2010
Derived Requirement for a 3 GEO System

- WAAS receiver is required to track two GEOs if available...if one GEO is lost, then the other is used seamlessly with no loss in continuity
- Continuity requirement is met as long as we have two GEOs in service...if we have only one GEO then the continuity is not met
- Individual satellite availability averages 96% based on historical data
  - GEO takes 4-5 years minimum to replace
- GEO constellation:
  - Availability of continuity (1 GEO) = zero
  - Availability of continuity (2 GEOs) = 96%
  - Availability of continuity (3 GEOs) = 99.98%
- GEO constellation is only one source of loss of continuity
  - Availability allocation to GEOs must be significantly >99%
- WAAS continuity is a key service parameter enabling the capability to reduce ground-based NAVAID infrastructure identified in the FAA Navigation Evolution Plan

- It takes 4-5 years to replace a GEO
- In a two GEO system if the remaining GEO fails, then we have a catastrophic loss of all service
GEO Sustainment

- **GEO 5/6 Satellite Acquisition**
  - Awarded GEO 5/6 Satellite Service Lease contract to Raytheon September 2012
  - SatMex 9 satellite will host the WAAS GEO Satellite Payload
    - Orbital slot (117°W) will provide full coverage over CONUS and Alaska
    - Critical Design Review (CDR) completed July 2014
    - Scheduled for operations in the 2017 timeframe
  - GEO 6 Satellite opportunities currently under investigation
• User Adoption - Build it and they will come…
WAAS Overview

September 2014

WAAS Procedures

• IOC Commissioning July 2003
  – LNAV/VNAV
  – 350’ / 1½

• LPV - 250’ Minimums
  – 1st LPV September 2003

• LPV - 200’ Minimum
  – Minimum decision height of new LPV approaches lowered 250’ → 200’DA in March 2006
  – 1st LPV-200 January 2008
  – Re-evaluating LPVs’ for lower decision height

• LP Approach
  – 1st LP March 2011
  – 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)
  – Unlike an ILS, will have LPV or LP on approach chart, but not both
  – If WAAS correction is lost, avionics defaults to LNAV procedure
Annual LPV and LP Production

<table>
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<th>Year</th>
<th>FY03</th>
<th>FY04</th>
<th>FY05</th>
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</table>
Airports with WAAS LPV/LP Instrument Approaches

As of August 21st, 2014
- 3,985 LP/LPVs combined
- 3,429 LPVs serving 1,690 Airports
- 867 LPV-200’s
- 2,310 LPVs to Non-ILS Runways
- 1,119 LPVs to ILS runways
- 1,568 LPVs to Non-ILS Airports
- 556 LPs serving 404 Airports
- 554 LPs to Non-ILS Runway
- 2 LPs to ILS Runways
WAAS LPV Annual Avionics Sales

Garmin, Universal, Rockwell Collins, Avidyne, Cobham, Honeywell/CMC, IS&S, and Thales WAAS Avionics Sales by Year

Data current as of August 6, 2014
Total combined avionics sales (all vendors): 105,859 units
Program office estimate for total WAAS-LPV equipped aircraft: 76,115 (all vendors)
WAAS Overview
September 2014

WAAS LPV Equipped Aircraft August 2014

Garmin
- GA Aircraft (See FAA Garmin Approved Model List (AML)). Most GA Part 23 aircraft.

Universal Avionics
- 122 fixed wing and 12 helicopter types and models

Rockwell Collins
- 37 Types and models

Honeywell /CMC Electronics)
- 22 types and models

Avidyne
- 6 types and models (Cirrus SR 20 & 22, Piper Matrix & Mirage, Piper Saratoga NX, and EA-500)
- IFD 540 WAAS LPV - (STC complete July 2014 – AML STC approved for over 1,000 aircraft makes and models)

Genesys Aerosystems (Chelton)

Innovative Solutions & Support (IS&S)
- Eclipse 550/500
- Boeing 737-400 (pending)
- MD-88/90 (pending)

Thales
- Airbus A300-600ST (Beluga)
- Airbus A400M (Military)
- Airbus A350XWB - pending
Transition to Performance Based Navigation

• In September 2008 the number of published LPVs surpassed the number of published ILSs
• As of August 2014 the number of published LPVs are more than twice the number of published ILSs
• In 2013 the FAA policy was to no longer publish any new CAT I ILSs
• In 2016 the FAA has committed to begin efforts towards a draw down of ILS based on WAAS implementation
WAAS – A Multi User System

- WAAS has become a relied upon utility for a number of non-aviation uses:
  - Shipping
    - Navigation of Harbors
  - Recreational Boating
    - Navigation of Channels
    - Location of Crab pots
  - Mapping & Survey
    - Precise location identification
  - Farming
    - Sub-meter accuracy for spreading, seeding and harvesting
• Future Efforts
Next Steps

• Dual Frequency (DF)
  – Award a Dual Frequency Contract
  – Development of DF WAAS MOPS capability
  – Maintain legacy Single Frequency availability

• Ground based infrastructure upgrade
  – Safety Computer
  – G-III Receivers
  – Terrestrial Comm upgrade

• Develop Dual Frequency User concepts
  – ARAIM
    • Offline vs Online
  – Dual Frequency Multi-Constellation (DFMC) SBAS
    • Beginning initial research and development
  – Validate concepts and propose standards
Future Applications

• WAAS is an enabler for multiple FAA initiatives
  – Performance-Based Navigation (Area Navigation) (RNAV)
  – Required Navigation Performance (RNP)
    • WAAS meets the requirement for RNP AR as defined in FAA Advisory Circular 90-101A
    • No restriction due to temperature
  – Point in Space (PinS) procedures
  – Automatic Dependent Surveillance Broadcast (ADS-B)
    • WAAS is currently the only technology that meets all of the most stringent requirements for a positioning source for ADS-B
## GNSS Enables Performance Based Navigation

<table>
<thead>
<tr>
<th></th>
<th>Navigation (≥ 99.0% Availability)</th>
<th>Surveillance (≥99.9% Availability)</th>
<th>Positioning</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Accuracy (95%)</td>
<td>Containment (10⁻⁷)</td>
<td>Separation</td>
</tr>
<tr>
<td>En Route</td>
<td>*10 nm</td>
<td>20 nm</td>
<td>5 nm</td>
</tr>
<tr>
<td></td>
<td>*4 nm</td>
<td>8 nm</td>
<td>2.5 nm DPA</td>
</tr>
<tr>
<td></td>
<td>*2 nm</td>
<td>4 nm</td>
<td>2.5 nm DPA</td>
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<tr>
<td>Terminal</td>
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<td>3 nm</td>
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<td>0.6 nm</td>
<td>3 nm</td>
</tr>
<tr>
<td>RNP (AR)</td>
<td>*0.1 nm</td>
<td>**0.1 nm</td>
<td>2.5 nm DPA</td>
</tr>
<tr>
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<td>40m/50m</td>
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<tr>
<td>LPV-200</td>
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<td>16m/4m</td>
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<tr>
<td>GLS Cat-III</td>
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<td>40m/10m</td>
<td>2.0 nm IPA</td>
</tr>
</tbody>
</table>

* Operational requirements are defined for total system accuracy, which is dominated by flight technical error. Position accuracy for these operations is negligible.

** Containment for RNP AR is specified as a total system requirement; value representative of current approvals.

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**Dependent Parallel Approach (DPA)**

**Independent Parallel Approach (IPA)**

**Surveillance Integrity Level (SIL)**

**Navigation Integrity Category (NIC)**

**Navigation Accuracy Category for Position (NACp)**
User Adoption Outreach Projects

• Delta MD88/90 – establish GIP to provide a demonstration project using Delta aircraft operating in the NY Metro area utilizing WAAS capability
• Gulfstream – demonstrate the effectiveness of guided visual departures, approaches at New York area airports and also validate oceanic track offsets inbound to the New York Metroplex;
• Maryland State Police Emergency Medical Services (EMS) - demonstrate how WAAS approaches permit EMS to operate during poor weather conditions and accomplish the FAA Mandate for Helicopter Safety
• Hudson River Corridor Project - demonstrate helicopters on flyable legs to RNP. 0.3 values.
• Porter Air - demonstrate de-coupling traffic at Newark for arrival/departure flow efficiency and demonstrating WAAS LPV procedures w/RF leg
• FAA/Insitu/ConocoPhillips Arctic Region UAS Project - Demonstrate the safe operation of small Unmanned Aircraft Systems (sUAS) beyond line of sight below 2000 feet above sea level per the FAA Reauthorization Act of 2012 through the integration of GPS/WAAS avionics
Future LPV-200 Coverage (Dual Frequency GPS)

WAAS
EGNOS
MSAS
Summary

• WAAS-provided messages improve the accuracy, availability and safety of GPS-derived position information
• WAAS results in safety and capacity improvements in the National Airspace System (NAS)
• WAAS will reduce FAA operations costs by enabling the decommissioning of some ground-based navigation aids
  – All new CAT I Approaches in the NAS shall be WAAS LPV Approaches
  – FAA committed to making a decision on the reduction of CAT I ILS in 2016
• WAAS provides a cost-effective means of integrating a precision approach capability into the cockpit
• Nearly 4,000 WAAS procedures are available with half published at runways that previously had no precision approach capability
• Continued support of International expansion of SBAS and adoption of future standards
Questions?