FAA WAAS Update

Presented by: Deborah Lawrence, FAA Manager of Navigation Programs

Presented to: Munich Satellite Navigation Summit

Date: March 2015
Topics

• WAAS Program Status
• WAAS Performance
• User Segment Update
Wide Area Augmentation System

- 38 Reference Stations
- 3 Master Stations
- 6 Ground Earth Stations
- 3 Geostationary Satellite Links
- 2 Operational Control Centers
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
### WAAS Phase IV Ground Segment Development

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March 2015
WAAS Phase IV Dual Frequency Operations

- Original WAAS plan was to enter DF phase in 2014 with a completion date by 2019
  - New dual frequency L1/L5 service needed to further improve WAAS availability and continuity
- Due to the changes to the GPS L5 launch schedule, the WAAS Program Office reassessed its DF integration schedule, dividing it into two segments
  - Segment 1 (5-7 year effort)
    - Develop infrastructure improvements to enable use of L5
    - G-III Reference Receiver Integration, Communications Infrastructure Upgrade, Safety Computer Integration
    - The Federal Aviation Administration awarded the Wide Area Augmentation System (WAAS) Dual Frequency Operations (DFO) Segment 1 contract to Raytheon Company on September 26, 2014
  - Segment 2 (5-7 year effort)
    - Implementation of L1/L5 user capability (follows L5 FOC)
      - Algorithm updates to use L5 and implement dual frequency service
      - Dual Frequency Messaging
- Program re-baseline approved by FAA’s Joint Resource Council (JRC), May 2014
- ‘Sunset’ of L2 P(Y) compels WAAS to use another signal to maintain current service
  - Change required independent of decision on whether to implement a dual frequency service
- GEO sustainment planned for rest of WAAS service life
  - Maintain minimum of dual coverage over WAAS service area
  - GEO Sustainment currently planned until 2044
Federal Register Notice

• L1/L2 Sunset
  – FAA interest to maintain semi-codeless technique for two years following 24 L5 satellites on orbit to provide transition time
  – Will review 2014 FRP language
GEO Activities

• Current WAAS GEO satellites
  – Intelsat Galaxy XV (CRW)
  – Anik F1R (CRE)
  – Inmarsat I4F3 (AMR) *

* - AMR is a non-ranging satellite

• GEO 5/6 Acquisition
  – Contract awarded September 2012
  – Eutelsat 117 West B (Satmex-9) satellite will host the WAAS GEO 5 Satellite Payload
    • Orbital slot (116.8º West) will provide full coverage
    • Scheduled for operations by Oct 2017
  – GEO 6 Satellite opportunities currently under investigation
G-III Comm Integration

- **Test Bed Operational**
  - Shadow system became operational December 9, 2014
  - To be completed by May 2015

- **G-III Software Integration Completed March 2015**

- **Cutover of Network 1 and Network 2 CORE Comm**
  - Scheduled to be completed August, 2015

- **Cutover of First WRS site (ZLA) projected operational September 2015**
  - All WRS sites cutover by July 2016
WAAS Phase IV Investigations

- **Dual-Frequency Multi-constellation Capability**
  - International Focus is on taking advantage of other GPS like constellations
    - International Civil Aviation Organization (ICAO) Navigation Systems Panel (NSP) has developed work plan that supports development of future standards for use of other Global Navigation Satellite Systems (GNSS)
  - User Equipment Standards for Dual-Frequency Operations
    - Minimum Operation Performance Standards (MOPS) for Dual-frequency GPS currently looking to obtain stakeholder involvement
    - FAA working with Interoperability Working Group (IWG) on definition document that provides the basis for interface design and MOPS development for L1/L5 and multi-constellation
    - RTCA is amending SC-159 Terms of Reference (ToR) to include MOPS work on GPS/GLONASS, GPS/SBAS DF and enabling Multi-Constellation (MC), GPS/GBAS DF

- **Advanced RAIM (ARAIM)**
  - Avionics-centric approach to dual-frequency multi-constellation
  - US/EU technical group finalizing concept definition the 3rd Milestone of their work plan
    - Milestone 3 will address stakeholder input to the concept and proposed architecture alternatives
    - It will also include a road map outlining a path toward requirements development, validation and implementation inline with current industry avionics development plans
Federal Aviation Administration

March 2015

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2003 IOC – LPV Coverage in lower 48 states only

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

2013 Coverage - Full LPV 200 Coverage in CONUS (3 Satellites)

WAAS LPV Coverage Contours
01/08/14
Week 1774 Day 3

Percent | CONUS | Alaska | Canada
--------|--------|--------|--------
95      | 100.00%| 98.99% | 98.00%
98      | 100.00%| 98.80% | 98.30%
99      | 100.00%| 97.66% | 91.15%
99.9    | 100.00%| 97.34% | 86.02%
100     | 100.00%| 97.34% | 85.02%

WAAS LPV Coverage Contours
99-08-2003
Week 1274 Day 4

WAAS LPV Coverage Contours
04-27-2008
Week 1476 Day 2

WAAS FAA Technical Center
WAAS Test Team
Airports with WAAS LPV/LP Instrument Approaches

As of Feb 5th, 2015
- 4,109 LP/LPVs combined
- 3,523 LPVs serving 1,731 Airports
- 908 LPV-200’s
- 2,385 LPVs to Non-ILS Runways
- 1,138 LPVs to ILS runways
- 1,630 LPVs to Non-ILS Airports
- 586 LPs serving 426 Airports
- 583 LPs to Non-ILS Runway
- 3 LPs to ILS Runways
Garmin – 73,184 aircraft
- GA Aircraft (See FAA Garmin Approved Model List (AML)). Most GA Part 23 aircraft.

Universal Avionics – 2,380 aircraft
- 122 fixed wing and 12 helicopter types and models

RockwellCollins – 1,930 aircraft
- 39 Types and models
- Latest Aircraft – Embraer Legacy 500

Honeywell /CMC Electronics) – 921 aircraft
- 22 types and models

Avidyne – 238 aircraft
- 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) – 247 aircraft

Innovative Solutions & Support (IS&S) – 200 aircraft
- Eclipse 550/500
- Boeing 737-400 (pending)

Thales – 5 aircraft
- Airbus A300-600ST (Beluga)
- Airbus A400M (Military)
- Airbus A350XWB - pending

TOTAL Estimated WAAS LPV Equipped Aircraft – 79,105
Questions
## GNSS Enables PBN and ADS-B

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* 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.

** Dependent Parallel Approach (DPA) ** Independent Parallel Approach (IPA) ** Surveillance Integrity Level (SIL) ** Navigation Integrity Category (NIC) ** Navigation Accuracy Category for Position (NACp)
G-III Capabilities

• **Satellite Tracking**
  – 18 GPS, 8 SBAS
  – Upgradable for Galileo, COMPASS…with additional cards

• **Signal Tracking**
  – L1 C/A, L1C, L2P(Y), L2C and L5
    • L1C; track pilot, L1C for data demodulation
    • L2C; track CL, CM for data demodulation
    • L5; track Q5, I5 for data demodulation
    • L5 SBAS; configurable with default as track/demodulate with I5
  – Non-standard codes
    • Loaded via data interface at startup
    • L1 C/A, L1C, L2CM and L5 loaded as memory codes
    • L2CL loaded as shift register value (same polynomial)
Live Satellite Tracking (L1 C/A, L2PY, L2C & L5)
Message Type 12 Overview (MT12)

- Message Type 12 (MT12) is an optional function standardized in Annex 10 (App. B, Section 3.5.7.6.1)
  - It is defined to carry UTC timing parameters
- Alternate Position Navigation and Timing (APNT) program considering MT 12 as a potential timing reference in absence of GPS signal
  - WAAS could populate MT-12 with the GPS–UTC offset parameters with simple modification to the system
  - WAAS Network Time (WNT) offset from GPS time is well within 50 ns limit defined by Annex 10 (Ch. 3, Section 3.7.3.4.5)
- Timing reference accuracy for APNT user anticipated to be within 25 ns once implemented (to be validated)
  - Proposal to use beam forming techniques to maintain tracking of GEO signals during interference conditions
SBAS Network Time / UTC Message (MT-12)

- 8 parameters identical to GPS
- 4 for leap second
  - Converts GPS time to UTC
  - (15 sec, 16 sec on 1 July)
- 4 to correct bias and drift
  - Small, correction ~ 10 nsec
- WAAS MT-12 has additional information
  - GPS Time of Week (sec)
  - GPS Week Number (WN)
  - UTC Standard Identifier (ie USNO)
  - GLONASS indicator (whether data will be provided)
  - GLONASS offset data (optional)

\[
\begin{align*}
\text{dt}_{\text{utc}} &= \text{dt}_{\text{LS}} + A_0 + A_1 \times (t_{\text{GPS}} - t_{\text{OT}} + 604800 \times (\text{WN} - \text{WN}_t)) \\
\text{t}_{\text{UTC}} &= t_{\text{GPS}} - \text{dt}_{\text{UTC}} \quad \text{*two's complement, sign bit MSB}
\end{align*}
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### Subframe 4, Page 18

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Questions