GBAS FOR ATCO

June 2017
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CONTENT

- Review the Basis of GNSS
- GBAS Operational Overview
- Advantages of GBAS
- Info for ATCO
- Q&A
Time Difference

The GPS receiver compares the time a signal was transmitted by a satellite with the time it was received. The time difference tells the GPS receiver how far away the satellite is.
BASIS OF GNSS - 2

Velocity x Time = Distance

Radio waves travel at the speed of light, roughly 186,000 miles per second (mps)
ATOMIC CLOCKS

GPS satellites use Atomic Clocks for accuracy, but because of the expense, most GPS receivers do not.

Solution: GPS software uses a fourth satellite to provide a cross check in the trilateration process and update the internal clock simultaneously.
Satellite navigation system or satellite constellation support GNSS

GPS (United States): GPS was the first GNSS system. GPS was launched in the late 1970s by the United States Department of Defense. As of Feb., 2016 there are 32 satellites in the GPS constellation.

GLONASS (Russia): GLONASS is operated by the Russian government. The GLONASS constellation is officially completed in 2015 (since 1996) which consists of 24 satellites and provides global coverage.

Galileo (European Union): Galileo is a civil GNSS system operated by the European Global Navigation Satellite Systems Agency (GSA). As of December 2016 the system has 18 of 30 satellites in orbit. Galileo started offering Early Operational Capability (EOC) on 15 December 2016 and is expected to reach Full Operational Capability (FOC) in 2019. The complete 30-satellite Galileo system (24 operational and 6 active spares) is expected by 2020.

BeiDou (China): BeiDou is the Chinese navigation satellite system. The system will consist of 35 satellites. A regional service became operational in December of 2012. As of 2016, 23 satellites were launched. BeiDou is expected to provide global coverage by end of 2020.
BASIS OF GNSS – 4

GNSS ERROR SOURCES

Image courtesy of www.novatel.com
## GNSS ERROR SOURCES

<table>
<thead>
<tr>
<th>Contributing Source</th>
<th>Error Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite Clocks</td>
<td>±2 m</td>
</tr>
<tr>
<td>Orbit Errors</td>
<td>±2.5 m</td>
</tr>
<tr>
<td>Inospheric Delays</td>
<td>±5 m</td>
</tr>
<tr>
<td>Tropospheric Delays</td>
<td>±0.5 m</td>
</tr>
<tr>
<td>Receiver Noise</td>
<td>±0.3 m</td>
</tr>
<tr>
<td>Multipath</td>
<td>±1 m</td>
</tr>
</tbody>
</table>

Data courtesy of www.novatel.com
Satellite Based Augmentation Systems (SBAS)
FAA-Wide Area Augmentation System (WAAS); EASA-European Geostationary Navigation Overlay Service (EGNOS); JCAB-MTSAT Satellite Based Augmentation Navigation System (MSAS); India-GPS-Aided GEO Augmented Navigation System (GAGAN); Russia-System for Differential Corrections and Monitoring (SDCM); China-SNAS (Satellite Navigation Augmentation System)

Ground Based Augmentation Systems (GBAS)
FAA-Local Area Augmentation System (LAAS); ICAO-GBAS Landing System (GLS)
# RESOLVING THE PROBLEM

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</tbody>
</table>

## Typical error budget (in metres)

<table>
<thead>
<tr>
<th></th>
<th>Standard GPS</th>
<th>Differential GPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Satellite clocks</td>
<td>1.5</td>
<td>0</td>
</tr>
<tr>
<td>Orbit errors</td>
<td>2.5</td>
<td>0</td>
</tr>
<tr>
<td>Ionosphere</td>
<td>5.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Troposphere</td>
<td>0.5</td>
<td>0.2</td>
</tr>
<tr>
<td>Selective availability*</td>
<td>30.0</td>
<td>0</td>
</tr>
<tr>
<td>Receiver noise</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>Multi-path (reflections)</td>
<td>0.6</td>
<td>0.6</td>
</tr>
</tbody>
</table>

### Typical positioning accuracy

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<thead>
<tr>
<th></th>
<th>Standard GPS</th>
<th>Differential GPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>50.0</td>
<td>1.3</td>
</tr>
<tr>
<td>Vertical</td>
<td>78.0</td>
<td>2.0</td>
</tr>
<tr>
<td>3D</td>
<td>93.0</td>
<td>2.8</td>
</tr>
</tbody>
</table>

*Note: Selective Availability error is shown to demonstrate the effectiveness of the DGPS technique, although the Selective Availability restriction has now been removed.*

Data courtesy of www.novatel.com
GBAS - OPERATIONAL OVERVIEW
LAND SECTION

Ground Facilities:
- GPS Reference Receivers (RR)
- Very High Frequency (VHF) Data Broadcast (VDB) Transmitter
- Equipment Room
- ATC Status Display

Image courtesy of Honeywell
GBAS - OPERATIONAL OVERVIEW
ONBOARD EQUIPMENT SECTION

Aircraft

Cockpit Displays

Pilot Interface

MMR

GPS Antenna

Datalink – VHF Data Broadcast (VDB)

Antenna

Differential Corrections, Integrity Status and Approach Coordinates

DGPS

Computes Differential Corrections
Provides Integrity Check
Provides Approach Coordinates

DATAVLINK – VHF Data Broadcast (VDB)

Local Ground Facility

Transmitter

Encoder

Receiver

Decoder

Data Broadcast Monitor

Aircraft Surfaces

GBAS – Operational Overview

Aircraft Surfaces

Aircraft Surfaces

737NG – GLS forward fit, retrofit
787 – GLS basic
747-8 – GLS basic

A-380 – GLS Option
A-320 – GLS option
A-340 – GLS option
A-330 – GLS option
A-350 – GLS Basic

GPS error corrections, integrity, AND path points

Image courtesy of Honeywell
• ILS look a like
  - Glideslope
  - Localizer

Image courtesy of Honeywell
GBAS - OPERATIONAL OVERVIEW
ONBOARD EQUIPMENT SECTION

- ILS look-alike architecture
- Similar guidance mode and flight control laws

Diagram showing the integration of GNSS signals, MMR, FMC, FCU, FCDC, and CDS with ILS look-alike architecture.
Introduction

Airbus xLS concept

- ILS look-alike HMI
  - Similar displays whatever the modes
ADVANTAGES OF GBAS - GENERAL

- **Increased airport capacity**: GBAS unlocks capacity constraints
  - Offers precision approach where ILS cannot due to geography
  - Relatively more flexible design criteria on approach and potentially for departure
  - Eliminates ILS sensitive/ critical area

- **Lower life-cycle cost**: GBAS is more cost efficient than ILS
  - For multiple runway, One GBAS system serves all runway ends, initial acquisition cost is lower
  - **Lower maintenance cost**
  - Lower flight inspection cost

- **Safety**: GBAS improves safety
  - Offers precision approach where ILS cannot due to geography
  - Signal stability (immune to signal interference inherent in ILS)

- **Reduced noise/shorter routes**: Variable glide slopes, RNAV/RNP to GLS finals
  - Airlines benefit: fuel and emission savings, increased schedule flexibility, avoid noise violations
  - Airports benefit: increased capacity and schedule flexibility, improved community relations
ADVANTAGES OF GBAS - ATC

GBAS: Programmable Touchdown Points and Path
- ILS: single defined vertical path, same touchdown point on runway
- SmartPath GBAS: multiple touchdown points and glide slope combinations

GBAS Offset Approaches

RNP + GBAS GLS: Enabling Maximum Efficiency

Multiple Concurrent Operations

ILS Clear Zones

Image courtesy of Honeywell
## INFO FOR ATCO-OTHER ISSUES

### GBAS: Programmable Touchdown Points and Path
- ILS: single defined vertical path, same touchdown point on runway
- SmartPath GBAS: multiple touchdown points and glide slope combinations

### GBAS Offset Approaches
- 3.2 degree Glide-slope
- 2.5 degree Glide-slope

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### INFO FOR ATCO-OTHER ISSUES

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<thead>
<tr>
<th>Issue</th>
</tr>
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<tbody>
<tr>
<td>Wake?</td>
</tr>
<tr>
<td>RWY Marking?</td>
</tr>
<tr>
<td>Lighting?</td>
</tr>
<tr>
<td>Spacing? Integration?</td>
</tr>
<tr>
<td>PAPI?</td>
</tr>
<tr>
<td>GBAS 3.2° vs ILS 3° spacing?</td>
</tr>
<tr>
<td>Service Volume?</td>
</tr>
<tr>
<td>GBAS VDB vs other NAVAIDs VHF?</td>
</tr>
<tr>
<td>Offset for Noise?</td>
</tr>
<tr>
<td>Spacing reduction? How much?</td>
</tr>
</tbody>
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### Multiple Concurrent Operations

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### ILS Clear Zones

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### RNP + GBAS GLS: Enabling Maximum Efficiency

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### GBAS: Programmable Touchdown Points and Path
THANK YOU!