Boeing GBAS and SBAS Overview

June 3-5, 2019 ICAO GBAS and SBAS Workshop

Bill Peterson
Topics to be covered

Boeing GLS/GBAS Overview

RNP to GLS Demonstration

Boeing LPV/SBAS Overview
Evolution of Global Navigation Satellite Systems (GNSS)

- **1930 to 1940**: Non-Directional Beacon (NDB)
- **1950s**: VHF omnidirectional range (VOR)
- **1990s**: Required Navigation Performance (RNP)
- **2010s**: Global Navigation Satellite Landing Systems (GLS)
- **2020s**: Next Generation GNSS Localizer Performance with Vertical Guidance (LPV)
GLS enhances safety, economics and provides positive environmental impacts

Boeing is supporting GBAS CAT III (GAST D) system design approval and certification efforts

GLS demonstrations drive growth in airport deployment and fleet
Boeing GLS Program

- 737NG GLS CAT I
- 747-8 & 787 GLS CAT I/II
- 737MAX GLS CAT I/II/III
- 777X GLS CAT I/II/III
737NG-700/800/900

Airplanes with GLS activated

20% In-Service Fleet with GLS
747-8

GLS CAT I/II Standard 140 Airplanes & Counting 100% In-Service Fleet
787-8/9/10

GLS CAT I/II
Standard

820
Airplanes & Counting

100%
In-Service Fleet
737MAX-7/8/9

GLS CAT I/II Option

250 Airplanes & Counting

90% In-Service Fleet

* GLS CAT III planned 20/21
GLS CAT I/II/III
CAT I/II Standard, CAT III Option
344 Airplanes on Order
Topics to be covered

Boeing GLS/GBAS Overview

RNP to GLS Demonstration

Boeing LPV/SBAS Overview
RNP to GLS Curved Approaches
San Francisco RNP to GLS Demonstration

Airlines, Boeing, Airport and ATC collaboratively designed procedures
San Francisco Geography
Operational Constraints at SFO

19R 19L
NO ILS ILS
Aircraft hangar

28R 28L
ILS ILS

10L 10R
NO ILS
San Bruno Mountain

1L 1R
NO ILS
San Francisco Geography
New Efficient Procedures to 28L and 28R

Automate ‘S’ turns manually flown today

Maintain continuous descent path to the runway

Increase vertical separation between aircraft streams using displaced threshold (2000 ft) and higher glideslope (3.25°)
Optimized Vertical Profiles

- **Continuous Descent at 30-35% Throttle**

- **GLS V RWY 28R (3.25°)**
  - 4000 ft Level Off
  - Power Up to 70% Throttle

- **ILS RWY 28L (2.85°)**
  - 1900 ft Level Off
  - Power Up to 70% Throttle

**Distance to Threshold, nmi**

**Altitude, ft**
New Efficient Procedures to 19R

First precision approach to 19R

De-conflict approach with Oakland airspace

Continuous descent reduces noise and emissions instead of a long, straight-in final
Benefits of New Efficient Procedures to 19R

<table>
<thead>
<tr>
<th>Noise Level (dBA)</th>
<th>FLIGHT TRACK</th>
<th>FUEL BURN</th>
<th>CARBON EMISSIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>55</td>
<td>36.3 nm</td>
<td>792 lb / 360 kg</td>
<td>2499 lb / 1136 kg</td>
</tr>
<tr>
<td>60</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>65</td>
<td></td>
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<tr>
<td>70</td>
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<td>80</td>
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<td></td>
</tr>
<tr>
<td>85</td>
<td></td>
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</tbody>
</table>

**Typical Short Vector Route**
Estimated Population: 329,600 to 55dBA

**SFO GLS R RWY 19R**
Estimated Population: 47,300 to 55dBA

↓60% Reduction in Fuel Burn & Emissions
↓86 Reduction in Community Noise Exposure
Topics to be covered

Boeing GLS/GBAS Overview

RNP to GLS Demonstration

Boeing LPV/SBAS Overview
# Operational Comparison

<table>
<thead>
<tr>
<th>Approach Capability</th>
<th>RNP + Baro-VNAV</th>
<th>SBAS (LPV)</th>
<th>GBAS (GLS)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Category I (to 250’ DA)</td>
<td>Supported with low RNP</td>
<td>Supported</td>
<td>Supported</td>
</tr>
<tr>
<td>Category I (to 200’ DA)</td>
<td>N/A</td>
<td>LPV 200</td>
<td>Certified with autoland</td>
</tr>
<tr>
<td>Category II (to 100’ DH)</td>
<td>N/A</td>
<td>TBD</td>
<td>By 2019</td>
</tr>
<tr>
<td>Category III (Autoland)</td>
<td>N/A</td>
<td>N/A</td>
<td>By 2021</td>
</tr>
</tbody>
</table>
SBAS on Air Transport Class Airplanes

Basic SBAS
- 2-D positioning
- Improved support for RNP operations
- Supports ADS-B

SBAS Approach
- 3-D positioning
- Supports LPV approaches
- Integrated as xLS
# Regional GNSS Mandates

<table>
<thead>
<tr>
<th>Region</th>
<th>GNSS Receiver</th>
<th>Date</th>
<th>Aircraft Applicability</th>
</tr>
</thead>
<tbody>
<tr>
<td>India</td>
<td>SBAS/GAGAN</td>
<td>2019</td>
<td>India Registered</td>
</tr>
<tr>
<td>United States</td>
<td>No Mandate*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Europe</td>
<td>No Mandate</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Australia</td>
<td>SA-Aware</td>
<td>Dec 2016</td>
<td>Airspace</td>
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<tr>
<td>China</td>
<td>SA-Aware</td>
<td>Dec 2022</td>
<td>China Registered</td>
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<tr>
<td>Russia</td>
<td>GLONASS</td>
<td>2017</td>
<td>Airspace</td>
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<tr>
<td>Canada</td>
<td>No Mandate</td>
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* Exemption from US ADS-B Out pre-dispatch performance check for SBAS (WAAS) and FAA authorized ABAS
FAA ADS-B Out Mandate

Permanent exemption for SBAS

Permanent exemption for FAA authorized Hybrid GNSS/Inertial

FAA Exemption 12555 for SA-Aware

- Exemption from 1 Jan 2020 to 1 Jan 2025
- Exemption request deadline was 1 Aug 2018

No exemptions for SA-On
# Boeing Basic SBAS Implementation

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<thead>
<tr>
<th>Airplane Model</th>
<th>Honeywell (iMMR)</th>
<th>Rockwell (GLU 2100)</th>
</tr>
</thead>
<tbody>
<tr>
<td>737MAX</td>
<td>Available</td>
<td>Available</td>
</tr>
<tr>
<td>737NG</td>
<td>Available</td>
<td>2019</td>
</tr>
<tr>
<td>777</td>
<td>2019</td>
<td>Available</td>
</tr>
<tr>
<td>777X</td>
<td>2020</td>
<td>2020</td>
</tr>
<tr>
<td>747-8</td>
<td>Not Planned</td>
<td>2019</td>
</tr>
<tr>
<td>767</td>
<td>Not Planned</td>
<td>Not Planned</td>
</tr>
<tr>
<td>787</td>
<td>Current Study</td>
<td>Not Planned</td>
</tr>
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# Boeing SBAS Approach Implementation

<table>
<thead>
<tr>
<th>Airplane Model</th>
<th>SBAS Approach (LPV)</th>
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<tbody>
<tr>
<td>737MAX</td>
<td>Current Study</td>
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<tr>
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Over 3,000 Boeing GLS airplanes

72% of new airplane deliveries have GLS

GLS CAT III in 2020

Demonstrated benefits

SBAS receivers growing, LPV in 2020