GBAS/SBAS Implementation in China

ICAO ASIA/PACIFIC REGIONAL
GBAS/SBAS WORKSHOP
Seoul, ROK, 3~5 June 2019

Li Xin
Technical Center
Air Traffic Management Bureau, CAAC
contents

• Background and Strategy
• GBAS R&D and Certification
• SBAS R&D and Test
The global implementation Road Map of GBAS/SBAS has been defined in ASBU.

Many highland airports with complex topography where the conventional Navaids can not work well.

More large busy airports need new Navaids than ILS or VOR/DME, to improve the flexibility, efficiency and safety of landing and takeoff movements.

With deployment progress of BDS, CAAC need to verify and introduce BDS’s core and augmentation service for air navigation, and make it more reliable and safety.
### Strategy - ICAO Plan vs CAAC Plan

<table>
<thead>
<tr>
<th>Navigation</th>
<th>Block 0</th>
<th>Block 1</th>
<th>Block 2</th>
<th>Block 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Enablers (Conventional)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ILS/MLS</td>
<td>Retain to support precision approach and mitigate GNSS outage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DME</td>
<td>Optimize existing network to support PBN operations</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VOR/ND</td>
<td>Rationalize based on need and equipage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Enablers (Satellite-Based)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core GNSS Constellations: Single frequency (GPS/GLONASS)</td>
<td>Multi-Frequency/Multi Constellation (GPS/GLONASS/BeiDou/Baizhou)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>GNSS Augmentations</strong></td>
<td>SBAS</td>
<td>GBAS Cat I</td>
<td>GBAS Cat II/III</td>
<td>Multi-Freq GBAS/SBAS</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Year</th>
<th>GBAS</th>
<th>SBAS</th>
<th>2030~</th>
</tr>
</thead>
<tbody>
<tr>
<td>~2020</td>
<td>• Complete development and certification of CAT-I SF GBAS</td>
<td>• Initiate deployment of BDSBAS</td>
<td>• Fully provide BDSBAS service up to CAT-I for China and neighboring area</td>
</tr>
<tr>
<td>~2020</td>
<td>• Initiate development of DFMC(BDS/GAL/GPS) GBAS</td>
<td>• Complete performance test of BDSBAS</td>
<td></td>
</tr>
<tr>
<td>2030</td>
<td>• Initiate deployment of CAT-I SF GBAS in specific airport</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2030~</td>
<td>• Complete development and certification of DFMC GBAS (CAT-I/II/III)</td>
<td>• Complete test and certification of BDSBAS for air navigation services by CAAC</td>
<td>• Deploy GBAS as the main precise Approach/Landing Navaids, and keep ILS as backup in minimum level.</td>
</tr>
<tr>
<td>2030~</td>
<td>• Deploy CAT-I DFMC GBAS in airport which cannot use ILS, and in busy airports as backup for ILS</td>
<td>• Provide qualified service, under monitor and endorse by CAAC, gradually</td>
<td></td>
</tr>
<tr>
<td>2030~</td>
<td>• Initiate deployment of CAT-II/III GBAS in specific airport</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Contents

• Background and Strategy
• GBAS R&D and Certification
• SBAS R&D and Test
### GBAS Technical Classification

**GAST C**
- Service level - CAT I
- Service Signal - GPS L1, GLN L1, BDS B1

**GAST D**
- Service level - CAT II/III
- Service Signal - GPS L1, GLN L1, BDS B1

**GAST E**
- Service level - CAT I
- Service Signal - GAL E5, BDS B2a

**GAST F**
- Service level - CAT III
- Service Signal - GPS L1/L5, GAL E1/E5, GLN L1/L3, BDS B1/B2a
GBAS Technical Architecture

GAST-C/E/F

GAST-D
GBAS R&D – Baseline Review

2006-2010
GAST C Technical Research
GPS GBAS Key technology research and over 80 precision approaches

2011-2015
GNSS GBAS Technical Research
GNSS Key technology research, engineering prototype development and demonstration of Tianjin airport

2016-Now
GAST C Equipment Certificate
GAST D/F Technical Research

2006-2008
GBAS Test Bed
Linzhi Airport LAAS Test Project
GBAS R&D - Standards

- GBAS - Signal-in-Space Interface Control Document
- GBAS - Ground Equipment Technical Requirements
- GBAS - Ground Equipment Test Method
- GBAS - Ground Equipment Site Specification
GBAS R&D - initial TEST BED

Research results (GPS L1)

- Positioning accuracy (95%) $\geq 1$ m
- VPL $\geq 10$ m, HPL $\geq 40$ m
- VDB availability $\geq 0.999$, System availability $\geq 0.995$
- Verifies GBAS system architecture and data flow, as well as core algorithm (differential correction, integrity)
Research results (GPS L1)

1. Established a prototype of the ground-based augmentation system that meets the RTCA/DO-245A and RTCA/DO-246D standards;
2. Static testing and more than 80 precision approach show that the technical indicators reach CAT I level.
GBAS R&D - GNSS GBAS (2011-2015)

Research results (GPS/BDS/GAL)

1. DFMC GBAS prototype;

2. Static testing and more than 20 precision approach for GPS L1/BDS B1I&B2I GBAS, showed technical indicators reach CAT II/IIIa level.
GBAS R&D - Certification (2016~)

Main Station equipment cabinet
Reference receiver
VDB antenna

LGF-1A GBAS Features

Expansion DFMC GNSS
Supports GPS, monitors BDS signals, and can be configured to monitor GAL and GLO signals

Expansion VDB
1 local VDB station, Expansion 3 remote VDB stations

Expansion Position monitoring
Monitoring position performance
GBAS R&D – Certification (2016~)

GBAS Certification scheme

Technical review
- Document technology Review: 2017.03
- Factory technology Review: 2017.09
- Specialized design Review: 2018.08-2019.02

System test
- Factory Type test: 2017.12
- Operating environment test: 2018.05-2019.01
- Flight test: 2018.09/11/12

Verify flight
- First verification flight: 2019.04
- Second verification flight: 2019.07
Service Performance Analysis - Receiving Satellite Counting Statistics

The number of received satellites is one measure of satellite performance, indicating how many satellites are used by the GBAS system for differential correction, also a common indicator of system availability.

<table>
<thead>
<tr>
<th>Receiver number</th>
<th>Minimum number of satellites</th>
<th>Maximum number of satellites</th>
<th>Mean number of satellites</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rev1</td>
<td>6</td>
<td>12</td>
<td>9.4524</td>
</tr>
<tr>
<td>Rev 2</td>
<td>6</td>
<td>12</td>
<td>9.4290</td>
</tr>
<tr>
<td>Rev 3</td>
<td>6</td>
<td>12</td>
<td>9.4712</td>
</tr>
<tr>
<td>Rev 4</td>
<td>6</td>
<td>12</td>
<td>9.4995</td>
</tr>
</tbody>
</table>
The protection level is a value calculated by the airborne receiver to determine if the performance of the GBAS meets the integrity requirements of the precision approach.

<table>
<thead>
<tr>
<th></th>
<th>99%</th>
<th>95%</th>
<th>50%</th>
<th>Mean</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPL</td>
<td>3.714</td>
<td>2.692</td>
<td>2.113</td>
<td>2.212</td>
<td>0.441</td>
</tr>
<tr>
<td>VPL</td>
<td>6.460</td>
<td>5.620</td>
<td>3.861</td>
<td>3.992</td>
<td>0.839</td>
</tr>
</tbody>
</table>
Integrity is a measure of the credibility of a GBAS differential correction signal. Integrity requires that be provided with an alarm in time to user when the signal provided by the system is not available.

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Available number</th>
<th>Percentage available</th>
<th>HMI</th>
<th>MI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal</td>
<td>1209286</td>
<td>1209286</td>
<td>100%</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Vertical</td>
<td>1209286</td>
<td>1208446</td>
<td>99.9305%</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
The error cumulative probability distribution map is used to describe the statistical result of the real-time positioning error. The cumulative probability distribution curve can visually see the distribution range of the horizontal and vertical errors and the corresponding cumulative probability value less than a certain error value.

<table>
<thead>
<tr>
<th></th>
<th>99%</th>
<th>95%</th>
<th>50%</th>
<th>Mean</th>
<th>Variance</th>
</tr>
</thead>
<tbody>
<tr>
<td>HPE</td>
<td>0.932</td>
<td>0.682</td>
<td>0.305</td>
<td>0.335</td>
<td>0.193</td>
</tr>
<tr>
<td>VPE</td>
<td>1.574</td>
<td>1.149</td>
<td>0.386</td>
<td>0.464</td>
<td>0.367</td>
</tr>
</tbody>
</table>

Service Performance Analysis - Error cumulative probability distribution

Error cumulative probability distribution
| Flight inspection result: Meet the performance requirement of CAT-I GBAS ground system | GBAS R&D – Certification (2016~) | Inspection Aircraft - Flight Test |
Transport aircraft - Flight Test

- Static check, taxi check GBAS reception, flight test (long five-sided mode, standard five-sided mode automatic landing and landing slip).
- Tests have shown that the LGF-1A GBAS equipment is capable of providing aircraft precision approach, automatic landing and taxi guidance services, and provides services that meet current regulatory requirements.
GBAS R&D - CAT-Ⅱ/Ⅲ Research (2018~)

CAT II/III Research

• GAST-D Prototype development
  ➢ B1C/L1

• GAST-F Simulation
  ➢ MC/DF BDS/GPS/GAL

CAT II/III Research

• GAST-D Technical test
  ➢ Research on ionosphere of Baiyun Airport
  ➢ Research on ionosphere of Baoan Airport

• GAST-F Technical test
  ➢ MC/DF BDS/GAL

CAT II/III Research

• GAST-D Technical test
  ➢ Research on ionosphere of Baiyun Airport
  ➢ Research on ionosphere of Baoan Airport

• GAST-F Flight test
  ➢ MC/DF BDS/GAL/GPS
Contents

• Background and Strategy
• GBAS R&D and Certification
• SBAS R&D and Test
## BDSBAS Technical Architecture

### Constellation
BDS/GNSS

### Purpose
Providing CAT I Service for Aviation Users; Meets ICAO standards;

### Interface
SFSBAS ICD/ DFMC SBAS ICD

### Frequency
B1C(1575.42MHz)+B2a(1176.45MHz)

### Satellite
3 GEOs(80° E, 110° E, 140° E)
The GEO-1 satellite (SBAS PRN 130) has been launched on November 1 2018, and broadcasted BDSBAS signal from November 9 2018 on plan.

**RF characteristics**

BDSBAS RF characteristics

**Comparison with ICAO requirements**

<table>
<thead>
<tr>
<th>NO</th>
<th>item</th>
<th>signal</th>
<th>ICAO requirement</th>
<th>BDSBAS Test results</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Carrier FRE</td>
<td>SBAS B1C</td>
<td>1575.42MHz</td>
<td>1575.42MHz</td>
</tr>
<tr>
<td></td>
<td>SBAS B2a</td>
<td>1176.45MHz</td>
<td></td>
<td>1176.45MHz</td>
</tr>
<tr>
<td>2</td>
<td>spurious FRE</td>
<td>SBAS B1C</td>
<td>≤-40dBc</td>
<td>-56.66</td>
</tr>
<tr>
<td></td>
<td>SBAS B2a</td>
<td>≤-40dBc</td>
<td></td>
<td>-62.34</td>
</tr>
<tr>
<td>3</td>
<td>modulation</td>
<td>SBAS B1C</td>
<td>BPSK (1), symbol rate 500sps, code length 1023, Chip rate 1.023Mchip/s</td>
<td>BPSK (1), symbol rate 500sps, code length 1023, Chip rate 1.023Mchip/s</td>
</tr>
<tr>
<td>4</td>
<td>SBAS B2a</td>
<td>BPSK (10),</td>
<td>symbol rate 500sps, code length 10230, Chip rate 10.23Mchip/s</td>
<td>BPSK (10), symbol rate 500sps, code length 10230, Chip rate 10.23Mchip/s</td>
</tr>
<tr>
<td>5</td>
<td>Phase noise</td>
<td>SBAS B1C/B2a</td>
<td>PLL of 10 Hz one-sided noise bandwidth is able to track the carrier to an accuracy of 0.1 radian</td>
<td>0.00578 rad</td>
</tr>
<tr>
<td>6</td>
<td>spectrum</td>
<td>SBAS B1C</td>
<td>At least 95 contained within 3 dB bandwidth</td>
<td>Band wide: ±18.414MHz</td>
</tr>
<tr>
<td></td>
<td>SBAS B2a</td>
<td>At least 95 contained within 3 dB bandwidth</td>
<td>Band wide: ±35.805MHz</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>FRE stability</td>
<td>SBAS B1C</td>
<td>&lt;5e-11(1s~10s)</td>
<td>1.5e-12/1s</td>
</tr>
<tr>
<td></td>
<td>SBAS B2a</td>
<td>&lt;6.7e-11(1s~10s)</td>
<td>5.2e-13/10s</td>
<td></td>
</tr>
</tbody>
</table>
| 8  | Coherence of code & carrier | SBAS B1C   | short-term: <0.15m  
long-term: <0.19m                                            | 0.12m                       |
|    |                         | SBAS B2a     | Short-term: <0.2m  
long-term: <0.255m                                           | 0.1m                        |
| 9  |                         |             | 0.16m                                                                             | 0.178m                       |
| 10 | Coherent of L1 & L5     | SBAS B1C/B2a | short-term: <0.2m  
long-term: <0.255m                                           | 0.13m                       |
BDSBAS Test Performance

- **Accuracy Performance**
The accuracy of BDSBAS is consistent with different orbit determination methods.

- **Integrity Performance**
The rate of UDRE bounding user range error and GIVE bounding user ionosphere error are both above 99.9%

### Positioning Accuracy of BDSBAS

<table>
<thead>
<tr>
<th>BDSBAS</th>
<th>Beijing</th>
<th>Sanya</th>
<th>Chengdu</th>
<th>average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dynamic orbit determination</td>
<td>1.67</td>
<td>1.42</td>
<td>1.27</td>
<td>1.45</td>
</tr>
<tr>
<td>Kinematics orbit determination</td>
<td>1.97</td>
<td>1.87</td>
<td>1.27</td>
<td>1.70</td>
</tr>
</tbody>
</table>

### Integrity parameters of BDSBAS

- Red: UDRE
- Black: URE
- Red: GIVE
- Blue: UIE
BDSBAS plans to broadcast SBAS L1/L5 signal in accordance with ICAO standards

BDS and GPS will be augmented by BDSBAS

Galileo E1C/E5a and GLONASS L1/L3 will be considered if the signals are recommended by ICAO SARPs.

BDS will provide SF (B1C)/DF(B1C+B2a) services for users.
Thanks for your attention