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

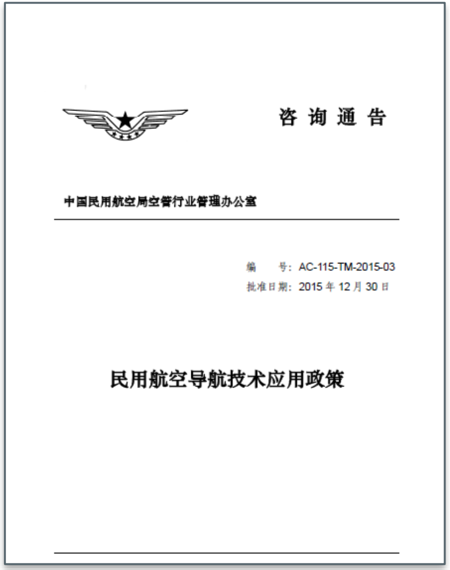
Background-Requirement

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 ofBDS,CAAC need to verify and introduce BDS’s core and augmentation service for air navigation, and make it more reliable and safety.


咨 询 通 告

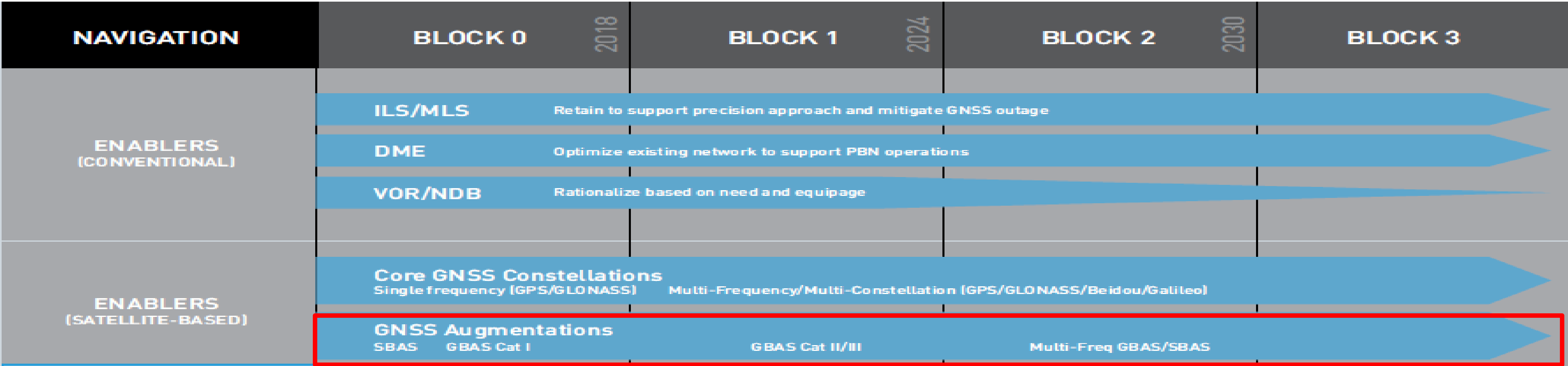
中国民用航空局空管行业管理办公室

编　　号：AC-115-TM-2015-03
批准日期：2015 年 12 月 30 日

民用航空导航技术应用政策

Navigation technology application policy
—Issued by CAAC

Strategy-ICAO Plan vs CAAC Plan



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

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 E

- Service level - CAT I
- Service Signal - GAL E5，BDS B2a

GAST D

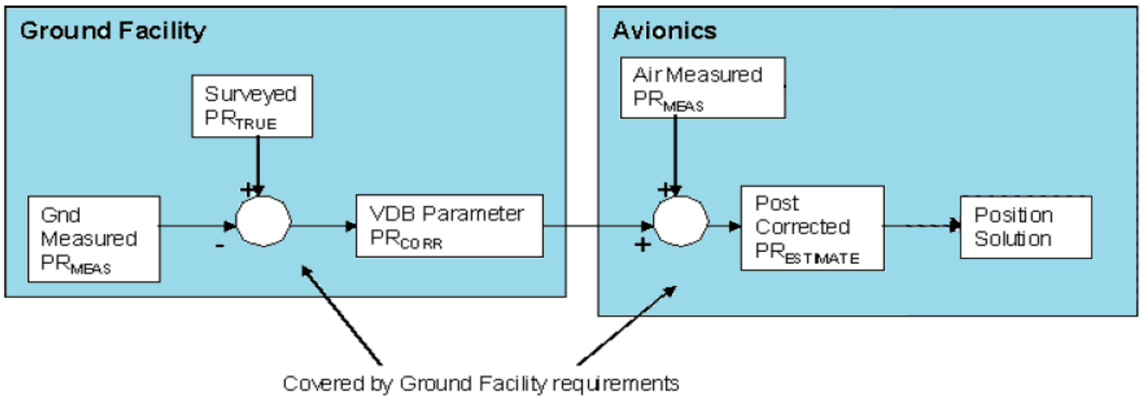
- Service level - CAT II/III
- Service Signal - GPS L1，GLN L1，BDS B1

GAST F

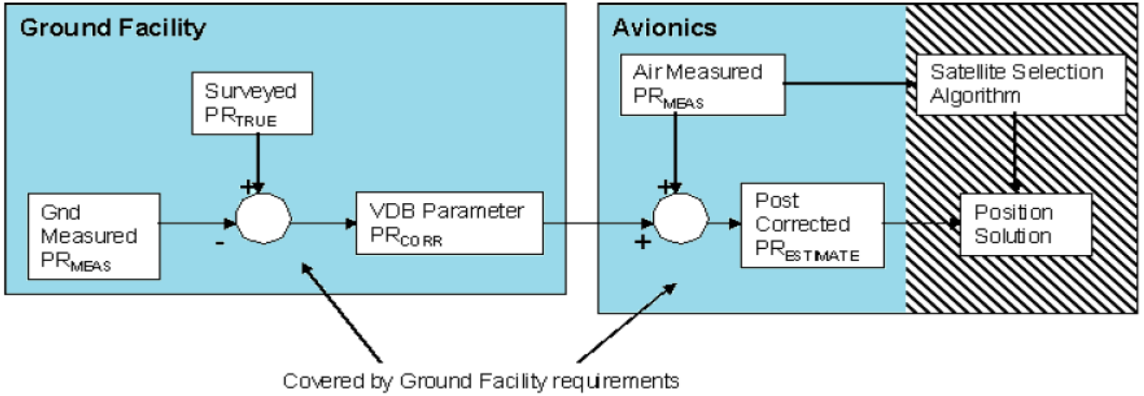
- Service Signal - CAT III
- Service Signal - GPS L1/L5，GAL E1/E5，GLN L1/L3，BDS B1/B2a

GBAS Technical Architecture

GAST-C/E/F



GAST-D



GBAS R&D – Baseline Review

2008

2006-2008

GBAS Test Bed

Linzhi Airport LAAS Test Project

2006-2010

GAST C Technical Research

GPS GBAS Key technology research and over 80 precision approaches

2010

2015

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

NOW

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

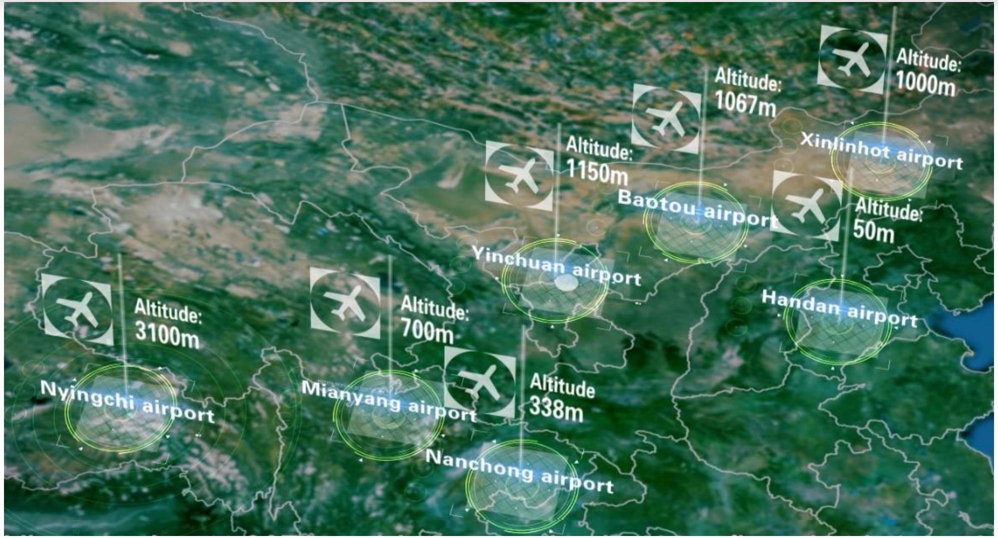
GBAS R&D - initial TEST BED

Research results(GPS L1)

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

GBAS R&D - GPS GBAS (2006-2010)

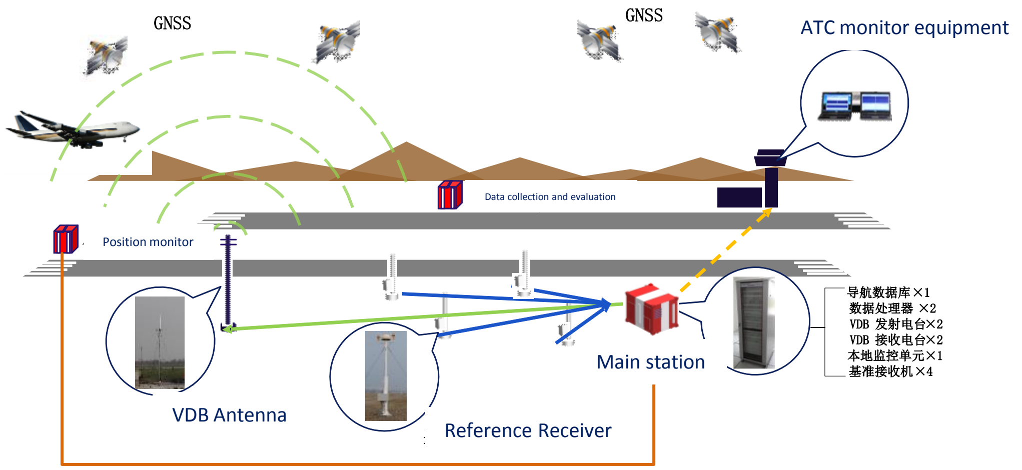
Flight Test Process



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	

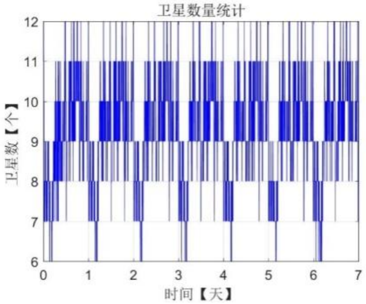
GBAS R&D – Certification (2016~)

Service Performance Analysis - Receiving Satellite Counting Statistics

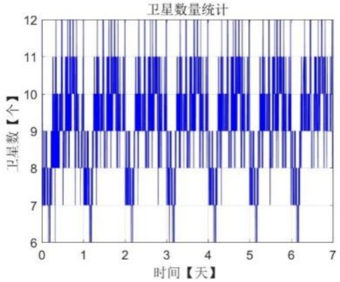
The number of received satellites is one measure of satellite performance, indicating how many satellites are used by the GBAS system for differential correction , also a common indicators of system availability.

Receiver number	Minimum number of satellites	Maximum number of satellites	Mean number of satellites
Rev1	6	12	9.4524
Rev 2	6	12	9.4290
Rev 3	6	12	9.4712
Rev 4	6	12	9.4995

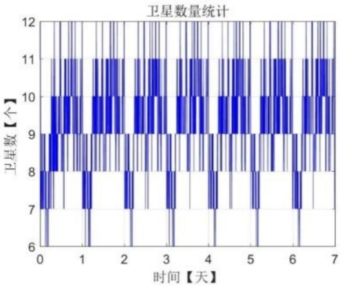
Satellite number chart



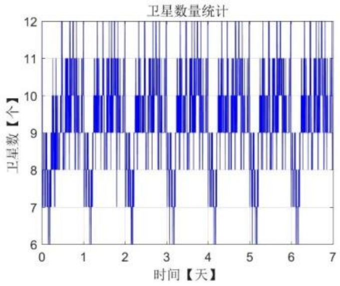
Receiver No. 1



Receiver No. 2



Receiver No. 3



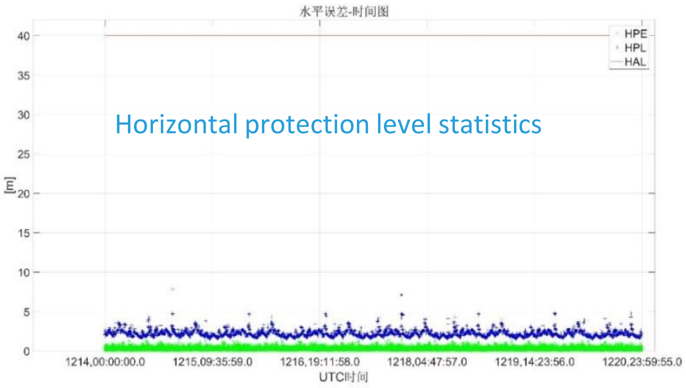
Receiver No. 4

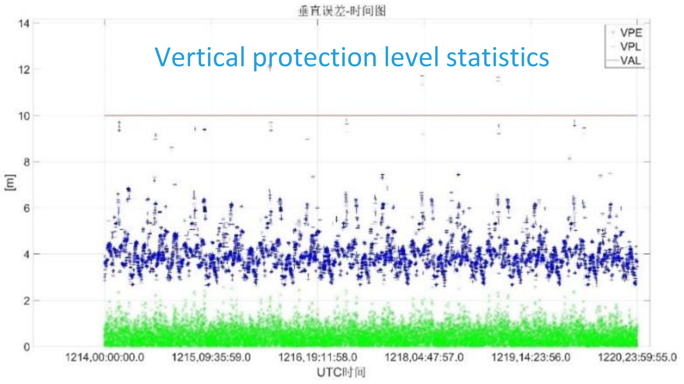
GBAS R&D – Certification (2016~)

Service Performance Analysis - Protection level statistics

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.

	99%	95%	50%	Mean	Variance
HPL	3.714	2.692	2.113	2.212	0.441
VPL	6.460	5.620	3.861	3.992	0.839



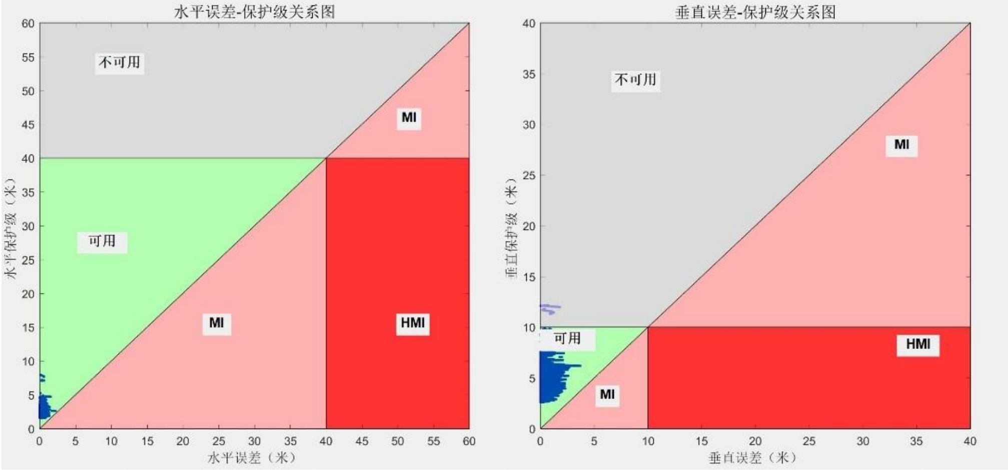


GBAS R&D – Certification (2016~)

Service Performance Analysis - Error and Protection Level Relationship

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.

Error and Protection Level Relationship



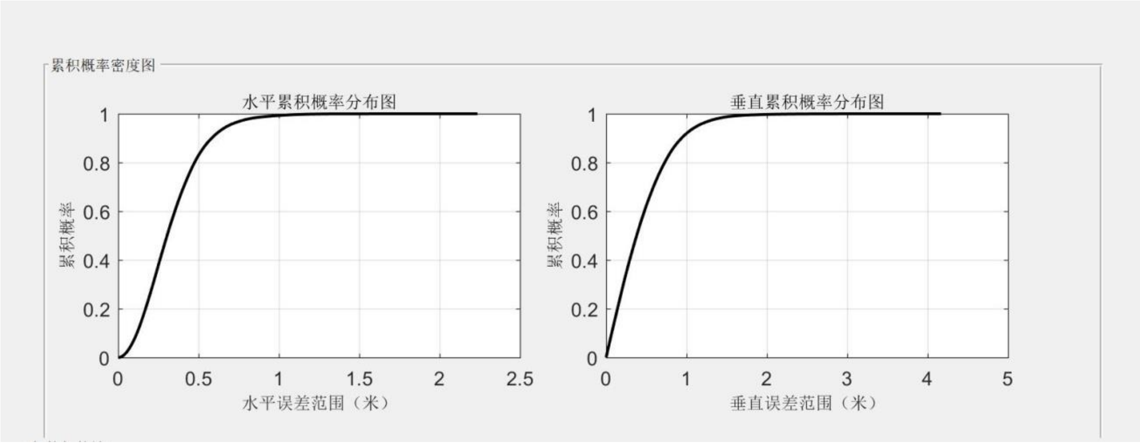
	Total	Available number	Percentage available	HMI	MI
Horizontal	1209286	1209286	100%	0	0
Vertical	1209286	1208446	99.9305%	0	0

GBAS R&D – Certification(2016~)

Service Performance Analysis - Error cumulative probability distribution

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.

Error cumulative probability distribution



	99%	95%	50%	Mean	Variance
HPE	0.932	0.682	0.305	0.335	0.193
VPE	1.574	1.149	0.386	0.464	0.367

GBAS R&D – Certification (2016~)

Inspection Aircraft - Flight Test

卫星着陆系统飞行测试报告表

CAAC

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报告编码：GZBTJ34L20180908

1. 机场名称	天津/滨海	2. 跑道号	34L	3. 机号	B-9301	4. 机场识别	ZBTJ	5. 日期	2018. 09. 08		
6. 校飞种类	投产		定期		特殊	✓	7. 频率	116. 75M	8. 波道号	20350	9. 状态	正常

10. FAS 数据飞行校验结果

参数	校验显示	校验结果	参数	校验显示	校验结果
台站识别	ZBTJ	正确	LTP 点高度（m）	-4. 4	正确
跑道号	34L	正确	频率（M）	116. 75	正确
下滑角（°）	3. 00	正确	入口高度（m）	15. 0	正确
LTP 点经度（°）	N 39-06-41. 0688	正确	FPAP 点经度（°）	N 39-08-14. 3124	正确
LTP 点纬度（°）	E 117-21-14. 8680	正确	FPAP 点纬度（°）	E 117-20-17. 6496	正确

11.VDB 信号飞行校验结果

圆周飞行 1	高度 m	1500	半径	20nm	角度°	261.98	VDB 最小信号强度 dBm/dBW/M²	-79.3/-90.41
圆周飞行 2	高度 m	3000	半径	20nm	角度°	267.05	VDB 最小信号强度 dBm/dBW/M²	-66.3/-77.41

12.进近飞行校验结果

开始距离 15 海里

程序的一致性	一致	进近精度	满意	VDB 最小信号强度 dBm/dBW/M²	-67.3/-78.41						
航向校直 °/μA	-0.00/-0.28	航向结构 μA/NM	0/15.06	1/0.61	0/0.17						
下滑角/入口高度°/m	2.98/15.87	下滑结构 μA/NM	1/6.56	9/0.57	5/0.15						
可见卫星数量	12	可用卫星数量	9								
可用卫星编号	11	18	28	30	07	08	17	22	03		
信噪比	46	48	47	50	51	45	50	49	45		

开始距离 10 海里

程序的一致性	一致	进近精度	满意	VDB 最小信号强度 dBm/dBW/M²	-52.3/-63.41						
航向校直 °/μA	-0.00/-0.27	航向结构 μA/NM	1/12.21	0/0.58	0/0.23						
下滑角/入口高度°/m	2.99/15.28	下滑结构 μA/NM	1/6.55	5/0.58	3/0.16						
可见卫星数量	12	可用卫星数量	10								
可用卫星编号	01	11	28	18	30	07	17	22	08	03	
信噪比	50	47	48	49	49	49	48	49	46	48	

开始距离 20 海里

程序的一致性	一致	进近精度	满意	VDB 最小信号强度 dBm/dBW/M²	-52.3/-63.41						
航向校直 °/μA	0.01/0.64	航向结构 μA/NM	0/20.33	0/1.22	0/0.17						
下滑角/入口高度°/m	3.01/17.4	下滑结构 μA/NM	1/6.62	1/0.57	4/0.16						
可见卫星数量	12	可用卫星数量	9								
可用卫星编号	18	07	08	01	30	28	27	10	16		
信噪比	49	49	50	48	50	47	47	47	46		

中国民用航空飞行校验中心 GBAS 飞行测试报告 18-05 版

卫星着陆系统飞行测试报告表

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报告编码：GZBTJ34L20180908

13.水平飞行校验结果

距离 NM	15/-2.5	高度 m	600	宽度及对称性°/%	0.75/50.02	VDB 最小信号强度 dBm/dBW/M²	-65.3/-76.41
距离 NM	15/-2.5	高度 m	900	宽度及对称性°/%	0.75/50.04	VDB 最小信号强度 dBm/dBW/M²	-63.3/-74.41
距离 NM	15/-2.5	高度 m	1200	宽度及对称性°/%	0.75/50.06	VDB 最小信号强度 dBm/dBW/M²	-60.3/-71.41

14.圆弧飞行校验结果

半径/高度 NM/m	20/600	角度°	±35	宽度及对称性°/%	3.41/50.24	VDB 最小信号强度 dBm/dBW/M²	-83.3/-94.41
半径/高度 NM/m	15/600	角度°	±35	宽度及对称性°/%	3.43/50.17	VDB 最小信号强度 dBm/dBW/M²	-85.3/-96.41

中国民用航空飞行校验中心 GBAS 飞行测试报告 18-05 版

Flight inspection result:
Meet the performance requirement of CAT-I GBAS ground system

卫星着陆系统飞行测试报告表

CAAC

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报告编码：GZBTJ34L20180908

15.电磁环境情况	良 好

16.校验结论：

符合《"GBAS 地面设备-I 类精密进近"的天津机场飞行校验方案》中给定的容限要求。

17.备注：

1、本次为对安装在天津机场的二十所 GBAS 地面设备进行合格审定而进行的飞行测试（第一次）。

2、本次飞行测试的方法依据来源于二十所出具的《"GBAS 地面设备-I 类精密进近"的天津机场飞行校验方案》。

3、本次飞行测试的标准依据来源于二十所出具的《"GBAS 地面设备-I 类精密进近"的天津机场飞行校验方案》。

4、机长建议：GBAS 机载系统中应增加距离指示功能。

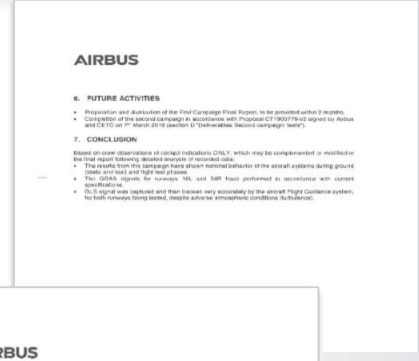
机长签字		飞行校验员签字	

中国民用航空飞行校验中心 GBAS 飞行测试报告 18-05 版

GBAS R&D – Certification (2016~)

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.



AIRBUS

6. FUTURE ACTIVITIES

- Preparation and distribution of the First Campaign Final Report, to be provided within 2 months.
- Completion of the second campaign in accordance with Proposal CT1900779-V2 signed by Airbus and CETC on 7th March 2019 (section D "Deliverables Second campaign: tests").

7. CONCLUSION

Based on crew observations of cockpit indications ONLY, which may be complemented or modified in the final report following detailed analysis of recorded data:

- The results from this campaign have shown nominal behavior of the aircraft systems during ground (static and taxi) and flight test phases.
- The GBAS signals for runways 16L and 34R have performed in accordance with current specifications.
- GLS signal was captured and then tracked very accurately by the aircraft Flight Guidance system, for both runways being tested, despite adverse atmospheric conditions (turbulence).

AIRBUS

James FAWCETT
T +33 (0)6 38 78 97 81
E james.fawcett@airbus.com
Our Reference: X34RP1908507

15 April 2019

X ZHANG
Executive General Manager and
President of CETC Northwest
CETC Northwest Group CO., LTD.
No. 1 Beisha Road, Xi'an,
Shaanxi Province,
CHINA.

GBAS Operation on TIANJIN BINHAI Airport - First campaign - Preliminary Report

Dear Sir,

Please find enclosed the Preliminary Report for the First campaign of GBAS Operation on TIANJIN BINHAI Airport, which took place on 9th April 2019.

Do not hesitate to contact us if you have any questions.

Yours faithfully,

Jim FAWCETT
Lead Flight Test Engineer
Airbus department EVTS

Captain Jean-Christophe LAIR
Experimental Test Pilot
Airbus department EVXE

GBAS R&D - CAT-II/III Research (2018~)

2018

CAT II/III Research

- GAST-D Prototype development
  - B1C/L1

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

2019

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

2020

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

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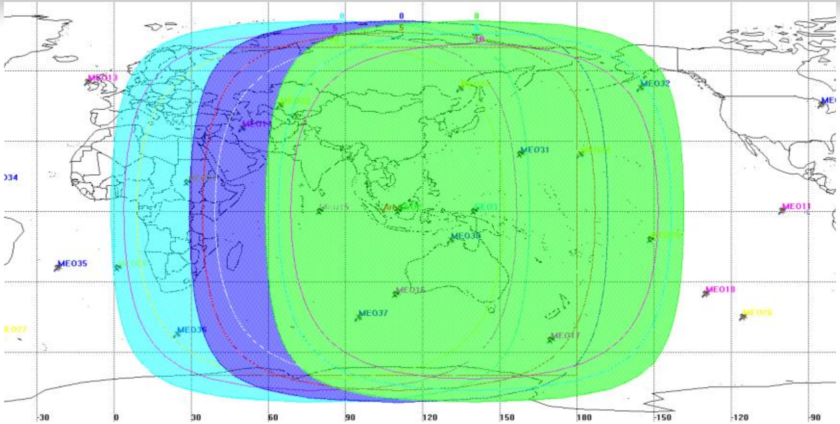
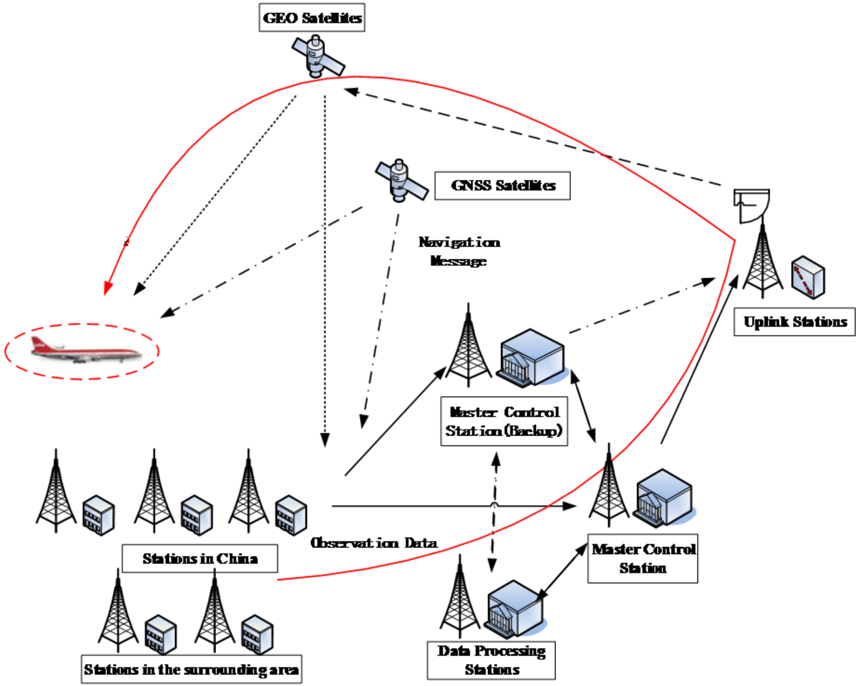
BDSBAS Technical Architecture



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)



BDSBAS Test Performance

- 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

NO	item	signal	ICAO requirement	BDSBAS Test results
1	Carrier FRE	**SBAS B1C**	1575.42MHz	1575.42MHz
2		**SBAS B2a**	1176.45MHz	1176.45MHz
3	spurious	**SBAS B1C**	≤-40dBc	-56.66
4		**SBAS B2a**	≤-40dBc	-62.34
5	modulation	**SBAS B1C**	BPSK（1），symbol rate 500sps，code length 1023， Chip rate 1.023Mchip/s	BPSK（1），symbol rate 500sps，code length 1023， Chip rate1.023Mchip/s
6		**SBAS B2a**	BPSK（10），symbol rate 500sps，code length 10230， Chip rate 10.23Mchip/s	BPSK（10），symbol rate 500sps，code length 10230， Chip rate 10.23Mchip/s
7	Phase noise	**SBAS B1C/B2a**	PLL of 10 Hz one-sided noise bandwidth is able to track the carrier to an accuracy of 0.1 radian	0.00578 rad
8	spectrum	**SBAS B1C**	At least 95 contained within 3 dB bandwidth	Band wide：±18.414MHz
9		**SBAS B2a**	At least 95 contained within 3 dB bandwidth	Band wide：±35.805MHz
10	FRE stability	**SBAS B1C**	<5e-11(1s~10s)	1.5e-12/1s
11		**SBAS B2a**	<6.7e-11(1s~10s)	5.2e-13/10s
12	Coherence of code & carrier	**SBAS B1C**	short-term：＜0.15m long-term：＜0.19m	0.12m 0.133m
13		**SBAS B2a**	Short-term：<0.2m long-term：<0.255m	0.1m 0.16m
14	Coherent of L1 & L5	**SBAS B1C/B2a**	short-term：<0.2m long-term：<0.255m	0.13m 0.178m

BDSBAS Test Performance

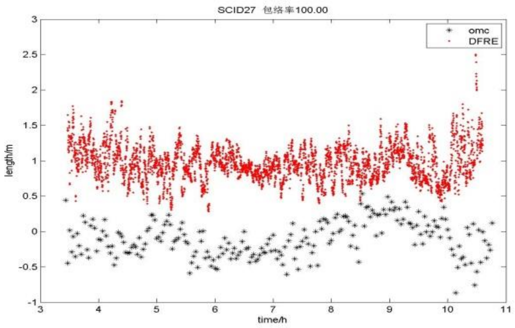
- **Accuracy Performance**
  The accuracy of BDSBAS is consistent with different orbit determination methods.

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

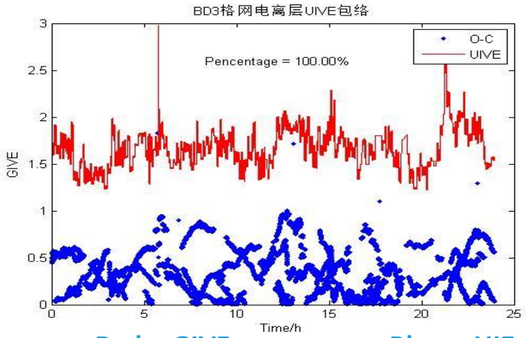
Positioning Accuracy of BDSBAS

BDSBAS	Beijing	Sanya	Chengdu	average
Dynamic orbit determination	1.67	1.42	1.27	1.45
Kinematics orbit determination	1.97	1.87	1.27	1.70

Integrity parameters of BDSBAS

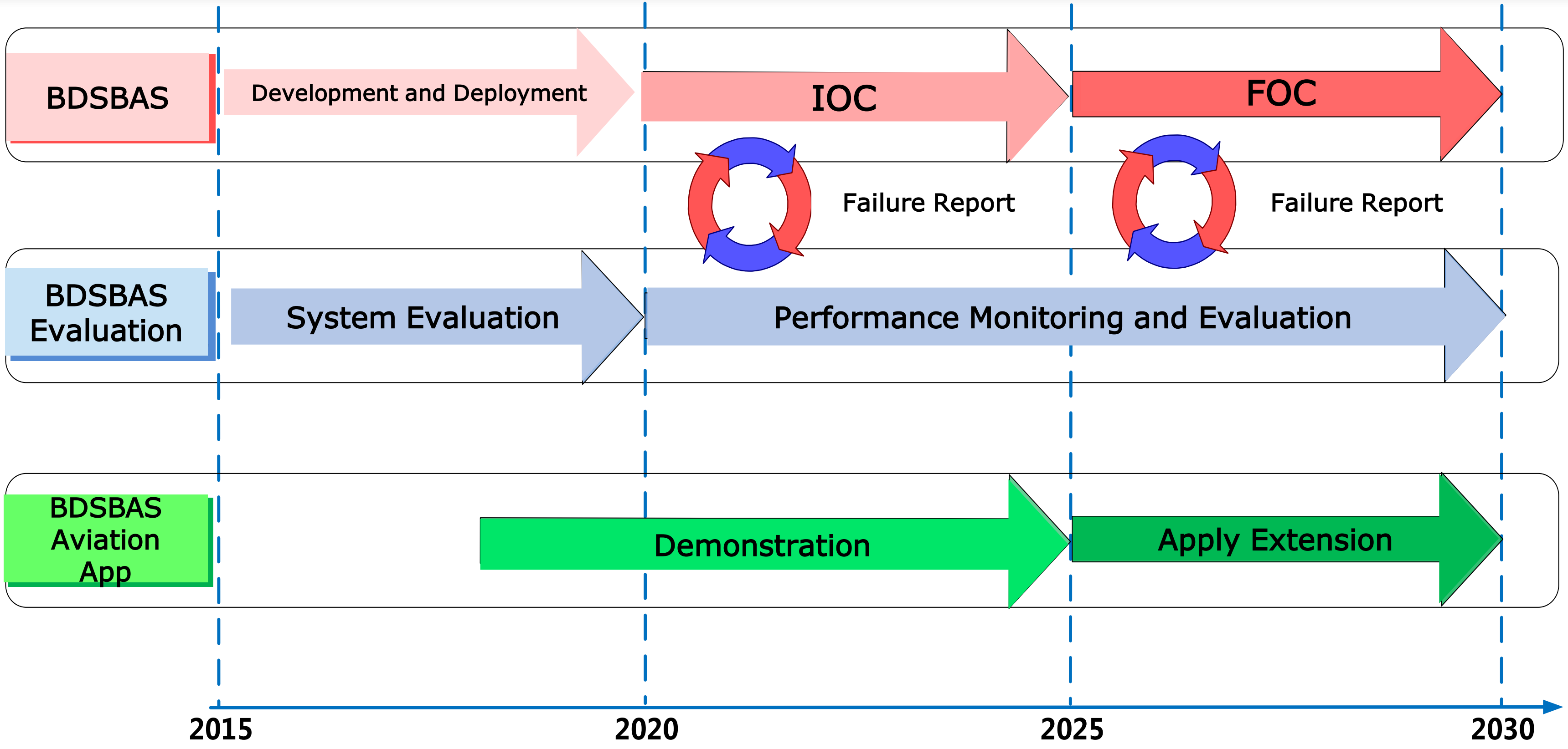


Red: UDRE Black: URE



Red: GIVE Blue: UIE

BDSBAS Implementation Baseline



BDSBAS Near-term Goals

- 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