



Development of BeiDou Navigation Satellite System

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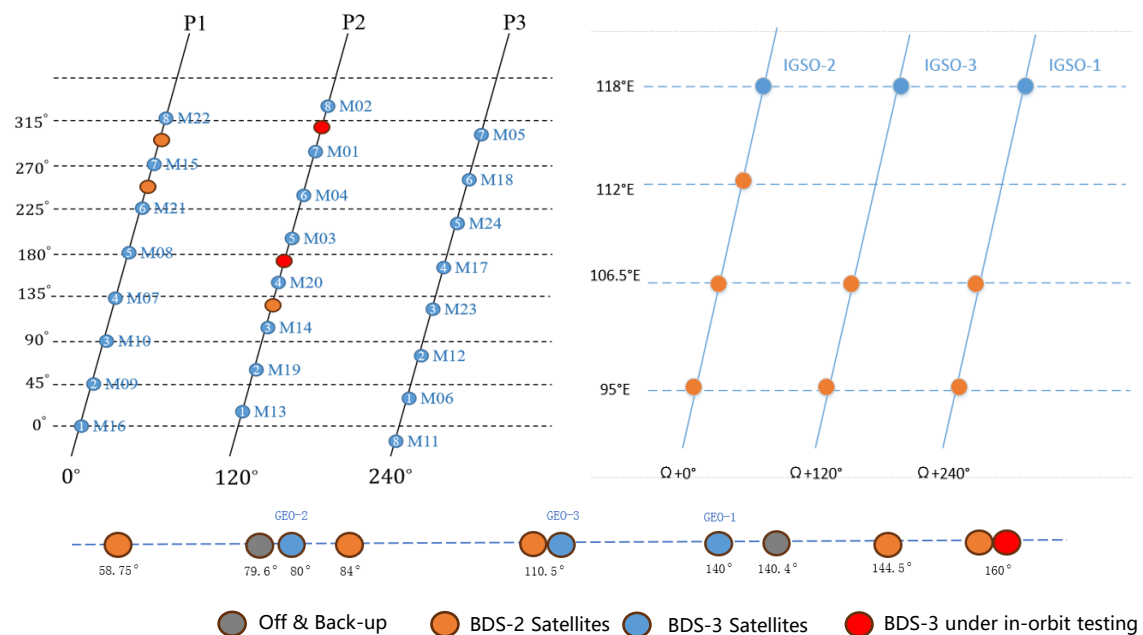
22 April 2024

Constellation Status

A total of **48** satellites operational in orbit

15 BDS-2 Satellites

33 BDS-3 Satellites (**30** networking satellites, **3** satellites under in-orbit testing)



The **56th** satellite for BDS was launched at Xichang on May 17, 2023



The **57th** and **58th** satellites for BDS were launched at Xichang on Dec 26, 2023

- Promoted network's availability and stability
- Expanded communication capacity of the system's regional short-messaging function by 1/3
- Enhanced positioning accuracy of satellite-based augmentation and precise point positioning and realize quick high-accuracy positioning
- Upgraded functions and performance in various areas, including global short message communication capacity, onboard atomic clock technology, and intelligent payloads
- Improved reliability and service capabilities

Diversified Services

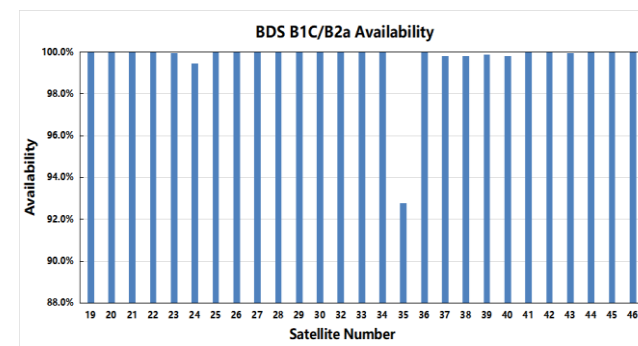
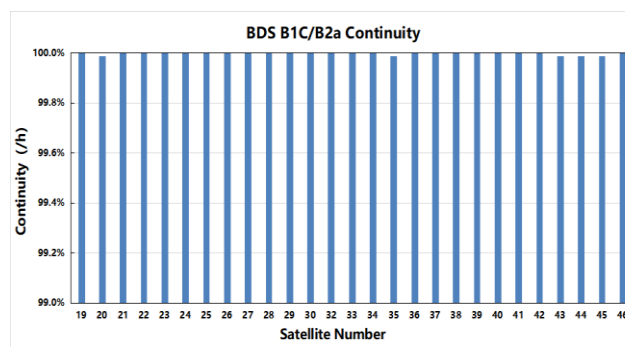
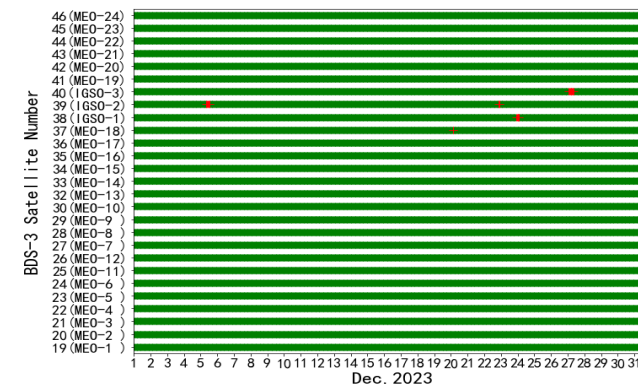
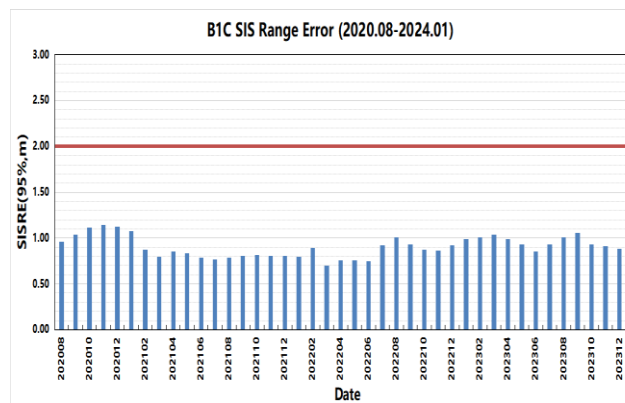
Service Types		Signals/Bands	Broadcast Approaches
Global	RNSS	B1I、 B3I	3GEO+3IGSO+24MEO
		B1C、 B2a、 B2b	3IGSO+24MEO
	GSMC	Up: L Down: GSMC-B2b	Up: 14MEO Down: 3IGSO+24MEO
		SAR	Up: UHF Down: SAR-B2b
China and Surrounding Areas	SBAS	BDSBAS-B1C、 BDSBAS-B2a	3GEO
	GAS	2G、 3G、 4G、 5G	Mobile communication networks, Internet
	PPP	PPP-B2b	3GEO
	RSMC	Up: L Down: S	3GEO

RNSS Service Performances

BDS provides RNSS services for users on the ground and 1,000 km above space users.

Main BDS RNSS Performance Indicators^[1]

Performance Characteristics		Performance Indicators
Service Accuracy (95%)	Positioning	$H \leq 9m, V \leq 10m$
	Timing	$\leq 20ns$
	Velocity Measurement	0.2m/s
Service Availability		$\geq 99\%$

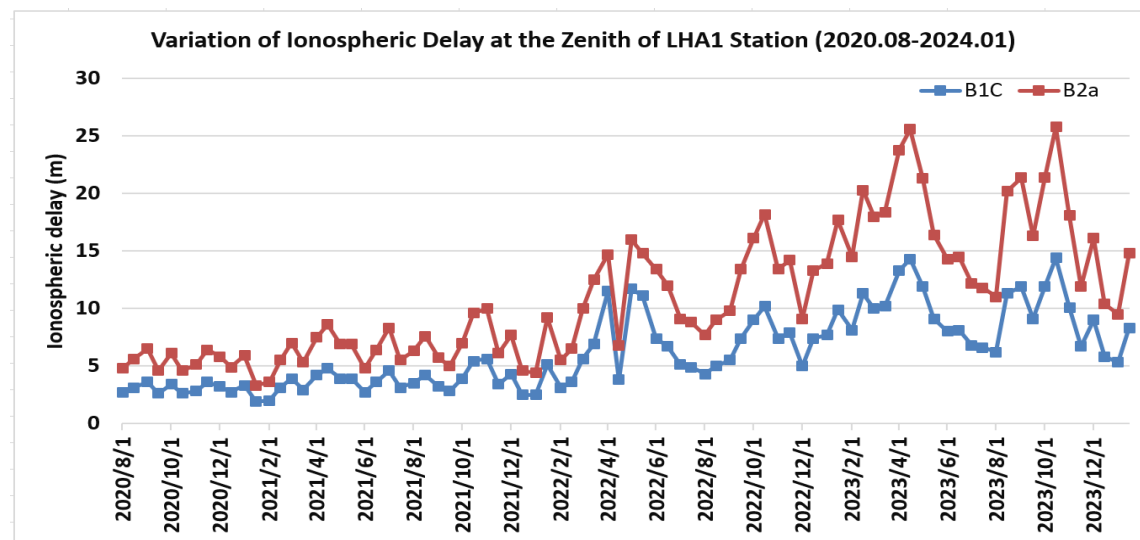
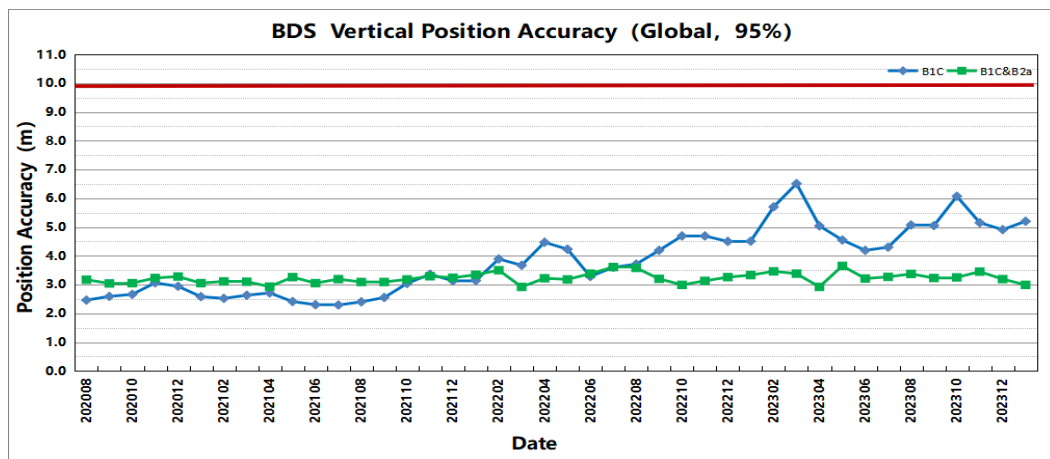
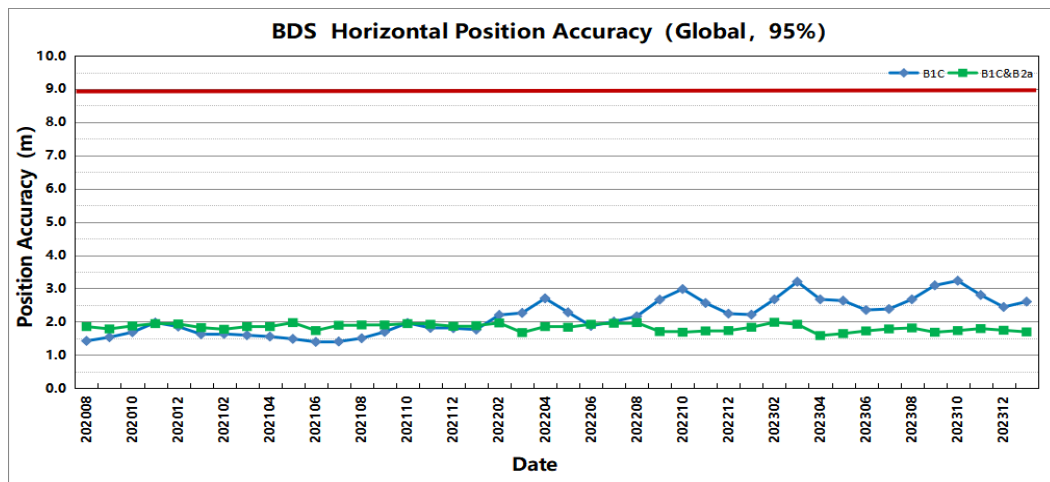


- B1C/B2a Continuity from Jan,2023 to Dec ,2023 is 0.9998/h
- B1C/B2a Availability from Jan,2023 to Dec ,2023 is 0.9968

BDS-3 service performances fully better than indicator requirements by ICD since commissioning.

[1] BeiDou Navigation Satellite System Open Service Performance Standard (Version 3.0), 2021.05

RNSS Service Performances



- Stable BDS B1C/B2a positioning accuracy, with horizontal better than 2m and vertical better than 4m
- Affected by ionospheric activities, SF service performances of GNSS fluctuated. DFMC improves fluctuation.

Global Short Message Communication

➤ GSMC^[1]

- Coverage: Global
- Space Segment: 14 MEO satellites support up link; 3 ISGO and 24 MEO support down link;
- Maximum length of a single message: About 560 bits (40 Chinese characters per message)

	Performance Indicators ^[1]	Test Result
GSMC	Delay ≤ 60s	16s



● BDSMC used in the newly-launched Einstein Probe

The Einstein Probe was launched in Jan 2024, where BDSMC used for wide-field-view sky survey



● BDSMC used in China-France SVOM Joint Space Observatory

Space-based multi-band astronomical Variable Objects Monitor launched in 2023, where BDSMC used for signal transmission and joint observation.



● BDSMC used in China's Space Station

BDSMC sub-system launched with Mengtian experiment module into orbit in Oct 2022 to provide telemetry information transmission and emergency communication.



● BDSMC used in GECAM Space Probe

BDSMC used in Gravitational wave high-energy Electromagnetic Counterpart All-sky Monitor (GECAM) in 2021 to provide information transmission of space

Regional Short Message Communication

➤ RSMC^[1]

- Coverage: Asia-Pacific Region
- Space Segment: 3 GEO satellites (main) and 2 GEO satellites (Backup)
- Maximum length of a single message : 14,000 bits (around 1,000 Chinese characters)
- Main functions: search & rescue, location report, short message communication, etc.
- Service Capability: Up:12,000,000 times/h, Down: 6,000,000 times/h

	Performance Indicators ^[1]	Test Results
RSMC	Success Rate≥95% Delay≤2s	Success Rate: 99% Delay: 1s



In Nov. 2022, BDMSS was recognized by the International Maritime Organization (IMO) as the third global maritime distress and safety system (GMDSS)

Accelerating Commencement of BDS GMDSS

● Frequency Coordination of BDS GMDSS



Provisional regulations for BDMSS GMDSS service were approved during WRC-23 in December 2023.

● EGC Service Manual Review

In September 2023, the 15th session of the International Hydrographic Organization World-wide Navigational Warning Service approved the review of BDMSS EGC service manual.

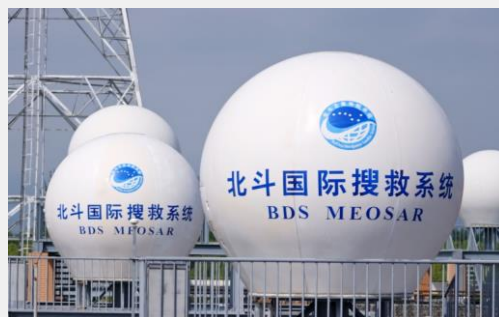


- Developing BDS GMDSS Ship Earth Station
- Construction of the backup Master Control Station and Gateway and contingency arrangements with the main stations
- BDS GMDSS Operation Manual Drafted
- Accelerating signing PSA with IMO

Search and Rescue

➤ MEOSAR

In Nov. 2022, China formally becomes the provider of COSPAS-SARSAT space segment



Performance Characteristics	Performance Indicators ^[1]
Positioning Accuracy	≤5km
Detection Probability	≥99%
Availability	≥99%

Performance results better than indicators

➤ Return Link

Following Galileo and GLONASS, BDS becomes the 3rd RLS provider globally

In October 2023, at the 69th session of the Open Council of COSPAS-SARSAT, the revised proposals related to the service of BDS RLS were considered and adopted, BDS RLS was incorporated into COSPAS-SARSAT



- Beacons supporting RLS developing;
- Tested in cities of the northern, southern, eastern and western parts of China with an average delay of 11.26s;
- Tested in Alexandria, Egypt with average delay 11.5s;

Better than 2 mins indicator requirement

➤ Potential Cooperation

RLS joint testing to be carried out globally

RLS-based Two-way Communication Service to be developed

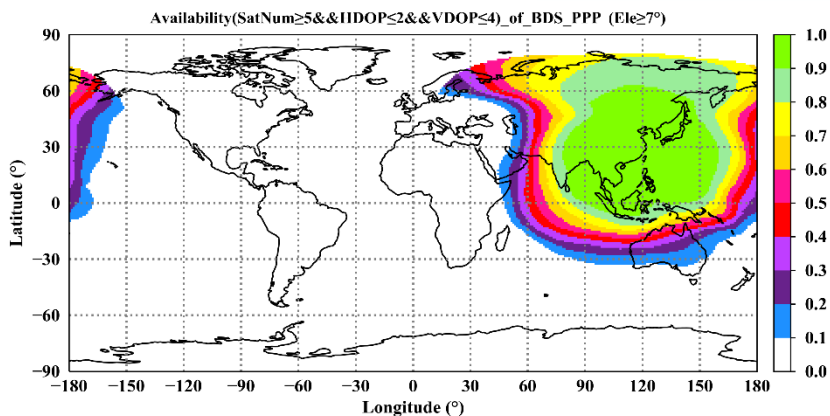
Global service to be formally commissioned for global users

Evolution and Innovation to be pushed forward for BDS MEOSAR

Precise Point Positioning

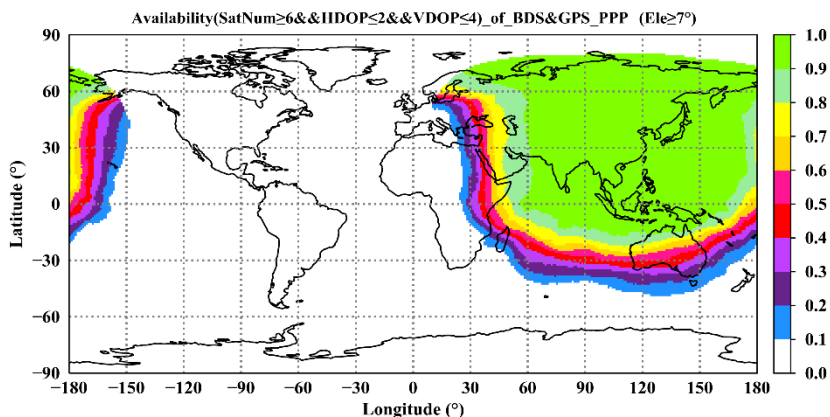
Coverage

Asia-Pacific Region



BDS PPP service availability

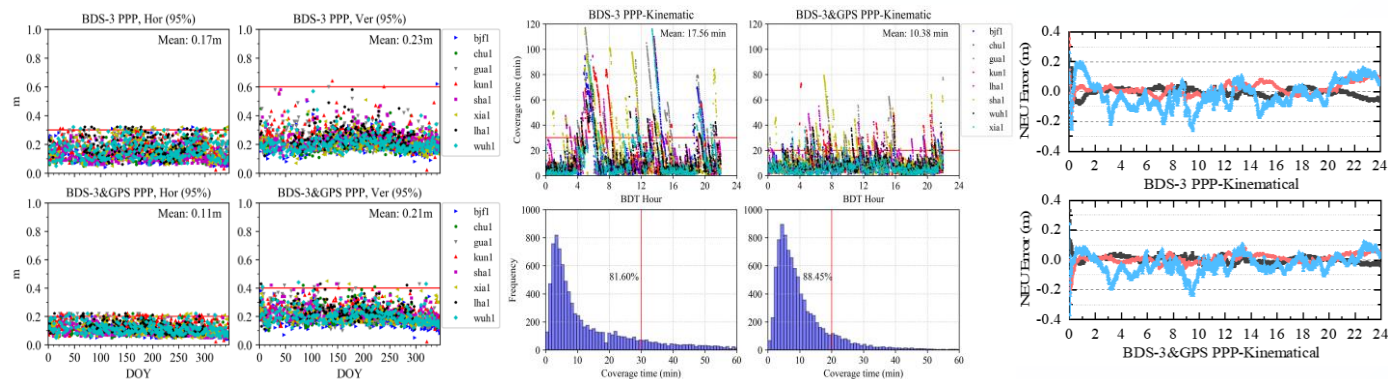
Sat numbers ≥ 5 , HDOP ≤ 2 & VDOP ≤ 4



BDS+GPS PPP service availability

Sat numbers ≥ 6 , HDOP ≤ 2 & VDOP ≤ 4

Positioning accuracy and convergence time



Station	BDS-3 PPP			BDS-3&GPS PPP		
	Hor/m	Ver/m	convergence time/min	Hor/m	Ver/m	convergence time/min
BJF1	0.14	0.20	15.6	0.10	0.19	11.2
CHU1	0.15	0.21	18.7	0.11	0.21	12.8
GUA1	0.20	0.26	22.0	0.13	0.23	13.2
KUN1	0.17	0.25	18.1	0.14	0.23	9.8
LHA1	0.20	0.26	22.8	0.13	0.23	10.9
SHA1	0.13	0.25	12.7	0.09	0.21	9.4
WUH1	0.17	0.22	15.8	0.11	0.19	8.1
XIA1	0.19	0.22	14.5	0.10	0.20	8.8
Mean value	0.17	0.23	17.5	0.11	0.21	10.4

- BDS**
Positioning accuracy: H (95%) 0.17m, V (95%) 0.23m, **Convergence time:** 18min better than 30 mins requirement
- BDS+GPS**
Positioning accuracy: H (95%) 0.11m, V (95%) 0.21m, **Convergence time:** 11min better than 20 mins requirement

Satellite-based Augmentation



中国民用航空局
Civil Aviation Administration of China

北斗系统今后可全球民航通用

来源: 中国民航网 2023-11-16 08:02

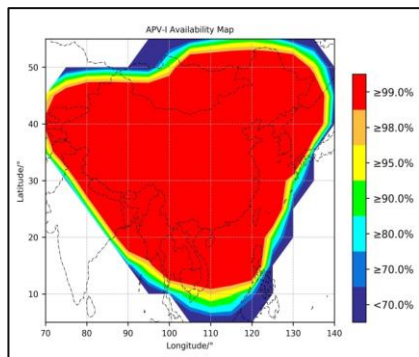
日前, 包含北斗卫星导航系统(以下简称“北斗系统”)标准和建设措施的《国际民用航空公约》附件10最新修订版正式生效。这标志着北斗系统正式加入国际民航组织(ICAO)标准, 成为全球民航通用的卫星导航系统。

北斗系统是中国着眼于国家安全和经济社会发展需要, 自主建设、独立运行的卫星导航系统, 也是联合国认可的四大全球卫星导航系统之一, 已服务全球200多个国家和地区用户。北斗系统民航国际标准化工作是其全球民航应用的基础, ICAO需对北斗系统建设过程中所能达到的功能和性能进行验证, 确认北斗系统满足提供全球民航应用的要求, 以及其他卫星导航系统的兼容互操作性等要求, 最终根据验证结果, 在其现有标准文件中加入北斗系统相关技术标准和建设措施。

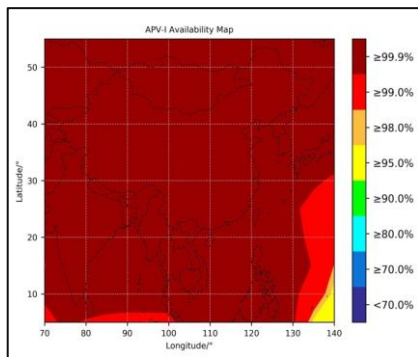
民航局于2010年在ICAO第37届大会上正式提交了北斗系统进入ICAO标准的申请, 并与中国卫星导航系统管理办公室共同组织北京航空航天大学空天一体新航行系统技术全国重点实验室等产学研单位组成工作团队系统推进相关工作, 十余年间历经28次工作会议、50余次技术讨论、提交

ICAO OACI ICAO
国际民航组织

In Nov. 2023, Recognized by ICAO, BDS becomes globally used satellite navigation system



APV-I availability of the BDSBAS



APV-I availability of the BDSBAS DFMC

Performance Indicators^[1]

Performance requirements	BDSABS		
	SF service	DFMC service	
Augmentation Objects	GPS L1C/A	BDS B1C/B2a GPS L1C/A/L5	
Frequency	BDS GEO B1C	BDS GEO B2a	
Accuracy	H: 16m, V: 20m	H: 16m, V: 4m	
Integrity	Time-to-alert	10s	6s
	Integrity risk	$2 \times 10^{-7}/150s$	
	Alert limit	HAL: 40 m VAL: 50 m	HAL: 40 m VAL: 10 m
Continuity	$1-8 \times 10^{-6}/15s$		
Availability	Better than 99%	Better than 99.9%	

BDSBAS Positioning Accuracy (95%)

	Horizontal	Vertical
SF	1.29m	1.99m
DFCM	0.77m	1.41m

Better than indicators

Civil Aviation Administration of China has initiated verification of BDSBAS. Single-frequency augmentation will be approved to provide for aviation users after verification

BDS/GNSS Applications

- Overall scale of BDS space-time information application steadily increasing
- Industrial applications going further and deeper
- User experience continuously improved



Smart Transportation

Comprehensively raise information level of transportation and help to smart city management



Agriculture, Forestry and Fisheries

Realizing cross-domain operating data integration, greatly improving operation management efficiency



Electric Power

Continuing to contribute BDS-based wisdom to the digitization of power grid



Express Delivery Logistics

99% accuracy, achieving faster delivery and higher efficiency



Traffic in Airport

Reducing accident risk in airport and enhancing operation and management efficiency



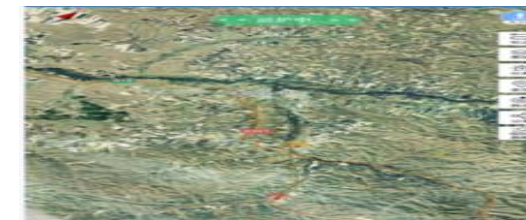
Smart Resources

Realizing smart operation and maintenance of photovoltaic hydropower stations



Emergency Management

Share emergency information and upgrade emergency response efficiency



Wild Life Protection

Track and monitor range of activity and migration trajectory of wild animals



Deformation Monitoring

High accuracy Safeguarding for the dam in Sarez Lake



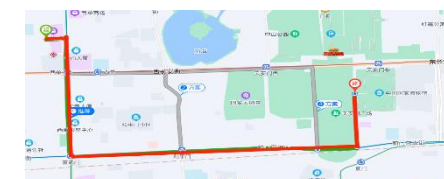
Smart Construction

Safeguarding life security, improving the quality and efficiency of construction



Mass Consumption

Becoming the standard configuration of smart phones, mobile phones supporting BDS accounted for 98.5%



Mobile Map

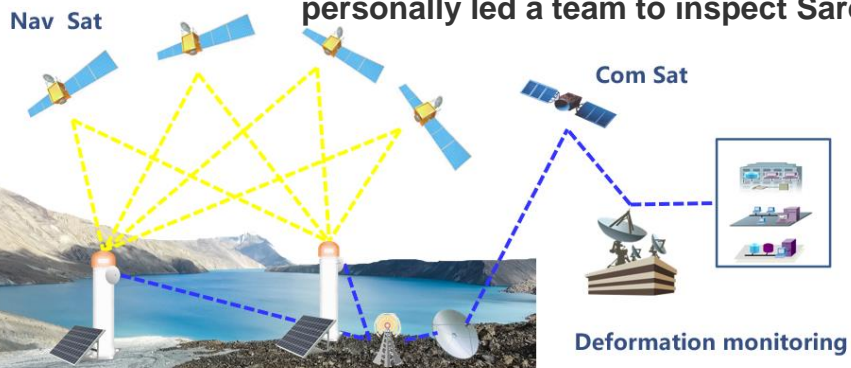
Daily use of BDS positioning service exceeding 360 billion times by mainstream map applications in China.

BDS/GNSS Applications

High Accuracy Application—Terrain Monitoring



In June 2017, UN secretary general, Antonio Guterres personally led a team to inspect Sarez lake



- Confronted with the threat of potential natural disaster in Sarez Lake in Tajikistan, China and Tajikistan utilized BDS to undertake the deformation monitoring and disaster warning in surrounding area in millimeter-level accuracy, providing important scientific and technological reference for the safety of the dam.

Monitoring achievement fully shown for scientific communication



- During the Second International Summit on BDS Applications in Oct. 2023, Dr. Majid Gulayozov from Dushanbe Branch Center of CAS Research Center for Ecology and Environment of Central Asia delivered a report of BDS Monitoring Systems for Safety on Lake Sarez.



- In Oct. 2023, China-Tajikistan cooperation on the Dam proudly listed one of the ten typical cases of the third Belt and Road Forum for International Cooperation

BDS/GNSS Applications

High Accuracy Application—Precision Agriculture

- Based on BDS real-time high-precision positioning technology, the positioning solution of intelligent agricultural machinery for conservation tillage automation and precision operation is realized in protection of Black Soil in China.



Routing Inspection and Soil Surveying Machinery



Broadcasting system

Building a **space-based augmentation information broadcasting system** for high-precision agricultural applications on black soil



Intelligent Terminals

Realizing **high-precision positioning is an effective measure** in agricultural applications such as intelligent agricultural machinery, precision seeding, variable fertilization, etc.

Processing System

Studying high-level augmented information generation algorithms for wide-area areas to form a comprehensive **information fusion processing system**



Tractor



Rice Transplanter



Reaping



Plant Protection

- Adaptive for different kinds of agricultural machineries
- Available for different application scenarios
- Different farming route selections

Without manual intervention



Precision Farming



Variable Rate Fertilization



Precision Harvesting



Precision Tillage

BDS/GNSS Applications

BDS Used to Offer Real-Time Three-Dimensional Immersed Tube Data



The E3 immersed tube of the Shenzhen-Zhongshan Bridge was connected to the E2 tube 20 meters underwater with guidance from BDS

During connection of tubes, BDS antennas equipped on board and nearby reference stations were used for differential positioning with millimeter-level accuracy. The reliable and stable performance of BDS positioning makes construction efficient and quality.



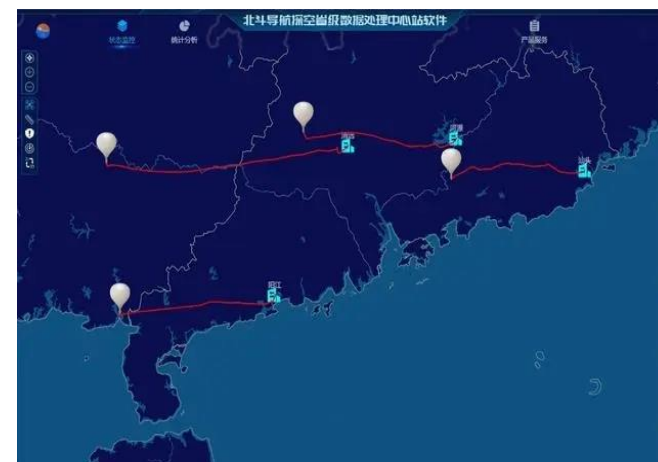
BDS/GNSS Applications

BDS Used for Horizontal Drift Air Sounding, Reducing Errors of Air Pressure and Wind Speed Measurement

Time: 1ST July, 2023

Location: Heyuan, Guangdong Province, China National Upper Air Synoptic Station

A researcher was flying a BDS-based radiosonde



In July 2023, China Meteorological Administration upgraded from L-band Radar to BDS-based Air Sounding. In September, BDS horizontal drift sounding system was carried out to realize the interaction of typhoon observation and forecast, and effectively improve the monitoring and forecast accuracy of "Typhoon Saola". The observation data based on BDS played an important role in CMA-GFS (China Meteorological Administration Global Forecast System).

BDS/GNSS Applications

BDS/GNSS Served for "The Belt and Road "Applications



BDS satellites are used to locate the trajectory of China-Europe Railway Express freight trains, record and save operation information in bad signal reception areas, then guarantee the integrity.



Silk Road Shipping, China's first cross-border e-commerce express container shipping alliance, deployed specially designed smart containers, and used Internet of Things technology, enabling users to visualize container flows through BeiDou and mobile communication.

International Cooperation | Bilateral Exchange

Exchange with GNSS

Exchange with RNSS



GPS



GLONASS



Galileo



QZSS



NavIC



KPS

Compatibility and Interoperability coordination and cooperation with GNSS providers:

- B2a compatibility coordination with GPS L5;
- Further implemented augmentation system and ground station construction, joint monitoring and assessment with GLONASS

Discussions with RNSS providers on topics of interests at different multi-lateral platforms:

- Discussion with QZSS, KPS on service performances of PPP and EWS, system development plan and visions.

International Cooperation | Multi-lateral Exchange

ICG



COPUOS



- Participated in ICG-17, Providers 'Forum, Planning Meeting, WG-Meetings, etc.
- Participated in 66th Session of Committee on the Peaceful Uses of Outer Space Sixty-sixth session, and 61st Session of Scientific and Technical Subcommittee;

International Cooperation | Share Development



BDS/GNSS Global Partner Forum (2023.04 Beijing, China)



Second International Summit on BDS Applications (2023.10 Hunan, China)



2023 International Training Workshop on BeiDou Technologies and its Applications in the Belt and Road Countries and Regions (2023.09 Beijing, China)



China-Arab States BDS Cooperation Forum (2023.10 Alexandria, Egypt)

International Cooperation | Potential Cooperation

Ionospheric Monitoring and Warning

Current solar activity requires to establish early warning and monitoring platform through coordination and discussion to eliminate the impact of solar activities on satellite navigation users.

- To Integrate Multi-source Products
- To Promote Information Sharing
- To Monitor Performance Fluctuation
- To Release Warning Message

LEO PNT

As an important augmentation to satellite navigation, LEO PNT providers are encouraged to join ICG PNT discussion.

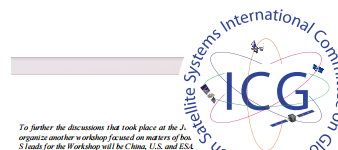
- Frequency Coordination
- LEO PNT Compatibility and Interoperability
- Compatibility and Interoperability between LEO and GNSS
- Discussion on Augmentation Features, Service Modes, Rules and Regulations, etc.

ICG REC/2023
Recommendation for Committee Decision

Prepared by: Working Group S
Date of Submission: 18 October 2023
Issue Title: Integration of Emerging Low Earth Orbit (LEO) PNT Providers into ICG
Background/Brief Description of the Issue:
Recognizing:

- The emergence of numerous new entities intending to provide PNT services, many utilizing Low Earth Orbit (LEO) satellites;
- The vital role played by ICG in promoting coexistence, cooperation, interoperability, and standardization among space-based PNT providers;
- The need for any PNT provider to thoroughly and transparently document expected and/or actual levels of performance to bolster confidence and promote adoption of the provider's services; and
- New providers' activities logically being relevant to the activities and responsibilities of several ICG Working Groups.

 Working Group S should incorporate the views of LEO PNT system providers into its activities and work on ways to better interact with these providers.
Discussion/Analysis:
The plans for LEO PNT systems need to be better understood. The Workshop organized by WG-S in June 2023 attempted to gather information about the systems, but it has become apparent that further engagement and coordination is needed to ensure compatibility and interoperability with the existing GNSS providers.
Recommendation of Committee Action:
ICG members should consider inviting domestic LEO PNT system providers (governmental and non-governmental) to participate in the ICG activities and its relevant working group meetings. This participation could be in various forms, including requesting ICG Observer Status if interested.



Lunar PNT

Lunar PNT under a heated discussion recent years. It's imperative to build up a compatible and interoperable Lunar PNT system together.

- Lunar PNT and Constellation Layout
- Service Requirements for PNT
- Signal Frequency, Message Structure, Service Standards
- Lunar PNT Coordinates and Time System

Future Visions



Back-up satellites for BDS-3 constellation will be launched in 2024 based on requirement to ensure a smooth transition from BDS-2 to BDS-3 without service interruption and performance degradation.

To comprehensively integrate satellite navigation with inertial, indoor, underwater, deep space and other navigation technologies, and new technologies such as 5G, big data and AI, to form seamless space-time information service capabilities on land, sea, air and space.

BDS willing to actively promote international development through pragmatic international cooperation on compatibility and interoperability with providers to better serve global users.



Thanks for your attention to BDS!

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<http://www.beidou.gov.cn>