Development of BeiDou Navigation Satellite System

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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**)
## Diversified Services

<table>
<thead>
<tr>
<th>Service Types</th>
<th>Signals/Bands</th>
<th>Broadcast Approaches</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Global</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RNSS</td>
<td>B1I, B3I</td>
<td>3GEO + 3IGSO + 24MEO</td>
</tr>
<tr>
<td></td>
<td>B1C, B2a, B2b</td>
<td>3IGSO + 24MEO</td>
</tr>
<tr>
<td>SBAS</td>
<td>BDSBAS-B1C, BDSBAS-B2a</td>
<td>3GEO</td>
</tr>
<tr>
<td><strong>China and Surrounding Areas</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GAS</td>
<td>2G, 3G, 4G, 5G</td>
<td>Mobile communication networks, Internet</td>
</tr>
<tr>
<td>PPP</td>
<td>PPP-B2b</td>
<td>3GEO</td>
</tr>
<tr>
<td>RSMC</td>
<td>Up: L Down: S</td>
<td>3GEO</td>
</tr>
</tbody>
</table>
BDS provides RNSS services for users on the ground and 1,000 km above space users.

Main BDS RNSS Performance Indicators\(^1\)

<table>
<thead>
<tr>
<th>Performance Characteristics</th>
<th>Performance Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Accuracy (95%)</td>
<td></td>
</tr>
<tr>
<td>Positioning</td>
<td>(H \leq 9\text{m}, \ V \leq 10\text{m})</td>
</tr>
<tr>
<td>Timing</td>
<td>(\leq 20\text{ns})</td>
</tr>
<tr>
<td>Velocity Measurement</td>
<td>0.2m/s</td>
</tr>
<tr>
<td>Service Availability</td>
<td>(\geq 99%)</td>
</tr>
</tbody>
</table>

- 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)

<table>
<thead>
<tr>
<th>Performance Indicators[1]</th>
<th>Test Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSMC</td>
<td>Delay≤60s</td>
</tr>
</tbody>
</table>

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- BDSMC used in the newly-launched Einstein Probe
- BDSMC used in China-France SVOM Joint Space Observatory
- BDSMC used in China’s Space Station
- BDSMC used in GECAM Space Probe

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

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

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

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

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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

<table>
<thead>
<tr>
<th>Performance Indicators[1]</th>
<th>Test Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>RSMC</td>
<td>Success Rate ≥ 95%</td>
</tr>
<tr>
<td></td>
<td>Delay ≤ 2s</td>
</tr>
<tr>
<td></td>
<td>Success Rate: 99%</td>
</tr>
<tr>
<td></td>
<td>Delay: 1s</td>
</tr>
</tbody>
</table>

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 IMSO**

Search and Rescue

MEOSAR

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

<table>
<thead>
<tr>
<th>Performance Characteristics</th>
<th>Performance Indicators$^{[1]}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positioning Accuracy</td>
<td>≤5km</td>
</tr>
<tr>
<td>Detection Probability</td>
<td>≥99%</td>
</tr>
<tr>
<td>Availability</td>
<td>≥99%</td>
</tr>
</tbody>
</table>

Performance results better than indicators

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


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

In November 2022, China formally becomes the provider of COSPAS-SARSAT space segment, performance results better than indicators

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

Positioning accuracy and convergence time

### BDS PPP service availability
Sat numbers ≥ 5, HDOP ≤ 2 & VDOP ≤ 4

### BDS+GPS PPP service availability
Sat numbers ≥ 6, HDOP ≤ 2 & VDOP ≤ 4

<table>
<thead>
<tr>
<th>Station</th>
<th>BDS-3 PPP</th>
<th>BDS-3&amp;GPS PPP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hor/m</td>
<td>Ver/m</td>
</tr>
<tr>
<td>BBJ1</td>
<td>0.14</td>
<td>0.20</td>
</tr>
<tr>
<td>CHU1</td>
<td>0.15</td>
<td>0.21</td>
</tr>
<tr>
<td>GUA1</td>
<td>0.20</td>
<td>0.26</td>
</tr>
<tr>
<td>KUN1</td>
<td>0.17</td>
<td>0.25</td>
</tr>
<tr>
<td>LHA1</td>
<td>0.20</td>
<td>0.26</td>
</tr>
<tr>
<td>SHA1</td>
<td>0.13</td>
<td>0.25</td>
</tr>
<tr>
<td>WUH1</td>
<td>0.17</td>
<td>0.22</td>
</tr>
<tr>
<td>XIA1</td>
<td>0.19</td>
<td>0.22</td>
</tr>
<tr>
<td>Mean value</td>
<td>0.17</td>
<td>0.23</td>
</tr>
</tbody>
</table>

- **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

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

**Performance Indicators**

<table>
<thead>
<tr>
<th>Performance requirements</th>
<th>BDSABS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Augmentation Objects</strong></td>
<td>SF service</td>
</tr>
<tr>
<td><strong>Frequency</strong></td>
<td>GPS L1C/A</td>
</tr>
<tr>
<td><strong>Accuracy</strong></td>
<td>BDS GEO B1C</td>
</tr>
<tr>
<td><strong>Time-to-alert</strong></td>
<td>H: 16m, V: 20m</td>
</tr>
<tr>
<td><strong>Integrity risk</strong></td>
<td>2×10⁻⁷/150s</td>
</tr>
<tr>
<td><strong>Alert limit</strong></td>
<td>HAL: 40 m, VAL: 50 m</td>
</tr>
<tr>
<td><strong>Continuity</strong></td>
<td>1-8×10⁻⁶/15s</td>
</tr>
<tr>
<td><strong>Availability</strong></td>
<td>Better than 99%</td>
</tr>
</tbody>
</table>

**BDSBAS Positioning Accuracy (95%)**

<table>
<thead>
<tr>
<th></th>
<th>Horizontal</th>
<th>Vertical</th>
</tr>
</thead>
<tbody>
<tr>
<td>SF</td>
<td>1.29m</td>
<td>1.99m</td>
</tr>
<tr>
<td>DFCM</td>
<td>0.77m</td>
<td>1.41m</td>
</tr>
</tbody>
</table>

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

**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

**Deformation Monitoring**
High accuracy Safeguarding for the dam in Sarez Lake

**Smart Construction**
Safeguarding life security, improving the quality and efficiency of construction

**Wild Life Protection**
Track and monitor range of activity and migration trajectory of wild animals

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

**Express Delivery Logistics**
99% accuracy, achieving faster delivery and higher efficiency

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

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.

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
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.

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

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

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 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.
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.
● 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)
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

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.

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
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.

Build a comprehensive space-time system and draw up new visions for future development
Accelerate the construction of the next generation of BeiDou and help build a community with a shared future for mankind
Thanks for your attention to BDS!

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http://www.beidou.gov.cn