Development of BeiDou Navigation Satellite System

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National Time Service Center,
Chinese Academy of Sciences
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Constellation Status

A total of 46 satellites operational in orbit

Including:

15 BDS-2 Satellites

31 BDS-3 Satellites (30 networking satellites and 1 back-up satellite)

The 56th satellite for China’s BeiDou Navigation Satellite System (BDS) was launched at Xichang

- To promote the network’s availability and stability
- To expand the communication capacity of the system’s regional short-messaging function by 1/3
- To enhance positioning accuracy of satellite-based augmentation and precise point positioning and realize quick high-accuracy positioning
- In-Orbit test and assessment of GEO-4 finished
## Diversified Services

<table>
<thead>
<tr>
<th></th>
<th>RNSS</th>
<th>GSMC</th>
<th>SAR</th>
<th>RSMC</th>
<th>PPP</th>
<th>SBAS</th>
<th>GAS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Channel</strong></td>
<td>24MEO + 3GE O + 3IGSO</td>
<td>Up: 14MEO Down: 3IGSO + 24MEO</td>
<td>Up: 6MEO Down: 3IGSO + 24MEO</td>
<td>3GEO</td>
<td>3GEO</td>
<td>3GEO</td>
<td>Mobile Communication &amp; Internet</td>
</tr>
<tr>
<td><strong>Information Provided</strong></td>
<td>GNSS</td>
<td>Short Message</td>
<td>Alarming Message</td>
<td>Short Message</td>
<td>Corrections</td>
<td>Error Corrections and integrity</td>
<td></td>
</tr>
<tr>
<td><strong>Functions</strong></td>
<td>Positioning, Navigation, Timing</td>
<td>Location Reporting, Emergency Rescue, Short Message Communication</td>
<td>Warning &amp; Alarming</td>
<td>Precise Positioning Point</td>
<td>Augmentation and Integrity</td>
<td>RTK</td>
<td></td>
</tr>
<tr>
<td><strong>Performances</strong></td>
<td>Horizontal 9m Vertical 10m</td>
<td>Maximum length of a single message: 560 bits</td>
<td>Return link delay: ≤2mins Return link success rate: ≥95%</td>
<td>Maximum length of a single message: 14000 bits</td>
<td>Horizontal 0.3m Vertical 0.6m Convergence time 30 mins</td>
<td>Positioning, warning time, integrity risk</td>
<td>Real-time cm-level, post-processing mm-level</td>
</tr>
<tr>
<td><strong>Service Area</strong></td>
<td>Global</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

Ref.: China's BeiDou Navigation Satellite System in the New Era  (scio.gov.cn)
BDS-3 system and service performances fully better than indicator requirements by ICD.
Intelligent operation and management, in-orbit software refactoring, real-time monitoring and assessment, stable operation and better performances realized since officially commissioned.
RNSS service performances

BDS B1C/B2a Continuity
99.996%

BDS B1C Position Accuracy (Global, 95%)

BDS B1C/B2a Availability 100%

BDS B1C Position Accuracy (August, 2023)
Short Message Communication Service

Global Short Message Communication
- 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)

Global Short Message Communication
- Coverage: China and surrounding area
- Space Segment: 3 GEO satellites at 80°E, 110.5°E, 140°E
- Maximum length of a single message: 14,000 bits (around 1,000 Chinese characters)
- Main functions: search & rescue, location report, short message communication, etc.

Available for Authorized Users

In 2023, two-way BDS short message communication service is realized on some domestic smart phone brands. "Directly-connected to satellite" has become the standard of some domestic series products, and the number of social units has exceeded 10 million.

Missing people sent distress messages and positioning coordinates through the short message communication function on mobile phone and were successfully rescued.
Search and Rescue Service

Monitoring and assessment was carried out in accordance with the guidelines for monitoring and assessment. The assessment results in May, 2023 showed that:

- MEO SAR meets technical requirement, six BDS SAR payloads meet standards, and have the ability to transmit distress signals.
- The return-link service meets the technical requirements. Within 2 minutes, 99% of the return-link messages should be broadcast.

### MEOSAR

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positioning Accuracy</td>
<td>4.38km</td>
</tr>
<tr>
<td>Detection Probability</td>
<td>99.2%</td>
</tr>
<tr>
<td>Availability</td>
<td>99%</td>
</tr>
</tbody>
</table>

### RLS

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time Delay</td>
<td>15s</td>
</tr>
<tr>
<td>Service Success Rate</td>
<td>99%</td>
</tr>
</tbody>
</table>

Unscripted Maritime Search and Rescue Exercise

**Danger Scene Simulation:** A boat flipped over by strong wind and 11 people missing on the sea

Hebei Province Maritime Search and Rescue Center coordinates and directs the national professional rescue vessels, fisheries and other public vessels, and social rescue forces for interaction.

**BDS search and rescue beacons**, and integrates new technologies and equipment such as rescue helicopters, drones, underwater robots and intelligent unmanned boats utilized.

SAR performances tested in real maritime environment, distress alert procedure review carried out for all services, a comprehensive search and rescue network covering sea-land-air and space established.

### RLS Delay Test and Assessment

- **Beijing**
  - RLS (from ground-based supporting system to user terminals)
  - Average Delay 9.1s

- **London**
  - RLS (from ground-based supporting system to user terminals)
  - Average Delay 34s
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

<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>BJF1</td>
<td>0.14</td>
<td>0.19</td>
</tr>
<tr>
<td>CHU1</td>
<td>0.21</td>
<td>0.30</td>
</tr>
<tr>
<td>GUA1</td>
<td>0.23</td>
<td>0.30</td>
</tr>
<tr>
<td>KUN1</td>
<td>0.12</td>
<td>0.25</td>
</tr>
<tr>
<td>LHA1</td>
<td>0.24</td>
<td>0.30</td>
</tr>
<tr>
<td>SHA1</td>
<td>0.15</td>
<td>0.27</td>
</tr>
<tr>
<td>WUH1</td>
<td>0.16</td>
<td>0.21</td>
</tr>
<tr>
<td>XIA1</td>
<td>0.13</td>
<td>0.22</td>
</tr>
<tr>
<td>Mean value</td>
<td>0.17</td>
<td>0.26</td>
</tr>
</tbody>
</table>

BDS
• Positioning accuracy:
  • Horizontal (95%) 17cm, Vertical (95%) 26cm
• Convergence time:
  • 17min (H≤30cm, V≤60cm)

BDS+GPS
• Positioning accuracy:
  • Horizontal (95%) 11cm, Vertical (95%) 22cm
• Convergence time:
  • 10min (H≤20cm, V≤40cm)

Coverage

**PPP-B2b Service Performance**
**Indicator Requirement**

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

- BDSBAS positioning accuracy (average)
  - SF service: $HPE(95\%)=1.82m$, $VPE(95\%)=2.32m$;
  - DFMC service: $HPE(95\%)=1.17m$, $VPE(95\%)=1.91m$;
- During the evaluation period, no HMI occurred;
- Availability better than 99.99%.
BDS Product Steady Growth

BDS Basic Product

- A complete industrial chain of chips, modules, antennas, boards formed, software and algorithms are completely independently developed, forming a sound development trend.

- By the end of 2022, the accumulated sales volume of chips and modules compatible with BDS exceed 300 million, quantity of terminals supporting BDS positioning (including smart phone) is over 1.28 billion.

BDS Terminals

- Based on GNSS/LBS Association of China, the sales volume of terminals supporting BDS was 376 million in 2022, including 264 million smart phones, 12 million onboard navigators, and more than 100 million IoT, wearable, and onboard high accuracy terminals.
BDS/GNSS Applications in Precision Agriculture

**Automatic Driving of Farm Machinery**

- Accuracy of 2.5 cm, 30% increase in machinery scheduling efficiency, 5% enhancement in crop production, 10% saving in fuel consumption
- Over 1.6 million intelligent agricultural machineries supporting auto-steering and remote management put into application, and all supporting 62 reference stations are established and in operation

**Plant Protection UAV**

- Based on RTK-based centimeter-level high-precision, autonomous flight of the plant protection UAV realized according to the route generated by pre-mapping and the parameters set. It can adjust the translation distance and flight speed on the set regional route, to control the flight operation spray range and improve the operation efficiency.
- To spray 300 to 500 acres of land/ per day, and the operation efficiency is 60 to 80 times that of manual labor.

**Heat Map Based on BDS-based Statistics in Harvest Time**

- Agricultural Machineries equipped with BDS terminals played important role in grain production in summer and autumn harvests.
- Trillions of big data statistics were generated.

**Annual cumulative operation area reached 10 million acres, significantly improving agricultural production efficiency**
Intelligent Analysis of Heavy Truck Pollution and Environmental Protection Information

Real-time pollution emission assessment and intelligent monitoring system of heavy trucks collects multi-source real-time data including BDS-based positioning monitoring in urban area and carries out intelligent real-time analysis.

BDS used in driving monitoring, infrastructure and facility safety monitoring, and environmental protection monitoring of heavy trucks. By the end of 2022, more than 8 million BDS-supporting terminals registered in one of the largest dynamic transportation monitoring systems, realizing the 100% coverage in business areas such as public service vessel and costal navigation equipment.

BDS installed in

- More than 8 million road transport vehicles nationwide
- More than 90,000 express vehicles nationwide
- More than 48,000 vessels nationwide
- More than 13,000 costal navigation aid facilities
BeiDou Services including PNT, Timing and Frequency, and Short Message Communication all fully applied in the field, with more than 380,000 devices and terminals.

- Safety management of employees ensured based on BDS-based electronic fence, crane arm alarming and protection and other sub-systems.
- High precision positioning based UAV supports automatic correction of deviation and powerline inspection. Employees check the extent of damage with the UAVs which can inspect powerline according to presuppose settings.
- BDS short message communication also can be used for safe transmission of relevant data information and control instruction.

100% Power Regulation, Information Management
All applying BDS Timing Signals

100% Frequency Synchronization Backbone Network
All receiving BDS Frequencies

100% Vehicles in Power Industry
All equipped BDS Terminals
BDS/GNSS Applications

High Accuracy Application——Terrain Monitoring

- BDS successfully used in national coordinate framework monitoring and plate movement monitoring with accuracy better than 3mm
- In landslide and deformation monitoring, BDSMC used for transferring alert information
- “BDS + Smart Monitoring and Early Warning Cloud Platform” being applied in more than 600 buildings and structures in different areas in China and gave alarm 600 times, with 8000+ monitoring points distributed

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.

In June 2017, UN secretary general, Antonio Guterres personally led a team to inspect Sarez lake
Based on BDSBAS PPP, real-time decimeter-level measurement and downlink information realized.

BDS location report covered the whole height measurement procedure.

China and Nepal announced the Mount Everest stands at 8848.46m (about 29032 feet) on December 8, 2020.
Disaster Relief

"BDS + Smart Monitoring and Early Warning Cloud Platform" being applied in more than 600 buildings and structures in different areas in China and gave alarm 600 times, with 8000+ monitoring points distributed.

Resource Management

Forest rangers used BDS-based forestry patrol terminal to carry out inspection

Public Security

More than 110,000 BDS terminals applied in forestry and grassland fire prevention, forestry inspection and management, realizing route planning and navigation, positioning for vehicles, disaster monitoring, and personnel safety management.

The public security industry has promoted and applied more than 4.5 million BDS terminals in information collection, mobile policing, communication support, and command and dispatch.
BDS-based location service industries remains active, becoming the most important engine for the development of China's satellite navigation and location service industry, significantly improving travel experience of users.

The number of shared bike users exceeds 300 million. The average daily order volume exceeds 45 million.

In 2022, a total of more than 5 million online car driver licenses were issued across the country, and 6.96 billion orders were completed throughout the year.
BDS/GNSS Applications in Civil Aviation

Vehicle Management in Airport

- BDS+5G+Multi-Sensors, high-accuracy/active secure onboard terminal and management platform in different airports established in China
- Lane-level positioning, tracing and management realized in every corner of airport
- Comprehensive visual monitoring of vehicles moving in airport realized

Reduce accident risk in airport and enhance operation and management efficiency

Civil Aviation Tracking and Positioning

- Consist of BDS tracking and positioning device, BDS system, BDS main positioning station, and data receiving stations
- Real-time positioning and tracking, also monitoring on speed, direction, height, angle, fuel quantity realized
- Accumulated 19,000 hours for 9,700 flights with 1.05 million data on flight, success rate of data report within 1 minute reaching 97%

Meet 4D/15 tracking requirement by ICAO
BDS basic products have been applied in more than half of the world’s countries and regions, with more diverse models and constantly expanding fields. BDS products, technologies, and services are gaining more recognition from international users.
International Cooperation

Compatibility and Openness through Bilateral and Multilateral Exchange

- Continuing to carry out compatibility and interoperability coordination and cooperation with providers including GPS, GLONASS, Galileo, QZSS, NavIC, etc.
- Joint discussion and platform construction with The Belt and Road countries, promoting global satellite navigation industry development together.

Deeply and continuously engaged in activities under multi-lateral framework such as UNOOSA, held ICG annual meetings twice in 2012 and 2018, participated the ICG-16 in Abu Dhabi, UAE in Oct. 2022, ICG-17 planning meetings to promote compatibility and mutual development with other systems and better serve the world.
International Cooperation

Active Participation to Academic Exchange

International Cooperation

Ratification by International Standards to Better Serve the World

In Nov. 2022, BeiDou has been adopted as the third operator to provide tracking systems for ships after being given a certificate by the International Maritime Organization (IMO).

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

In June 2022, BDS B2a and B3I signal technology standard proposals passed 3GPP deliberations. BDS positioning technology standards, which are supported by the Fourth- and Fifth-generation mobile communication system network, have been officially released.

BDS technical indicators have been verified by ICAO and meet the standards. It has the ability to provide PNT services for global civil aviation users.
Future Visions

• ①1-3 back-up satellites for BDS-3 constellation will be launched in 2023, to further improve the stability and availability.

• ②Continuously improve the intelligent operation and services of BDS ground segment, to ensure the steady operation and to upgrade performance.

• ③Further promote marketization, industrialization, and internationalization of BDS scale applications.
Thanks for your continuous attention and support to the BDS development!

http://www.beidou.gov.cn