Update on BeiDou Navigation Satellite System

China Satellite Navigation Office
BDS Development

Near-term Plans
BD-2 System

- FOC services from December, 2012 (5GEO+5IGSO+4MEO)
- Two on-orbit backup satellites launched in 2016 (1 IGSO+1 GEO)
- Further improve the stability and availability of BD-2 constellation
- Position accuracy meets with the nominal specification within service area (10 m), and the mean value is 2.3 m (Horizontal) and 5.7 m (Vertical), according to the iGMAS analysis data

![BDS Position Accuracy in Oct. 2017](image1)

![GPS Position Accuracy in Oct. 2017](image2)
## BD-3 System

<table>
<thead>
<tr>
<th>Space Segment</th>
<th>Ground Segment</th>
<th>User Segment</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 3 GEO</td>
<td>• Master Control Station</td>
<td>• BDS terminal</td>
</tr>
<tr>
<td>• 3 IGSO</td>
<td>• Uplink Stations</td>
<td>• Terminal compatible with other navigation systems</td>
</tr>
<tr>
<td>• 24 MEO</td>
<td>• Monitoring Stations</td>
<td></td>
</tr>
</tbody>
</table>

- **Space Segment**
  - 3 GEO
  - 3 IGSO
  - 24 MEO

- **Ground Segment**
  - Master Control Station
  - Uplink Stations
  - Monitoring Stations

- **User Segment**
  - BDS terminal
  - Terminal compatible with other navigation systems
Development Steps of BD-3 System

Step I: Experimental System
(2 IGSO+3 MEO)
Already completed

Step II: Basic System
(18 MEO+1 GEO)
RNSS services before Dec. 2018

Step III: Complete System
(24 MEO+3 GEO+3 IGSO)
Global services before Dec. 2020
BS-3 Experimental System

- 5 BD-3 experimental satellites were launched (2 IGSO+3 MEO)
- Test 4 frequencies and signals of RNSS signals
  - B1 (1575.420MHz); B2 (1191.795MHz)
  - B3 (1268.520MHz); Bs (2492.028 MHz)
- Add Ka-band inter-satellite-link
- New Hydrogen and Rubidium clocks
- Verification of
  - inter-satellite-link
  - timing system
  - precision orbit determination and prediction
  - PVT specifications assessment
BS-3 Experimental System Performance

- Based on the results of experiments and verifications, BD-3 signal status has been solidified.
- BD-3 System performance is much better than that of BD-2:
  - Frequency accuracy has been improved from $5 \times 10^{-13}$ to $6 \times 10^{-14}$
  - Frequency stability has been improved from $2 \times 10^{-14}(1d)$ to $6 \times 10^{-15}(1d)$
  - Inter-satellite-link supports the high-precision determination and prediction of satellite orbit and clock offset
  - Stability of rubidium atomic clock: $10^{-14}$
  - Stability of hydrogen atomic clock: $10^{-15}$
  - Time synchronization accuracy: 0.14 ns
  - Multipath effect and pseudo range noise is greatly approved.

Time series of pseudo-range errors
- Pseudo-range multipath of BDS2 has the elevation angle related systematic effects, especially in B1I signal
- In the new test constellation, however, the elevation angle related multipath is significantly decreased
**BS-3 Global Constellation**

- On November 5, 2017, the first pair of the 24 BD-3 MEO satellites was successfully launched.

- These two satellites are operating in-orbit normally, will provide services after tests and networking validation, and accelerate the global coverage of BDS.

- By utilizing new technologies, the signal-in-space (SIS) accuracy will be superior to 0.5m, the position accuracy will be doubled or quadrupled, and reach 2.5m to 5m.
Information Dissemination

- The BDS Signal In Space Interface Control Document Open Service Signals B1C and B2a (test version) has been released on website http://en.beidou.gov.cn
- The official version will be released by the end of 2017

### Other Disseminations

<table>
<thead>
<tr>
<th>Other Disseminations</th>
<th>Date of Release</th>
</tr>
</thead>
<tbody>
<tr>
<td>BDS SIS ICD (beta version)</td>
<td>Dec. 2011</td>
</tr>
<tr>
<td>BDS SIS ICD (V 1.0)</td>
<td>Dec. 2012</td>
</tr>
<tr>
<td>BDS Open Service Performance Standard (V 1.0)</td>
<td>Dec. 2012</td>
</tr>
<tr>
<td>BDS SIS ICD Open Service Signal (V 2.0)</td>
<td>Dec. 2013</td>
</tr>
<tr>
<td>BDS SIS ICD Open Service Signal (V 2.1)</td>
<td>Nov. 2016</td>
</tr>
</tbody>
</table>
## Planning of BD-3 Services

<table>
<thead>
<tr>
<th>Service type</th>
<th>Signal frequency</th>
<th>Satellite</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNSS</td>
<td>Open</td>
<td>B1I, B3I, B1C, B2a, B2b</td>
</tr>
<tr>
<td></td>
<td>Authorized</td>
<td>B1A, B3Q, B3A</td>
</tr>
<tr>
<td>SBAS</td>
<td>Open</td>
<td>B1C, B2a</td>
</tr>
<tr>
<td></td>
<td>Authorized</td>
<td>B1A</td>
</tr>
<tr>
<td>Regional short message communication services</td>
<td>Authorized</td>
<td>L(Inbound), S(Outbound)</td>
</tr>
<tr>
<td>Global short message communication services</td>
<td></td>
<td>L (uplink), B2b (downlink)</td>
</tr>
<tr>
<td>International SAR service</td>
<td></td>
<td>uplink: 406MHz</td>
</tr>
<tr>
<td>Transmission of precise positioning information</td>
<td></td>
<td>downlink: 1544-1545MHz</td>
</tr>
</tbody>
</table>
### Planning of BD-3 Services

<table>
<thead>
<tr>
<th>Service type</th>
<th>Service area</th>
<th>Nominal Specification</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>RNSS</td>
<td>Global</td>
<td>Positioning accuracy &lt; 10 m</td>
<td>In the Asia-Pacific region, services are improved by the GEO and IGSO satellites</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Timing accuracy &lt; 20 ns</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Velocity accuracy &lt; 0.2 m/s</td>
<td></td>
</tr>
<tr>
<td>short message communication</td>
<td>China and the surrounding</td>
<td>Regional communication ability &lt; 1000 Chinese</td>
<td>RDSS, GEO satellites</td>
</tr>
<tr>
<td>services</td>
<td>areas</td>
<td>characters per time</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Global</td>
<td>Trial communication ability &lt; 40 Chinese</td>
<td>Communication + RNSS, MEO satellites</td>
</tr>
<tr>
<td></td>
<td></td>
<td>characters per time</td>
<td></td>
</tr>
<tr>
<td>Transmission of precise</td>
<td>China and the surrounding</td>
<td>Transmission of decimeter-level precise</td>
<td>B2b signal of GEO satellites</td>
</tr>
<tr>
<td>positioning information</td>
<td>areas</td>
<td>positioning information (1 kbps)</td>
<td></td>
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<tr>
<td></td>
<td></td>
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</tbody>
</table>
Progress of BDSBAS

➢ In October 2017, 3 PRN codes (No. 130, 143, 144) at L1C/A and L5 for the BDSBAS were assigned

➢ BDSBAS has been recognized as an official SBAS provider in the ICAO family
  • The SBAS service provider identifier has been assigned
  • The UTC standard identifier has also been assigned by the ICAO

➢ Above progress has laid foundation for the follow-up construction of BDSBAS, as well as its provision of standard navigation services for the civil aviation sector
Planning of BDSBAS

- **Space Segment**
  - Three BD-3 GEO satellites (80°E, 110.5°E, 140°E)

- **Ground Segment**
  - Operation and Control Center, Data Centers, Uplink Stations, Monitoring Stations

- **User Segment**
  - SBAS terminals can receive RNSS navigation messages and wide area differential integrity information broadcast by GEO satellites
Planning of BDSBAS

- Following the ICAO standards
- Service area: China and surrounding areas
- Providing CAI-I service

<table>
<thead>
<tr>
<th>Service accuracy(95%)</th>
<th>Positioning accuracy</th>
<th>Single frequency</th>
<th>Double frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>H &lt; 2.5m, V &lt; 4.0m</td>
<td>H &lt; 1.5m, V &lt; 2.0m</td>
</tr>
<tr>
<td>Timing accuracy</td>
<td></td>
<td>10ns</td>
<td></td>
</tr>
<tr>
<td>Velocity accuracy</td>
<td></td>
<td>0.1m/s</td>
<td></td>
</tr>
<tr>
<td>Availability</td>
<td></td>
<td>&gt;99%</td>
<td></td>
</tr>
<tr>
<td>Integrity</td>
<td></td>
<td>Alarm time: 6s</td>
<td>Risk probability: 10^-7/approach</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(threshold: H 40m, V 10-15m)</td>
<td></td>
</tr>
<tr>
<td>Continuity</td>
<td></td>
<td>Risk probability: 10^-6/15s</td>
<td></td>
</tr>
</tbody>
</table>
Planning of SAR Services

- Six MEO satellites with SAR payloads
- Following the IMO standards to serve the global users
- Providing reliable distress alert
- Meeting with the basic requirements of joining in COSPAS-SARSAT
BDS Applications

- The domestic output value of BDS-related industry in 2016 surpassed RMB 210 billion, of which BDS contributed more than 70%.
- By October 2017, the sales volume of BDS navigation chips and modules exceeded 50 million pieces, and that of high-precision surveying boards and navigation antenna captured 30% and 90% of market shares respectively.
- At present, BDS has already covered more than 50 countries and over 3 billion people. BDS-related products have accessed to the markets of over 70 countries and regions.
- With the release of the first Chinese in-house developed meter-level fast positioning BDS chip, BDS applications have begun to embrace the era of meter-level positioning.
BDS Applications

- BDS has been widely applied in the transportation, logistics, marine fishing, precision agriculture, land mapping, deformation monitoring, emergency rescue, and other industries and fields:
  - In traffic management industry, the amount of major accidents has decreased by 46.7%, and the death toll has reduced by 48.9%
  - With the BDS-based maritime applications, over 10,000 lives have been saved
  - The production of precision agriculture has increased by 5%, and the oil consumption by agricultural machine has decreased by 10%
  - The time for surveying and mapping of national land is shortened from a few days to several seconds
BDS Applications

- BDS has been fully put into mass applications
- The BDS-based navigation services has been adopted by various enterprises in the fields of manufacturing of mobile and smart terminals, location-based services (LBS), e-commerce, and so on
- BDS-based LBS have been widely applied in mass consumption sector and people's livelihood, and many innovative applications have emerged, such as caring for the seniors and children, shared vehicles, BDS-based logistics, and so on, which have been changing people's life and providing more convenience for the public.
International Cooperation of BDS

- The Joint Statement on Civil Signal Compatibility and Interoperability between the GPS and the BDS was signed in November 2017
- The Fourth Meeting of China-Russia Cooperation Program Committee on Satellite Navigation was held in October 2017, while the joint iGMAS service statement was signed, and the service platform was kicked off
- In March 2017, a multi-system (GPS/GLONASS/BDS) ship-borne receiver standard was approved by the IMO
- BDS has been included in the PNT guidelines of maritime applications
International Academic Exchanges

- The 9th China Satellite Navigation Conference will be held between May 23rd and 25th, 2018, in Harbin, Heilongjiang Province.
- China will host the ICG-13 meeting from Nov. 4th to 9th, 2018, in Xi'an, Shaanxi Province, after the precedent organization of ICG-7 in
1
BDS Development

2
Near-term Plans
Near-term Plans

➢ Deployment of BD-3 System
  • 16 MEO+1 GEO satellites to be launched in 2018
  • Another 6 MEO+3 IGSO+2 GEO satellites to be launched between 2019 and 2020

➢ Construction of BDSBAS
  • First GEO satellite with BDSBAS payload to be launched in 2018, to implement system integration and test
  • Improve the construction of ground monitoring stations network in 2019
  • Another two GEO satellites with BDSBAS to be launched in 2020, to form initial operational capability

➢ Make plans to build a BDS-based PNT system
  • Covering indoor, underwater, space and other special areas
  • Looking forward to sharing proposals and experience with relevant countries regarding building a PNT system
Near-term Plans

- Continue to promote integrated applications and development of related industries
  - Bring GNSS high-precision services in combination with cloud computing, Internet of Things, big data and other technologies
  - Push forward the integration between BDS-related industries and high-end manufacturing, software, integrated data industries

- The domestic output value of BDS-related industry in 2020 will exceed 400 billion

- Keep enhancing cooperation and communication with other navigation satellite systems, and provide better services to the users along the “Belt and Road” area, and all over the world
Thanks for your attention and support for BDS!

China Satellite Navigation Office
http://en.beidou.gov.cn