



China's BeiDou Navigation Satellite System

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Preface

The BeiDou Navigation Satellite System (hereinafter referred to as the BDS) has been independently constructed and operated by China with an eye to the needs of the country's national security and economic and social development. As a space infrastructure of national significance, the BDS provides all-time, all-weather and high-accuracy positioning, navigation and timing services to global users.

In the late 20th century, China started to explore a path to develop a navigation satellite system suitable for its national conditions, and gradually formulated a three-step strategy of development: to complete the construction of the BDS-1 and provide services to the whole country by the end of 2000; to complete the construction of the BDS-2 and provide services to the Asia-Pacific region by the end of 2012; and to complete the construction of the BDS and provide services worldwide around 2020.

Along with the development of the BDS project and service ability, related products have been widely applied in communication and transportation, marine fisheries, hydrological monitoring, weather forecasting, surveying, mapping and geographic information, forest fire prevention, time synchronization for communication systems, power dispatching, disaster mitigation and relief, emergency search and rescue, and other fields. These products are gradually penetrating every aspect of social production and people's life, injecting new vitality into the global economy and social development.

Navigation satellite systems are public resources shared by the whole globe, and multi-system compatibility and interoperability has become a trend. China applies the principle that "The BDS is developed by China, and dedicated to the world" to serve the development of the Silk Road



Economic Belt and the 21st Century Maritime Silk Road (“Belt and Road Initiative” for short), and actively pushes forward international cooperation related to the BDS. As the BDS joins hands with other navigation satellite systems, China will work with all other countries, regions and international organizations to promote global satellite navigation development and make the BDS better serve the world and benefit mankind.



I. Goals and Principles of Development

China lays store by the construction of the BDS, ranking it one of its national key technical projects that supports its innovative development strategy.

(I) Goals of Development

Building a world-class navigation satellite system to meet the needs of the country's national security as well as economic and social development, and providing continuous, stable and reliable services for global users; developing BDS-related industries to support China's economic and social development, as well as improvement of people's living standards; and enhancing international cooperation to share the fruits of development in the field of satellite navigation, increasing the comprehensive application benefits of Global Navigation Satellite System (GNSS).

(II) Principles of Development

China upholds the principles of “independence, openness, compatibility and gradualness” in the BDS construction and development.

– By “independence,” it means to uphold independent construction, development and operation of the BDS, and acquire the capability to independently provide satellite navigation services to global users.

– By “openness,” it means to provide open satellite navigation services free of charge, and encourage all-scale, multilevel and high-quality international cooperation and exchange.

– By “compatibility,” it means to enhance BDS compatibility and interoperability with other navigation satellite systems, and encourage international cooperation and exchanges, so as to provide better services to users.



– By “gradualness,” it means to carry out the BDS project step by step, enhance BDS service performance, and boost the development of satellite navigation industry in a comprehensive, coordinated and sustainable manner.



II. Development of the BDS

Based on its national conditions, China has independently developed the BDS step by step with constant improvement.

(I) Three-Step Strategy of Development

– The first step is to construct the BDS-1 (also known as BeiDou Navigation Satellite Demonstration System). The project was started in 1994, and the system was completed and put into operation in 2000 with the launching of two Geostationary Earth Orbit (GEO) satellites. With an active-positioning scheme, the system provided users in China with positioning, timing, wide-area differential and short message communication services. The third GEO satellite was launched in 2003, which further enhanced the system's performance.

– The second step is to construct the BDS-2. The project was started in 2004, and by the end of 2012 a total of 14 satellites – 5 GEO satellites, 5 Inclined Geosynchronous Satellite Orbit (IGSO) satellites and 4 Medium Earth Orbit (MEO) satellites – had been launched to finish the space constellation deployment. Based on a technical scheme which was compatible with the BDS-1, the BDS-2 added the passive-positioning scheme, and provided users in the Asia-Pacific region with positioning, velocity measurement, timing, wide-area differential and short message communication services.

– The third step is to construct the BDS. The project was started in 2009 to inherit the technical schemes of both active and passive services. The goal is to provide basic services to the countries along the Belt and Road and in neighboring regions by 2018, and to complete the constellation deployment with the launching of 35 satellites by 2020 to provide

services to global users.

(II) Main Composition of the BDS

The BDS is mainly comprised of three segments: space segment, ground segment and user segment.

– The space segment. The BDS space segment is a hybrid navigation constellation consisting of GEO, IGSO and MEO satellites.

– The ground segment. The BDS ground segment consists of various ground stations, including master control stations, time synchronization/uplink stations, and monitoring stations.

– The user segment. The BDS user segment consists of various kinds of BDS basic products, including chips, modules and antennae, as well as terminals, application systems and application services, which are compatible with other systems.

(III) Characteristics of the BDS

The BDS development follows a model of developing regional service capacities, then gradually extending the service globally. This practice has enriched the development models for navigation satellite systems worldwide.

The BDS possesses the following characteristics: First, its space segment is a hybrid constellation consisting of satellites in three kinds of orbits. In comparison with other navigation satellite systems, the BDS operates more satellites in high orbits to offer better anti-shielding capabilities, which is particularly observable in terms of performance in the low-latitude areas. Second, the BDS provides navigation signals of multiple frequencies, and is able to improve service accuracy by using combined multi-frequency signals. Third, the BDS integrates navigation and communication capabilities for the first time, and has five major functions – real-time navigation, rapid positioning, precise timing, location reporting and short message communication services.



(IV) Improvement of BDS Performance

To meet the increasing user demand, BDS technical research and development in the areas of satellites, atomic clocks and signals will be strengthened, and a new generation of navigation, positioning and timing technologies will be explored to improve service performance.

– Providing global services. China will launch new-generation navigation satellites, develop airborne atomic clocks with enhanced performance, further improve the performance and lifetime of satellites, and build more stable and reliable inter-satellite links. It will broadcast additional navigation signals, and enhance the compatibility and interoperability with other navigation satellite systems, so as to provide better services for global users.

– Strengthening service capabilities. China will establish a grounded test and validation bed to accomplish the full coverage of tests and validation for space and ground equipment; continue to build and improve satellite based and ground based augmentation systems to substantially enhance BDS service accuracy and reliability; optimize the technical system of location reporting and short message communication to expand user volume and service coverage.

– Maintaining spatio-temporal reference. The BDT is related to the Coordinated Universal Time, and the time bias information is broadcast in the navigation message. China will push forward the clock bias monitoring with other navigation satellite systems, and improve their compatibility and interoperability. It will develop a BDS-based worldwide location identification system, increase the interoperability between BDS coordinate frame and that of other navigation satellite systems, and constantly refine the reference frame.



III. Reliable and Safe Satellite Navigation Services

China is committed to ensuring the safe and reliable operation of the BDS by taking multiple measures, and to providing continuous, stable and reliable open services to users free of charge.

(I) Ensuring Safe and Reliable BDS Operations

– Improving the management mechanism on operation. Perfecting a normalized multi-party response mechanism for BDS space segment, ground segment and user segment. Continuously enhancing the capability of assurance to manage the operation of large-scale constellations.

– Establishing a GNSS monitoring and assessment network. Constructing an international GNSS Monitoring and Assessment System, actively implementing international cooperation, extensively exploiting international resources, carrying out monitoring and assessment of the constellation status, signal accuracy, signal quality and service performance of the BDS at every scale, and providing references for users' applications.

– Taking a redundant and backup approach. Adopting a satellite backup strategy both in-orbit and on-ground to reduce and avoid the effects of emergent in-orbit satellite fault affecting service performance. Redundant and backup design is adopted to enable ground facilities to eliminate weak links, and to enhance BDS reliability.

(II) Providing Open Services Free of Charge

Currently, B1I and B2I open service signals are being broadcast by

the operating BDS-2 to provide open services to the Asia-Pacific region free of charge. The services cover an area extending 55°N-55°S and 55°E-180°E, with positioning accuracy less than 10 meters, velocity measurement accuracy less than 0.2 meter per second, and timing accuracy less than 50 nanoseconds.

(III) Disseminating BDS Information in a Timely Manner

– Publishing BDS documents related to open services and signals to provide inputs for global BDS product development efforts. The Interface Control Document of B1I and B2I signals has been published, which defines the interface specifications between the BDS-2 satellites and user terminals. It specifies the signal structures, basic characteristics, ranging codes, NAV messages and other contents. The Open Service Performance Standard has been published, which defines the service coverage area, accuracy, continuity, availability, and other performance indexes of the BDS-2. In the future, related documents will be updated and published in step with BDS construction and development.

– Establishing a multi-channel information dissemination mechanism. China holds news conferences when appropriate to disseminate important information about BDS development, and releases the latest news of the system in a timely manner through the official BDS website (www.beidou.gov.cn) from the aspects of system construction, operation, application, and international cooperation. It also issues notifications worldwide in advance before carrying out plans which might affect user services.

(IV) Protecting the Utilization of Radio-Navigation Satellite Frequency Spectrum

– Protecting the radio-navigation satellite frequency spectrum according to law. China protects the utilization of BDS frequency spectrum, and ensures the safety of BDS operation and BDS users pursuant to the national laws and regulations regarding the radio frequency spectrum.



– Firmly rejecting harmful interference. China prohibits the production, sale and use of illegal interference devices, investigates and punishes in accordance with the law any hostile interference actions which affect the system operations and services.



IV. BDS Application and Industrial Development

China strives to enhance BDS application development, in an effort to build a BDS industrial chain which comprises the basic products, application terminals, application systems and operational services, keeps strengthening BDS-related industrial supporting, promotion and innovation systems, continuously improves the industrial environment, expands the application scale for integrated development, and increases the economic and social benefits of the satellite navigation industry.

(I) Establishing an Industrial Supporting System

– Industrial policies. China has formulated development plans for the satellite navigation industry, making overall arrangement for medium- and long-term satellite navigation industrial development, and encourages competent departments and local governments to enact relevant policies to support BDS application and industrial development.

– Equitable market environment. China is making efforts to build a development environment for the satellite navigation industry marked by orderly competition, and increase the efficiency and effectiveness of resource allocation. It encourages and supports domestic and overseas organizations, including scientific research institutions, enterprises, colleges, universities and social organizations, to actively develop BDS applications, and fully release market vitality.

– Standardization process. In 2014 the National Technical Committee on BeiDou Satellite Navigation of Standardization Administration of China was established, and the BeiDou Satellite Navigation Standard Sys-

tem was set up, which has been constantly improved. China promotes the standards verification and implementation, and expedites the formulation and revision of standards which are fundamental, generally applicable and in urgent need, so as to enhance the quality and benefits of the procedure-based development of satellite navigation.

– Product quality system. China is working to establish and improve a public service platform for satellite navigation product quality assurance. It also actively promotes third-party quality test, type approval and authentication efforts of BDS basic products used in the security sector and application products in key fields. It is regularizing satellite navigation application services and operations, and cultivating the BeiDou brand. It aims to gradually establish satellite navigation product test and authentication institutions, strengthen admissibility of third-party certification, promoting the upgrading of the core competitiveness of BDS products on all scales, and pushing forward BDS applications in line with international conventions.

– Comprehensive service system of location data. China welcomes commercial operation to be introduced to help build the basic platform of location service based on its BDS augmentation systems, which will have extensive coverage of application fields and interconnections, and provide support services to different regions and industries and to public customers.

(II) Establishing an Industrial Application Promotion System

– Application in key sectors. Great efforts are being made to promote the application of BDS technologies and products, which are compatible with other systems, in the key sectors related to national security and economy, to provide important assurance for the steady and safe running of the national economy.

– Industrial and regional applications. China is pushing forward close integration between satellite navigation and each industry in the national economy, carrying out demonstrations of BDS industrial applications, formulating comprehensive application solutions for industries, and



promoting transformation and enhancement in the areas of transportation, national land resources, disaster prevention and reduction, agriculture, forestry and water conservancy, surveying and exploration, and emergency response and rescue. It encourages BDS regional application demonstrations to meet the requirements of the state strategies on regional development, such as the “Coordinated Development for the Beijing-Tianjin-Hebei Region,” the building of “Yangtze River Economic Zone” and the development of smart cities. It is also promoting commercial and large-scale BDS applications, and enhancing BDS-related industries, as well as regional economic and social development.

– Mass market application. The goal is to produce miniaturized, low power-consuming and highly-integrated BDS-related products, oriented to the mass market in the sectors of smart phones, vehicle-borne terminals and wearable devices. The focus is on pushing forward the adoption of satellite navigation and positioning functions based on the BDS and other compatible systems as a standard configuration in the fields of vehicle-borne and intelligent navigation, and promoting diversified applications in social services, transportation, caring for vulnerable groups, and smart cities.

(III) Establishing an Industrial Innovative System

– Research and development of basic products. To make breakthroughs in key technologies, China is developing chips, modules, antennae and other basic products based on the BDS and other compatible systems, and fostering an independent BDS industrial chain.

– Establishment of an innovation system. China encourages and supports the construction and development of key laboratories for satellite navigation application technologies, research centers of engineering (technology), technology centers of enterprises, and other innovative bodies, enhances the capacity of engineering experiment platforms and achievement transformation platforms, supports relevant enterprises, and makes more efforts to protect intellectual property rights, so as to form a





technology innovation system which relies on the enterprise as the main body and combines the efforts of universities, research institutes and application.

– Integrated industrial development. China encourages the integrated development of the BDS and Internet+, big data, and cloud computing, supports the integrated positioning and innovative utilization of satellite navigation together with mobile communications, WLAN, pseudo-satellites, ultra-wide band and Ad Hoc Network signals, promotes integrated development of satellite navigation and emerging industries such as the Internet of Things, geographic information, satellite remote sensing and communication, and mobile Internet, and encourages people to start their own businesses and make innovations, so as to vigorously upgrade the innovation capability of the industry.





V. International Cooperation and Exchanges

China will push forward the international development of the BDS, actively carry out international cooperation and exchanges in this field, so as to serve the Belt and Road Initiative, promote the development of global satellite navigation, and enable the BDS to serve the world and benefit mankind better.

(I) Strengthening Compatibility and Joint Applications with Other Navigation Satellite Systems

China actively pushes forward the cooperation and exchanges between the BDS and other navigation satellite systems in the fields of system construction and application from all perspectives, strengthening compatibility and interoperability, achieving resource sharing, complementarity and technology advancement, improving the services of navigation satellite systems, and providing users with more qualified, diversified, safe and reliable services.

(II) Utilizing Frequency and Orbital Slot Resources According to International Rules

As limited and valuable natural resources, frequencies and orbital slots provide a critical foundation for the development of navigation satellite systems. Adhering to the International Telecommunication Union (ITU) rules, China works to facilitate coordination of BDS frequencies and orbital slots through negotiations, actively participates in the research and formulation of ITU rules and other relevant activities, and expands radio-navigation frequency resources through cooperation with other nations. Since 2000 China has held effective coordination activities on more



than 300 satellite networks with more than 20 countries, regions and international organizations.

(III) Promoting the Ratification of the BDS by International Standards

The ratification of the BDS by international standards is a milestone for the integration of the BDS into international systems. China spares no effort to get the BDS ratified by the International Organization for Standardization and other international organizations in the industrial and professional application sectors. Currently, positive efforts are being made to advance the recognition of the BDS in the International Civil Aviation Organization, International Maritime Organization, Third-Generation Mobile Communication Standard Partnership Project, and other organizations. China advocates the involvement of enterprises, scientific research, colleges and universities in the formulation of satellite navigation terminals and application standards. In November 2014 the BDS gained recognition from the International Maritime Organization.

(IV) Participating in Multilateral Activities in the Field of International Satellite Navigation

The BDS is one of the major GNSS providers, and China actively participates in international satellite navigation affairs, attends the activities held by the International Committee on Global Navigation Satellite Systems (ICG) and other relevant international organizations, supports academic exchanges and cooperation in this area, and promotes satellite navigation applications with the contribution of the BDS. China actively takes part in relevant tasks within the orbit of the United Nations, successfully held the Seventh Meeting of the ICG in 2012, when the proposals for the international GNSS Monitoring and Assessment and the BDS/GNSS Application Demonstration and Experience Campaign were initiated, and the Joint Statement of Global Navigation Satellite Systems for serving the whole was issued. The China Satellite Navigation Conference

is held annually, and plays a positive role in the development of satellite navigation technologies and applications worldwide.

(V) Promoting International Satellite Navigation Applications

– To intensify publicity and popularization in this field, China has implemented the “BDS Tour” series of events, pushed forward the establishment of BDS Centers to enable better understanding of the BDS. BDS Centers have been jointly set up in a number of nations. The BeiDou International Exchange and Training Center has been opened, and a demonstration platform for education and training in the field of satellite navigation has been set up. In addition, academic education, summer schools, short-term training courses and symposiums, and other international education and training activities have been regularly held.

– To advance and implement internationalization projects, China is promoting research and consultancy services regarding the policies, markets, laws and finance related to international satellite navigation applications, and improving comprehensive international service capabilities. In line with the Belt and Road Initiative, China will jointly build satellite navigation augmentation systems with relevant nations, provide highly accurate satellite navigation, positioning and timing services, improve the overseas BDS service performances, and promote international applications of navigation technologies. China will also carry out application demonstrations in the fields of transportation, tourism, maritime application, disaster reduction and relief, and agriculture, and boost application on a large scale, through establishing an operation and service platform for highly accurate satellite navigation, positioning and timing services.

Conclusion

Navigation satellite systems are the common wealth of the development of mankind, and also a space infrastructure which can provide all-time precise time and space information. They promote the development of emerging industrial clusters that are technology- and knowledge-intensive with huge growth potentials and sound comprehensive benefits, thus becoming critical support for national security, economic and social development, and increasingly improve the people's production and living activities.

China will continue its BDS construction, improve the system performance, and fulfill its service commitments. It will persist in opening up and cooperation, promote the popularization in this field, strive to advance satellite navigation applications worldwide, and make satellite navigation better benefit the wellbeing of the people and the progress of mankind.



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