Report on the Development of BeiDou Navigation Satellite System

（Version 2.1）

China Satellite Navigation Office

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Contents

Preface

Navigation satellite systems can provide all time, all weather and high accuracy positioning, navigation and timing services to users on the earth surface or in the near-earth space. It is an important space infrastructure, which extends people's range of activities and promotes social development. Satellite navigation is bringing up revolutionary changes to the world politics, economy, military, technology and culture.

With a long history and a splendid culture, China is one of the important cradles of early human civilization. Chinese people used the Big Dipper (BeiDou) for identifying directions dating back ancient times. They also invented the world's first navigation device, the ancient compass (*Sinan*), which was a great contribution to the development of world civilization. Nowadays, the Chinese-built BeiDou System will become another contribution to the mankind.

In early 1980s, China began to actively study the navigation satellite systems in line with China's conditions. In 2000, BeiDou Navigation Demonstration System is basically established, which made China the third nation in possession of an independent navigation satellite system following the United States and Russia. China has been steadily accelerating the construction of the BeiDou Navigation Satellite System and has successfully launched 16 satellites by October 25th, 2012.

Many governmental departments in China have been involved in the construction, operation and application management of BeiDou System. As a joint office established by related national departments, China Satellite Navigation Office is in charge of management on the construction, application promotion and industrialization of the BeiDou System. Meanwhile, the Expert Committee and the Expert

Teams were also established to bring into full play of the experts' experience, as well as to make scientific and democratic decisions.

The BeiDou System will meet the demands of China's national security, economic development, technological advances and social progress, safeguard national interests and will enhance the comprehensive national strength. The BeiDou System will commit to providing stable, reliable and quality satellite navigation services for global users. Along with other GNSS providers, the BeiDou System will jointly promote the development of satellite navigation industry, make contributions to human civilization and social development, serve the world and benefit the mankind.

I. System Description

As a global navigation satellite system compatible with other navigation satellite systems worldwide, the BeiDou System is independently established and operated by China.

The BeiDou System is comprised of three major components: space constellation, ground control segment and user terminals. The space constellation consists of five GEO satellites and 30 non-GEO satellites. The GEO satellites are positioned at 58.75°E, 80°E, 110.5°E, 140°E and 160°E respectively. The non-GEO satellites include 27 MEO satellites and three IGSO satellites. The MEO satellites are operating in an orbit with an altitude of 21,500 km and an inclination of 55°, which are evenly distributed in three orbital planes. The IGSO satellites are operating in an orbit with an altitude of 36,000 km and an inclination of 55°, which are evenly distributed in three inclined geo-synchronous orbital planes. The subsatellite track for the three IGSO satellites are coincided while the longitude of the intersection point is at 118°E, with a phase difference of 120°.

Ground control segment consists of several Master Control Stations (MCS), Upload Stations (US) and a network of globally distributed Monitor Stations (MS). The main tasks of MCS are to collect observing data from each MS, to process data, to generate satellite navigation messages, wide area differential data and integrity information, to perform mission planning and scheduling, and to conduct system operation and control. The main tasks of Upload Stations include completing the upload of satellite navigation messages, wide area differential data and integrity information, controlling and managing the payload. The tasks of Monitor Stations include continuous tracking and monitoring of navigation satellites, receiving navigation signals, sending

observational data to the Master Control Station for the satellites orbit determination and time synchronization.

The user terminals include various BeiDou user terminals, and terminals compatible with other navigation satellite systems, to meet different application requirements from different fields and industries.

The time reference for the BeiDou Navigation Satellite System is the BeiDou Time (BDT). BDT adopts International System of Units (SI) seconds, instead of leap seconds, as the basic unit for continuous accumulation. It does not have leap seconds. The initial epoch of BDT was 00:00:00 on January 1, 2006 Coordinated Universal Time (UTC). BDT is related to UTC by UTC (NTSC) maintained by National Time Service Center, China Academy of Science. The difference between BDT and UTC will be maintained within 100ns (modulo 1s). Leap second message between BDT and UTC is broadcast in the navigation message.

The coordinate framework of the BeiDou System uses China Geodetic Coordinate System 2000 (CGCS2000).

Upon the full system completion, the BeiDou Navigation Satellite System can provide positioning, velocity measurement and timing services to worldwide users. It can also provide wide area differential services with the accuracy better than 1m and short messages services with the capacity of 120 Chinese characters each time. The functionality and performance parameters are as follows:

- Main functions: positioning, velocity measurement, one-way and two-way timing, short messages;
- Service area: global;
- Positioning accuracy: better than 10m;
- Velocity accuracy: better than 0.2m/s;
- Timing accuracy: 20ns.

II. System Development

i. System Planning

According to the overall requirements of "quality, safety, application and benefits", adhering to the development principle of "independency, openness, compatibility and gradualness" and following the general guideline of starting with regional services and then expanding to global services, The BeiDou System is steadily accelerating the construction based on a "three-step" development strategy, with specifics as follows:

First Step: BeiDou Navigation Satellite Demonstration System. In 1994, China started the construction of BeiDou Navigation Satellite Demonstration System. In 2000, two BeiDou navigation experiment satellites were launched, and the BeiDou Navigation Satellite Demonstration System was basically established, which made China the third nation in the world in possession of an independent navigation satellite system. In 2003, the third BeiDou navigation experiment satellite was launched, further enhancing the performance of the BeiDou Navigation Satellite Demonstration System.

BeiDou Navigation Satellite Demonstration System consists of three major components: space constellation, ground control segment and user terminals. The space constellation includes three geostationary orbit (GEO) satellites, positioned at longitude of 80 degrees East, 110.5 degrees East and 140 degrees East respectively above the equator. Ground control segment consists of the ground control center and a number of calibration stations. The ground control center is to complete satellite orbit determination, ionospheric correction, user location determination and user short message information exchange and processing. The calibration

ground control stations are mainly to provide the distance measurement and correction parameters to the ground control center.

The user terminals include hand-held type, vehicle type, command type and other types of terminals, which are capable of sending positioning and receiving location information.

The main functions and performance specifications of the BeiDou Navigation Satellite Demonstration System are as follows:

- Main functions: positioning, one-way and two-way timing, short message communications;
- Service Area: China and the surrounding areas;
- Positioning Accuracy: better than 20 meters;
- Timing Accuracy: one-way 100 ns, two-way 20 ns;
- Short message communications: 120 Chinese characters per time.

Second step: BeiDou Navigation Satellite (regional) System. In 2004, China started the construction of BeiDou Navigation Satellite System. By the end of 2012, the BeiDou System already consists of fourteen networking satellites, including five GEO satellites, five IGSO satellites, and four MEO satellites, and owns full operational capability for China and its surrounding areas.

The functions and performance parameters of BeiDou Navigation Satellite (regional) System are as follows:

- Main functions: positioning, velocity measurement, one-way and two-way timing, short message communications;
- Service Area: China and its surrounding area;
- Positioning Accuracy: horizontally, 10 meters; vertically, 10 meters;
- Velocity Accuracy: better than 0.2 m/s;
- Timing Accuracy: one-way 50 ns;
- Short message communications: 120 Chinese characters per time.

Third step: BeiDou Navigation Satellite System with global coverage will completely be established by 2020.

ii. Current Status of the System

By October 25th, 2012, sixteen BeiDou satellites have been launched to form the constellation and enter into operation by the end of 2012. It owns full operational capability and provides continuous passive positioning, navigation and timing services to China and most parts of its surrounding areas.

In order to encourage domestic and foreign enterprises to participate in the R&D of BeiDou System application terminals and promote its application, China Satellite Navigation Office announced the interface control document concerning BeiDou System signal-in-space (test version) on December 27th, 2011, and announced the ICD concerning open service signal B1I (version 1.0) on December 27th, 2012. Both Chinese and English versions have been published and are available on BeiDou governmental website (www.beidou.gov.cn). This document defines the B1I carrier signal interface relationship between the space segment and user terminals, identifies the coordinate framework and time reference of BeiDou System, specifies the signal structure, basic characteristics and parameters, and ranging code specifications related to B1I signal, defines navigation message. It is a necessary technical document for manufacturing and development of receivers and chips.

III. System Applications

Since the Beidou Navigation Satellite Demonstration System was officially brought into service in 2003, China has achieved remarkable progress in the field of theoretical study, technology R&D, receiver production, application and service development. Along with the construction of the Beidou Navigation Satellite System and the development the RNSS services, China has made breakthroughs in multi-mode chips, antenna, and receiver boards, which are compatible with other navigation satellite systems. Those lead to advances of independent intellectual property rights and product industrialization.

The BeiDou Navigation Satellite Demonstration System has been widely used in transportation, marine fisheries, hydrological monitoring, weather forecasting, forest fire prevention, timing for communication systems, power distribution, disaster mitigation, national security, and many other fields, which has been resulting in significant social and economic benefits. Particularly, the system has played an important role in the South China frozen disaster, earthquake relief in Wenchuan, Sichuan Province and Yushu, Qinghai Province, the Beijing Olympic Games, and the Shanghai World Expo.

• In the field of transportation, the Beidou Navigation Satellite System has been widely used in different areas such as the Demonstration System of Monitoring Management Services in Priority Transportation, the Highway Infrastructure Safety Monitoring System, and the Port Scheduling High-precision Real-time Position Monitoring System.

• In marine fisheries, built on the BeiDou Navigation Satellite Demonstration System, the marine fisheries integrated information service platform has provided vessel position monitoring,

emergency rescue, information distribution, fishing boats in and out of port management and other services to the fishery administration departments.

• The hydrological monitoring system successfully applied at the real-time transmission of hydrological forecast information in mountainous regions, which has improved the accuracy of the disaster forecasting and has helped the planning and scheduling programs for the flood and drought control.

• In the field of weather forecasting, a series of BeiDou terminal equipments have been developed for weather forecast, "Demonstration Application of Monitoring and Warning in Atmospheric, Oceanic and Space" has started, and various practical and feasible system solutions have been worked out to address the automatic data transmission issues among the China Meteorological stations.

• In the field of forest fire prevention, it has been successfully used in forest fire prevention system. Its positioning and short message communication services have achieved good results in practical application.

• In the field of time synchronization for communication systems, the successful implementation of BeiDou two-way timing demonstration program has achieved breakthroughs in some key technical areas such as long distant fiber technology, and an integrated satellite-based timing system has been developed.

• In the field of power distribution, built on the BeiDou System, the successful implementation of power system time synchronization demonstration program has created basis for the high precision applications such as the electric accident analysis, the electricity early warning and protection systems.

• In the field of disaster mitigation, the navigation, positioning, short message communications and position reporting capabilities of the BeiDou System have provided services for the nationwide real-time disaster relief commanding and dispatching, emergency communications, rapid reporting and sharing of disaster information,

which has significantly improved the rapid response of the disaster emergency relief and decision-making capability.

Upon the full completion, the BeiDou Navigation Satellite System will provide more high-performance positioning, navigation, timing and short-message communication services for civil aviation, shipping, railways, finance, postal, land resources, agriculture, tourism and other industries.

IV. International Exchange and Cooperation

The BeiDou Navigation Satellite System will carry out active and pragmatic international exchange and cooperation, in line with China's foreign policies, focusing on China's basic tasks and strategic objectives for the construction of navigation satellite systems, utilizing domestic and international markets and resources in a coordinated way. Upon the basis of equality, mutual benefit, mutual complementarity, peaceful utilization, mutual development and generally recognized international laws, BeiDou System will implement phased and focused international exchange and cooperation according to the overall planning of Chinese-built navigation satellite system.

China's international exchange and cooperation in the field of satellite navigation started in 1990s. In recent 20 years, various forms of activities have been carried out with extensive outcome. The BeiDou Navigation Satellite System adheres to the open and friendly attitude, and has already carried out extensive exchanges and consultation with countries that possess navigation satellite systems, to promote compatibility and interoperability between GNSS. Meanwhile, we extensively exchange and cooperate with countries that do not have navigation satellite system, to share the benefits of navigation satellites with them.

In 1994, under the framework of International Telecommunication Union (ITU), China started the BeiDou Navigation Satellite System frequency coordination activities. Satellite network information was submitted in accordance with the BeiDou System construction plan and progress. International frequency coordination has been carried out in a phased, step by step, focus-centered approach. China has actively participated bilateral frequency coordination activities with Europe, the United

States and Russia, and has actively taken part in the World Radiocommunication Conference and the meetings of ITU study groups and working groups. In 2012, Chinese delegation participated in the World Radiocommunication Conference 2012 (WRC-12) of the International Telecommunication Union (ITU), and actively promoted to extend the radiodetermination-satellite service (space-to-earth) allocations in the S-band, and strive after new adoptable band for navigation satellite systems. Together with delegates from other countries, China successfully pushed forward the S-band (2483.5-2500 MHz) as another band for navigation satellites.

China, as an important member of the International Committee on Global Navigation Satellite Systems (ICG), has participated in each ICG General Assembly Meeting and the ICG Providers' Forum. In 2007, China became one of the four core providers designated by the organization. During the Sixth Meeting of the ICG, China proposed the initiatives of international GNSS Monitoring & Assessment and BeiDou/GNSS Application Demonstration & Experience Campaign (BADEC), pushed forward the establishment of subgroups on international GNSS Monitoring & Assessment as well as application, and became the co-chair of these two subgroups. BADEC was successfully held in Pakistan in September 2012, and was launched in Korea in October 2012, which achieved primary progress. From November 4th to 9th, 2012, the Seventh Meeting of the ICG was successfully host by Chinese government in Beijing. It's a grand meeting of important landmark significance, during which, more than 200 delegates from 16 countries and regions, as well as 18 international organizations were present, over 20 items were promoted, and the joint statement of global navigation satellite systems were announced for the first time.

Focusing on compatibility and interoperability, China has carried out the extensive exchange and cooperation with the other navigation satellite systems in the world. The Technical Working Group (TWG) on compatibility and interoperability between

BeiDou and Galileo was established. Until now, seven TWG meetings have been held.

China actively participates, organizes and hosts international academic exchanges on satellite navigation, which include the American Institute of Navigation (ION) Conferences, the International Symposium on GPS/GNSS (ISGNSS), Munich Satellite Navigation Summit and European Navigation Conference (ENC), Moscow International Satellite Navigation Forum and other international academic conferences and forums. China Satellite Navigation Conference (CSNC) is held annually, together with many other relative forums and symposium from 2010. CSNC invite major providers of navigation satellite system, relative international organizations and representatives to achieve the purpose which is letting the international community deeper understand BeiDou itself and expand application.

China encourages and supports domestic research institutions, industrial enterprises, universities and social organizations, under the guidance of the government policy, to carry out international exchanges, coordination and cooperation activities with other countries and international organizations in the fields of the compatibility and interoperability, satellite navigation standards, coordinates frame, time reference, application development and scientific research. China actively promotes BeiDou/GNSS Application Demonstration & Experience Campaign (BADEC), International GNSS Monitoring & Assessment Service for OS (iGMAS) and other projects, develops navigation satellite technology and enhances system service performance.

The government attaches great importance to cultivate talents in navigation satellite area, keenly promote and develop international GNSS education and training, and has already established the GNSS International Communication and Training Center. Under the support of United Nations Office for Outer Space Affairs (UNOOSA), China is preparing to establish the “International GNSS Science and Technology Education Center”.

Conclusion

The rapid development of the BeiDou Navigation Satellite System is attributed to the growth of China's comprehensive national power and the sustainable development of economy. As always, China will continue to promote the Global Navigation Satellite System construction and industrial development, to encourage use of new satellite navigation technologies, and to expand application areas constantly, and satisfy the ever-growing diversified customer demand. By actively propelling international exchanges and cooperation, China will realize the compatibility and interoperability between the BeiDou Navigation Satellite System and other navigation satellite systems in the world. China will provide global customers with highly reliable positioning, navigation and timing services with excellent performance.

Annex

The Launch Record of BeiDou Navigation Satellites

• October 31, 2000, launch of 1st BeiDou navigation experiment satellite.

• December 21, 2000, launch of 2nd BeiDou navigation experiment satellite.

• May 25, 2003, launch of the 3rd BeiDou navigation experiment satellite.

• February 3, 2007, launch of the 4th BeiDou navigation experiment satellite.

• April 14, 2007, launch of the 1st BeiDou navigation satellite.

• April 15, 2009, launch of the 2nd Beidou navigation satellite.

• January 17, 2010, launch of the 3rd BeiDou navigation satellite.

• June 2, 2010, launch of the 4th BeiDou navigation satellite.

• August 1, 2010, launch of the 5th BeiDou navigation satellite.

• November 1, 2010, launch of the 6th BeiDou navigation satellite.

• December 18, 2010, launch of the 7th BeiDou navigation satellite.

• April 10, 2011, launch of the 8th BeiDou navigation satellite.

• July 27, 2011, launch of the 9th BeiDou navigation satellite.

• December 2, 2011, launch of the 10th BeiDou navigation satellite.

• February 25, 2012, launch of the 11th BeiDou navigation satellite.

• April 30, 2012, launch of the 12th and 13th BeiDou navigation satellites.

·September 19, 2012, launch of the 14th and 15th BeiDou navigation satellites.

·October 25, 2012,launch of the 16th BeiDou navigation satellites.