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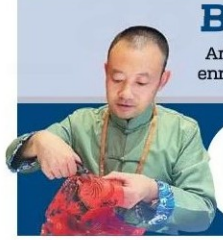

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Next-gen space-based positioning tech planned

By ZHAO LEI and JIANG CHENGLONG

China plans to establish a next-generation space-based navigation and positioning system by 2035, said a government official overseeing the sector.

Ran Chengqi, director of the China Satellite Navigation Office, said at a news conference held by the State Council Information Office on Friday in Beijing that the next-generation system, which has yet to be named, will be accessible to users anywhere, anytime on Earth.

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"The new system will be 'omnipresent, smarter and more integrated'. We plan to complete the system by 2035 and upon its completion, there will be Beidou service not only on land and sea, but also in the sky, outer space and deep within the oceans," Ran said.

The official said that the current Beidou network consists of satellites in medium and high-altitude orbits while system designers are considering the inclusion of low-orbit satellites in the new system to take advantage of low-orbit communication networks.

By doing so, the new-generation system will be able to provide navigation and positioning services with much better accuracy, Ran added.

On the improvement of the current Beidou system, he said project managers have made plans to deploy backup satellites.

"Our work schedule includes development and production of backup satellites. We plan to launch three to five backup craft into space next year to strengthen the space-based network's stability and reliability," the official said.

At the news conference, a white paper titled "China's Beidou Navigation Satellite System in the New Era" was distributed.

The document says that Beidou has been built into a world-class navigation system. It lays out how China plans to refine the system and pledges to step up international cooperation for better compatibility and interoperability between Beidou and other navigation satellite systems.

The white paper is the second of its kind. The first was published in June 2016. Beidou is currently China's largest civilian satellite system and one of four global navigation networks, along with the United States' GPS, Russia's GLONASS and the European Union's Galileo.

Since 2000, a total of 59 Beidou satellites, including the first four experimental ones, have been lifted on 44 Long March 3 series rockets from Xichang Satellite Launch Center in Sichuan province. Currently, there are 45 satellites in active service.

In June 2020, the final satellite to complete Beidou's third-generation network was lifted by a Long March 3B rocket at the Xichang center. The following month, President Xi Jinping announced that the system had been completed and had begun providing full-scale global services.

According to the Global Navigation Satellite System and Location-Based Services Association of China, by the end of 2021, the overall value of satellite-enabled navigation and positioning services in China stood at 469 billion yuan ($65 billion), a 16.3 percent increase year-on-year.

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China's BeiDou Navigation Satellite System in the New Era

Editor's note: *The State Council Information Office of the People's Republic of China published a white paper titled "China's BeiDou Navigation Satellite System in the New Era" on Friday. Full text below:*

Preamble

The BeiDou Navigation Satellite System (BDS) is a project built and operated by China as a component of the country's national security and economic and social development strategy. After many years in development, it has become an important new element of China's infrastructure, providing high-accuracy, round-the-clock positioning, navigation and timing services to global users in all weathers.

From the 18th National Congress of the Communist Party of China (CPC) held in 2012, BDS entered a new era of rapid development. On July 31, 2020, President Xi Jinping announced to the world that BDS-3 was officially commissioned – a sign that BDS began to provide global services. From the launch of reform and opening up in 1978 to the beginning of the new era, from BDS-1 to BDS-3, from two-satellite positioning to a configuration covering the entire globe, from serving the Asia-Pacific to serving the whole world, BDS has progressed together with China's development and advanced the process of national rejuvenation.

In the new era, BDS benefits not only the Chinese people but also the people of other countries. A first-class navigation satellite system developed by China and dedicated to the world, it has been applied worldwide, integrated with global infrastructure, and introduced into mass markets, empowering industries and profoundly changing people's lives and the way they work. It provides an essential spatiotemporal reference for economic and social development, contributing Chinese wisdom and strength to making navigation satellite systems better serve the world and benefit humanity.

In the new era, BDS demonstrates China's resolve and confidence in striving for greater strength and self-reliance in science and technology. It embodies the Chinese people's spirit and commitment to independence and self-reliance in overcoming difficulties through hard work, showcases the strength of China's socialist system in pooling resources on major projects, and epitomizes China's global vision and its sense of responsibility in helping others to achieve common development.

The Chinese government is publishing this white paper to present China's achievements and vision in developing BDS, and to share its ideas and experience.

I. BeiDou in the New Era

As China makes historic progress and undergoes historic transformations in the new era, BDS has also entered a new period of high-quality development, making further breakthroughs and reaching higher levels in its mechanisms and in the speed and scale of its deployment. It is a miracle created by China in the vault of the sky.

1. A Path of Independent Development

China has relied on independent innovation and taken a phased approach in developing BDS. Starting from scratch, the system has undergone steady improvements and upgrades, providing both active and passive positioning and expanding from regional to global coverage.

The three-step BDS strategy. China began to develop its own navigation satellite system in 1994. BDS-1 entered service and began providing positioning services in China at the end of 2000. At this point, China became the third country in the world with a navigation satellite system. BDS-2 was completed in 2012, providing passive positioning services to the Asia-Pacific region. In 2020, BDS-3 was formally commissioned to provide satellite navigation services worldwide. This marked the successful conclusion of the three-step BDS strategy.

Accelerated progress towards a global era. In December 2012, BDS-2 entered into service, marking a new stage of development. In March 2015, China launched the first BDS-3 experimental satellite. In November 2017, the first two Medium Earth Orbit (MEO) satellites joined the BDS-3 system. The global deployment of the BDS configuration began to gather pace. In December 2018, China completed the primary deployment of 19 satellites. In June 2020, it completed the entire constellation deployment of 24 MEO satellites, three Geostationary Earth Orbit (GEO) satellites, and three Inclined Geosynchronous Orbit (IGSO) satellites. The next month, BDS-3 began to provide global services, upgrading BDS to a worldwide system.

2. Better Services for the Whole World

In the new era, BDS will provide better services around the globe for the benefit of all humanity. To this end, China will intensify integration of different technologies, improve its capacity for diversified and specialized services, promote industries engaged in BDS applications, and reinforce international cooperation and exchanges on all fronts. Through this process, we can promote economic and social development, meet the people's desire for a better life, and share the results and benefits of BDS throughout the world.

Open services and greater compatibility. BDS provides open, free satellite navigation services, and its ability to serve the public across the world is being constantly improved. Through active international cooperation and exchanges, China calls for and works towards greater compatibility and broader sharing among different navigation satellite systems.

Innovation and upgrading. Under the innovation-driven development strategy, China is building up its capacity for independent development based on innovation. BDS is consistently being upgraded by adopting new and emerging technologies such as the latest communication technologies and low earth orbiter navigation augmentation. Efforts are also under way to incorporate non-satellite navigation technologies into its scope.

Quality services. BDS ensures stable and uninterrupted operation, shows strength in specialized services, and delivers high-quality satellite navigation services to users worldwide. In order to foster a more enabling environment for BDS-related industries, China has improved relevant standards, policies and regulations, intellectual property rights protection, and dissemination and promotion.

Sharing for the common good. China will expand BDS applications and promote higher quality in related industries, so that the system will be incorporated into every aspect of society and facilitate work and daily life. China shares the progress of its navigation satellite system with the rest of the world, with the goal of benefits for all.

3. BeiDou Spirit in the New Era

The BDS development team have worked hard through successive generations to surmount all difficulties in their research. In the new era, they have fostered a BeiDou spirit of independent innovation, openness and inclusiveness, unity of purpose, and pursuit of excellence. It is a telling example of China's national spirit centered on patriotism and defined by reform and innovation in the new era. It also makes a fine addition to the CPC's long line of inspiring principles.

Independent innovation as the core competitive advantage. China has maintained independence in the research, design, construction and operation of BDS, keeping core technologies in key fields firmly in our own hands. This is the approach we have taken in confronting challenges and overcoming difficulties in the development of BDS.

A global vision of openness and inclusiveness. The world is becoming increasingly open and integrated. By making BDS available worldwide, China honors its commitment to helping people of all countries share the opportunities and fruits of development. This clearly demonstrates China's farsighted vision and its will to share the best it has to offer.

Unity of purpose for success. BDS is the fruit of the cooperation and dedication of its developers, the support of the whole nation, and the collaboration among all parties concerned. It embodies China's great tradition of working together and the Chinese people's deep love for their country.

The constant pursuit of excellence. China is striving to make BDS one of the best navigation satellite systems in the world by achieving excellence in technology, construction, management and services. It is designed to become one of China's most recognizable brands in the new era.

4. Outlook for the Future

In the years to come, China will further upgrade BDS technologies, functions and services. The goal is to create a comprehensive spatiotemporal system that is more extensive, more integrated, and more intelligent, and that provides flexible, smart, precise and secure navigation, positioning and timing services. In doing so, China will help improve people's wellbeing and promote human progress.

In building a more powerful BDS, China will create its own smart and distinctive system for operation, maintenance and management, and gain a competitive edge in services such as short message communication, ground-based and satellite-based augmentation, and international search and rescue. By steadily improving the quality and increasing the scope of its services, BDS will build the capacity to provide global decimeter-level positioning and navigation with high integrity, thereby delivering better services to users worldwide.

China will promote large-scale BDS applications and encourage their market-oriented, industrialized and globalized development to offer a broader range of public services of higher quality. We will further unleash market potential, expand application scenarios, increase application scale, create new mechanisms and dynamics, improve the industrial system, strengthen international industrial cooperation, and forge a fuller, more resilient industrial chain. The goal is to share our achievements in BDS development with people all over the world for their benefit.

We will establish a comprehensive national system for positioning, navigation and timing services, develop a variety of navigation methods, and pursue cross-sector innovation in cutting-edge technologies, synergy of different methods for higher performance, and multi-source information fusion and sharing. We will extend BDS services to provide underwater, indoor and deep space coverage, and offer integrated spatiotemporal information services that are based on unified reference and seamless coverage, and are flexible, intelligent, secure, reliable, convenient and efficient. This will contribute to building a global community of shared future and make the world a better place to live.

II. A World-Class Navigation Satellite System

Aiming to build a world-class global navigation satellite system, China has adhered to an innovation-oriented approach, pursued excellence and kept improving its technologies. BDS is now a top-class system characterized by cutting-edge technologies, pioneering design, and powerful functions.

1. Independently Developed Core Technologies

China has achieved innovations in the constellation configuration, technology systems and service functions of the navigation satellite system conforming to international norms. It has made breakthroughs and reached a world-leading level in several core technologies in terms of hybrid constellation, inter-satellite links, and signal structure.

Innovative constellation configuration. China is the first country to adopt a hybrid navigation constellation in medium and high earth orbits. A satellite in a high orbit covers a larger area and has a better anti-shielding capability; those in medium orbits offer global coverage, and are core to providing global services. By complementing each other, satellites in multiple orbits have a greater capability to serve not only the region, but also the entire world.

Inter-satellite links. This is China's first inter-satellite and satellite-ground joint network, thus realizing high-precision measurement and data transmission through inter-satellite links, and providing global services based on domestic ground stations.

Optimized signal structure. With breakthroughs in core technologies such as modulation, multiplexing, and channel coding, BDS takes the lead in using triple-frequency signals, in integrating navigation and positioning with communication functions, and in providing both basic navigation information and differential augmentation information. It has reached world-class level in signal ranging accuracy, anti-interference performance, and anti-multipath capabilities. It is compatible with other navigation satellite systems and capable of providing diversified and specialized services.

2. Innovative System Configuration

BDS is composed of a space segment, a ground segment, and a user segment:

• The space segment comprises 30 satellites located in three types of orbit – MEO, GEO and IGSO;

• The ground segment mainly consists of the operation control system, the telemetry tracking and command system, the inter-satellite link operation management system, and various service platforms for international search and rescue, short message communication, satellite-based augmentation, and ground-based augmentation.

• The user segment consists of terminals and applications compatible with other navigation satellite systems.

Building the BDS integrated inter-satellite and satellite-ground network, China's first aerospace system offering global network services, has led to remarkable improvements in China's aerospace R&D capability, and leapfrog progress in China's aerospace technology.

Outstanding batch production capability. Innovations have been introduced in the research and manufacturing of satellite-ground equipment as well as satellites and launch vehicles. Carrier rocket upper stages and navigation satellite platforms have been developed to enable batch production, intensive launch of satellites and rockets, and fast constellation deployment. In less than three years, 18 rockets deployed 30 satellites into orbit, a pace unmatched by any other country.

Independent development and operation of key components. Components such as aerospace-grade memory chips, satellite-borne processors, high-power microwave switches, traveling-wave tube amplifiers, and solid-state amplifiers have been developed and produced independently by China. The 100 percent independent development and operation of BDS core components has laid a solid foundation for its widespread use.

3. Quality and Diverse Services

With its powerful functions and reliable performance, BDS is able to provide a wide range of services to meet various requirements. It mainly provides positioning, navigation, timing, international search and rescue, and short message communication services to global users, while it offers short message communication, satellite-based augmentation, precise point positioning, and ground-based augmentation services to users in the Asia-Pacific.

Positioning, navigation and timing. Through 30 satellites, BDS offers free services to users across the world. Its positioning accuracy is better than 9 meters horizontally and 10 meters vertically, its velocity measurement accuracy is higher than 0.2 meters per second, and its timing is accurate to less than 20 nanoseconds.

International search and rescue. Through six MEO satellites, BDS provides, free of charge, a global distress alert service that meets international standards. Return links have been designed so that rescue requesters can receive confirmation messages.

Global short message communication. BDS is the first navigation satellite system to provide a global short message communication service. Through 14 MEO satellites, it provides a global random-access service to specific users with a maximum single message length of 560 bits (40 Chinese characters).

Regional short message communication. BDS is the first navigation satellite system to provide a regional short message communication service for authorized users. Through three GEO satellites, it provides a data transmission service to users in China and neighboring areas with a maximum single message length of 14,000 bits (1,000 Chinese characters). It can transmit texts, graphics and audio.

Satellite-based augmentation. Through three GEO satellites, BDS provides users in China and neighboring areas with a Category I precision approach service that meets international standards. It supports both single-frequency and dual-frequency multi-constellation augmentation, providing greater security for the transport sector.

Precise point positioning. Through three GEO satellites, BDS provides users in China and neighboring areas with a cost-free high-precision positioning augmentation service. Its positioning accuracy is better than 30 centimeters horizontally and 60 centimeters vertically, and its convergence time is less than 30 minutes.

Ground-based augmentation. Network ground stations have been built across China to provide real-time meter-level, decimeter-level, centimeter-level, and post-processing millimeter-level positioning augmentation services for industrial users and the general public.

III. Improving BDS Operation Management

As a major player in the aerospace industry that takes its responsibilities seriously, China continues to improve BDS operation management and the system's performance. It ensures continuous and stable operation, open and transparent information, and sustained, healthy and rapid development of the BDS system, so as to provide reliable, secure and high-quality spatiotemporal information services.

1. Ensuring Operational Reliability

Stable operation is vital to a navigation satellite system. Applying systems thinking, China has built a BDS operation management system with Chinese characteristics, organized on the basis of multi-party support, providing a joint inter-satellite and satellite-ground network control as its system feature, and hardware-software coordination and intelligent operation and maintenance as its technical feature. The system integrates regularized operation management support, smooth transition, comprehensive monitoring and assessment, and intelligent operation and maintenance, providing basic support for continuous and stable operation.

Strengthening regularized support. China is improving the mechanisms for multi-party joint support, consultation on operation status, and equipment inspection and maintenance, and building a smooth and coordinated workflow that shares information and facilitates efficient decision-making, to constantly improve regularized support for BDS operation management.

Ensuring smooth transition. In terms of the space segment, ground segment and user segment, China has realized smooth and orderly transition from BDS-2 to BDS-3 and ensured that users do not need to replace equipment and can enjoy upgraded services at minimal cost.

Reinforcing monitoring and assessment. China is improving resource allocation for continuous global monitoring and assessment of BDS. It carries out comprehensive and regularized monitoring and assessment of the configuration status, signal accuracy, signal quality and service performance of the system, to obtain timely and accurate information on its operation and service status.

Boosting operation and maintenance. China makes full use of big data, artificial intelligence, cloud computing and other new technologies to build a BDS data pool. It integrates data from multiple sources such as system operation, monitoring and assessment, and space environment, provides on-demand information sharing, and strengthens intelligent operation management of the system.

2. Improving BDS Service Performance

Higher accuracy and reliability are constant priorities. Always seeking progress while ensuring stability, China makes constant efforts to improve the BDS system status, provide a better spatiotemporal reference, and increase application scenarios. It will continue to raise the capability of the system, expanding its service domains and upgrading its service quality.

Upgrading the system. China will upgrade and transform ground-based facilities, renew the software of in-orbit satellites as needed, and refine satellite-ground processing models and algorithms. It will continue to strengthen the capacity of the integrated inter-satellite and satellite-ground network, and elevate the accuracy and quality of space signals, to ensure a steady improvement in BDS service performance.

A better spatiotemporal reference. China will establish and maintain a high-accuracy BDS time reference and carry out the monitoring of clock bias against other navigation satellite systems. Time biases will be broadcast in navigation messages. It will increase interoperability between the BDS time and the time of other navigation satellite systems. The BDS coordinate system will remain aligned with the International Terrestrial Reference Frame, and increase interoperability with other navigation satellite systems in this regard.

Expanding service domains. China will strengthen the multi-approach navigation capability of BDS and enable the system to provide flexible positioning, navigation and timing services. It will carry out exploration and tests of cislunar space service applications, and extend the BDS service capacity into deep space. It will work for breakthroughs in key technologies in integrating navigation and communication, and improve the system's capacity to provide services in complex environments and densely populated areas.

3. Releasing the Latest Information on BDS

Releasing system information is a basic means of strengthening users' understanding of the navigation satellite system and increasing their trust. With regard to BDS, China applies the principle of openness and transparency. It is building information dissemination platforms, improving dissemination mechanisms, and publishing timely, authoritative and accurate information on the system, so as to provide services to global users in a responsible manner.

Building multi-channel information releasing platforms. Through these platforms, China publishes information on BDS construction and operation, application and promotion, international cooperation, and relevant policies and regulations. These platforms include the official BDS website (www.beidou.gov.cn), monitoring and assessment websites (www.csno-tarc.cn; www.igmas.org) and the BDS WeChat official account (beidousystem).

Releasing BDS service documents. China regularly updates and releases interface control documentation on BDS open services, defines the interface specifications between BDS satellites and user terminals, and specifies the signal structure, basic characteristics, ranging codes, navigation messages and other content, so as to provide inputs for global BDS product development efforts. It updates and releases the open service performance standards, and specifies the coverage area and performance indexes of BDS open services.

Releasing information on system status. China releases timely system status information about satellite launches and commissioning, in-orbit tests, monitoring and assessment outcomes, and decommissioning. It also issues notifications to domestic and foreign users when appropriate before carrying out plans and operations that might affect user services.

IV. Promoting Sustainable Development of the BDS Applications Industry

In the new era, China has synergized the development and application of BDS. It has made continuous efforts to refine the products supporting the BDS industry, expand application fields, improve the industry ecosystem, and promote large-scale applications. BDS applications have been better integrated into the overall development of the national economy to promote the sound development of the BDS applications industry, so as to inject strong impetus into socio-economic development.

1. Putting in Place Industrial Development Strategies

China has placed equal importance on the development and application of BDS, and promotes development through applications. It has made a well-conceived blueprint for the development of the BDS applications industry. China strives to push forward BDS applications across industries and regions through various projects, promotes use of the BDS system, and boosts high-quality development of the BDS industry.

Working out an innovative outline for BDS applications. Faced with new circumstances and requirements in the new era, China has focused its efforts on securing the industry ecosystem, developing basic and general-purpose technologies, and promoting the BDS applications industry. It has pooled strength from all sectors to create a new development dynamic based on concerted efforts and joint management.

Strengthening the planning and design of industrial development. China has formulated and implemented the Overall Plan for Comprehensively Promoting BDS Industrial Applications and a special plan for the development of the BDS industry. Various sectors and regions have made special plans and launched campaigns accordingly to improve the systems of industrial innovation, integrated applications, industrial ecosystems, and global services.

Implementing major projects of BDS industrial development. Focusing on ensuring security, encouraging innovation and developing industry, China has given play to the leveraging role of major projects to expedite the formation of a

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market-oriented and enterprise-based BDS industrial development framework. These efforts have advanced with a category-based approach following the principles of overall planning, intensive utilization, and prioritization.

2. Laying a Solid Foundation for Industrial Development

In developing BDS applications, China has focused on infrastructure, basic products, and basic software. With strengthened efforts in developing basic platforms for BDS applications and intensified support for application technology R&D, a solid foundation has been laid for the steady development of the BDS applications industry.

Improving infrastructure for BDS applications. China has established a set of platforms featuring BDS services including international search and rescue, short message communication, satellite-based augmentation, and ground-based augmentation. Featured BDS services have been more deeply integrated with various communication channels. With their expanding scope and depth, BDS applications have provided users with more efficient and convenient services.

Developing basic products for BDS applications. China has developed a series of basic products such as chips, modules and antennas, and realized 100-million-scale manufacturing of BDS products. In addition, basic products that integrate satellite navigation and inertial navigation, mobile communication, visual navigation, and other means have also been developed to strengthen the resilience of BDS application solutions.

Developing basic software for BDS applications. Through intensified efforts in independent research and development, China has made progress in turning basic generic technologies in areas such as positioning solutions, model development, data analysis, design, and simulation into software and tools, and ensuring that such software programs are functioning and easy to use.

3. Fostering a Sound Ecosystem for Industrial Development

By developing standards and norms, intellectual property rights, testing and certification, and industrial assessment in a systematic manner, China has created a sound industrial ecosystem for BDS applications with all necessary factors and a strong innovation capacity. With synergy across supply chains, industrial chains, innovation chains, and policy chains, the clustered development of the BDS applications industry has been pushed forward.

Advancing standardization. Leveraging the foundational and guiding role of standardization, China has updated the BDS standards system, and expedited the formulation and revision of standards concerning BDS applications. To promote industrial upgrading, China has made continuous efforts to form a comprehensive and sound BDS application standards system that covers organizational, sectoral, national and international standards, and ensures that all these standards are integrated and compatible with each other.

Strengthening intellectual property protection. China has raised the quality and efficiency of BDS-related patent examination to strengthen the BDS patent portfolio. The stakeholders of innovative BDS applications have been motivated to create, utilize, protect and manage intellectual property rights, laying solid foundations for the future development and exploitation of China's satellite navigation patents.

Improving product testing and certification systems. China has strengthened top-level design for the testing and certification of BDS-related navigation products and has built a network of public service platforms for product testing and certification. In order to improve the quality of BDS applications and ensure security and reliability, testing and certification of BDS products has been organized in key industries and fields.

Establishing an industrial assessment system. To ensure the healthy and sustainable development of the BDS applications industry, China has worked to improve the feedback mechanism for BDS applications and established an assessment system for key industries and fields, major regions, mass applications, and international applications.

Reinforcing collaborative efforts. To better meet market demand, China has encouraged the building of a BDS industry alliance to expand channels that bring together enterprises, universities, research institutes, and end-users. Relevant industry associations and societies have been mobilized to play their role in bringing together the government and enterprises, so as to facilitate communication and cooperation while improving industry self-discipline.

Building industrial clusters. Key regions and cities have been encouraged to deploy BDS applications extensively based on their own resource endowment, with due consideration given to national strategies. The objective is to consolidate the distinctive strengths of each region and create BDS industrial clusters with R&D institutions, key enterprises, and industrial parks as the mainstay.

4. Ways and Means to Promote Industrial Development

BDS has been widely used in various industries and fields in China's socioeconomic development. It has been deeply integrated with emerging technologies such as big data, the internet of things, and artificial intelligence, fostering new business forms based on BDS. Together these have underpinned digital socioeconomic transformation with improved quality and efficiency, adding convenience and color to people's lives.

Giving full play to the leading role of key industries. Some key industries that have the potential for scale application and significant socioeconomic benefits have been selected as pilot entities for BDS applications, along with their respective regions, with due consideration to national development strategies. In this way, China has worked out comprehensive solutions to push forward large-scale application of BDS.

Entering key fields. BDS has been swiftly applied to key fields that have a vital bearing on the national economy, people's lives, public interest, national security, public security, and economic security, and has effectively improved the reliability and security of these fields.

Empowering various industries and sectors. BDS has been deeply integrated into new infrastructure such as information infrastructure, integrated infrastructure, and innovative infrastructure, and has been widely used in key sectors such as transport, energy, agriculture, communications, meteorology, natural resources, the eco-environment, emergency management, and disaster mitigation, helping to reduce costs and increase efficiency.

The Fast Growing BDS Applications Industry

In 2021, the total output value of China's satellite navigation and location-based service industry reached RMB470 billion.

In terms of product manufacturing, breakthroughs have been made in a series of key BDS technologies such as chips and modules, which has effectively driven up the shipment volume. By the end of 2021, there were more than 1 billion terminals using the BDS positioning function nationwide.

In terms of its applications, BDS has been widely applied to various industries and sectors, generating significant socio-economic benefits. As of the end of 2021, BDS had been installed in more than 7.8 million road transport vehicles nationwide. Approximately 8,000 BDS terminals were in use on the country's railway network, and more than 100,000 agricultural machines were equipped with self-driving systems based on BDS. BDS-based services in health care, epidemic prevention, remote monitoring and online services sectors were worth almost RMB200 billion.

BDS-based applications have shown their growing relevance in scenarios closely related to daily life, notably in smartphones and smart wearable devices. BDS has been widely supported by products from international mainstream chip manufacturers, including smartphone device suppliers. In 2021, 324 million Chinese smartphones supporting BDS services were shipped, accounting for 94.5 percent of the country's total.

Serving everyday life. Through applications such as smartphones, vehicle terminals, and wearable devices, BDS has been widely applied in daily life, the sharing economy, and areas that are important to public wellbeing. It comprehensively serves every aspect of people's everyday life such as green travel, food delivery, elderly and child care, health care, and education.

V. Upgrading BDS Governance

China constantly upgrades its BDS governance in the new era. It has made consistent efforts to bring forward innovative ideas on systems, mechanisms and development methods, to improve policies and regulations, to optimize organization and management, to build up strengths in high-caliber professionals, to promote technological innovation through reform, and to better combine a well-functioning market with competent government.

1. Updating the Systems and Mechanisms of Management

Based on BDS development needs, China makes overall plans, improves relevant mechanisms, and maximizes its system strength in pooling resources from government, market and social sectors to achieve synergy in developing BDS.

Improving management of the BDS project through innovation. To ensure that the BDS project is operating in a smooth, concerted, efficient, orderly and rule-based manner, China gives full play to the role of the project's leading group, and has set up a management system in which various departments work in concert with clear divisions of tasks and responsibilities. It has also established a mechanism for promoting the coordinated progress of the project, its applications, and international cooperation.

Establishing a mechanism for overall planning and coordination. China makes systemic plans for BDS infrastructure construction, application and promotion, international cooperation, management of satellite radio frequencies and orbits, intellectual property rights protection, standards formulation, and human resource development, and ensures their concerted progress, creating a closely connected and well-coordinated framework.

2. Promoting Technological Innovation Through System Reform

In advancing its innovation-driven development, China relies on innovation in both technology and systems. To speed up technological innovation, it has established and is now improving a mechanism for propelling innovation in satellite navigation technology.

Establishing a mechanism for original, integrated and collaborative innovation. Following the principle of independent innovation while remaining open to exchanges, China fosters original innovation bases for satellite navigation technologies, plans strategic, fundamental and forward-looking research, and builds up advanced systems for tackling key technological problems and promoting R&D in new products. To meet the need to fully integrate BDS with new-generation information technology, China adopts an approach of phased and incremental development and multifunctional integration, and operates a collaborative innovation mechanism across disciplines, subjects and fields to concentrate resources and factors for innovation and stimulate exponential development through innovation.

Improving an incentive mechanism that encourages competition. Upholding the principles of transparency, fair play, and mutual learning, China operates a competitive mechanism in which the best products are selected from multiple enterprises based on comparison of specifications and comprehensive assessment. This can apply appropriate pressure on market players while maintaining their enthusiasm, and thus help to achieve sustainable development, high quality and efficiency, and low cost.

Upgrading the system for organizing research and production. China strengthens the leading role of digitalization and other new technologies, and builds smart systems of testing, verification and assessment. It optimizes the research and production procedures that evolve from R&D, verification, improvement to reverification, under a new model that adapts to synchronous R&D and batch production of multiple satellites, multiple rockets, and multiple stations, and increases the capability for fast deployment between space and ground.

3. Advancing Rule of Law in Satellite Navigation

In order to create a favorable domestic and international environment for the sustainable and healthy development of BDS, China has established a comprehensive legal framework for satellite navigation and taken part in global governance balancing considerations of development and security, current and future interests, and laws governing domestic and foreign-related matters.

Accelerating satellite navigation legislation. China is constantly building up the legal system of satellite navigation. The Regulations of the People's Republic of China on Satellite Navigation has been promulgated to regulate and strengthen the management of relevant activities. Support rules concerning system construction, operation and services, applications management, international cooperation, and security guarantees have also seen substantial improvement.

Continuing to improve the business environment. Committed to a business environment that is based on market principles, governed by law, and meets international standards, China has taken measures to regulate satellite navigation market order, create an enabling environment to protect market players' rights and interests, and improve government services. These have provided a stable, fair, transparent and predictable business environment, boosting market dynamism and development drive.

Regulating satellite navigation activities. Accurate and full information about BDS satellites is reported in a timely manner in line with the provisions on the registration of objects launched into outer space. Licenses for BDS radio frequencies, space radios, and ground stations are also issued in accordance with the law. The radio frequency bands used by BDS are protected by law, and the production, sale, or operation of any type of jamming equipment that interferes with satellite navigation is strictly prohibited and will be investigated and punished in accordance with the law.

Taking part in global governance of satellite navigation. In this field, China follows the principle of achieving shared growth through consultation and collaboration in global governance. It handles affairs concerning international interests within the framework of the International Committee on Global Navigation Satellite Systems (ICG) and participates in formulating relevant international rules, contributing to a fairer and more equitable international order in satellite navigation.

4. Fostering Talent for BDS

Talent is the resource of paramount importance for development and innovation. BDS always cultivates, attracts and guides talented individuals through its development, and encourages them to succeed. It has consistently expanded its personnel pool and given full play to their strengths, sustaining the industry with quality human resources.

Training competent professionals. China has updated its talent training framework in the fields relating to BDS positioning, navigation and timing. It has improved talent training, exchange and incentive mechanisms, set up platforms for talent growth, built national key laboratories, and enlarged the team of professionals with interdisciplinary training and a global vision.

Creating academic prosperity. To meet the requirements in developing frontier technologies in positioning, navigation and timing and the satellite navigation industry, China has strengthened research on basic theories and applications, and increased academic exchanges to raise the capacity for scientific and technological innovation.

Spreading scientific knowledge. China is continuing to build popular science bases, create immersive scenarios for experiential learning, carry out relevant activities, and publish content-rich books to spread knowledge about positioning, navigation and timing, and arouse the public's interest in science, especially in the fields related to time and space.

VI. Contributing to Building a Global Community of Shared Future

Navigation satellite systems are the common wealth of humanity. Following the principles of openness, integration, coordination, cooperation, compatibility, complementarity and sharing, China has carried out active international cooperation on BDS and advanced its international applications. This will enable the system to better serve the world, benefit humanity, and contribute to building a global community of shared future.

1. Increasing Compatibility and Interoperability of Diverse Systems

In order to provide users with more high-quality, diverse, secure and reliable services, China is active in advocating and advancing the compatibility and interoperability of different navigation satellite systems, carrying out coordination and consultation on the utilization of frequency and orbital slot resources, and working with other countries to make improvements.

Stepping up cooperation for better compatibility and interoperability. China continues to promote compatibility and interoperability between BDS and other navigation satellite systems and satellite-based augmentation systems, and to strengthen the compatibility and joint applications with other navigation satellite systems, so as to achieve resource sharing, complementarity and advances in technology. China works to establish bilateral and multilateral cooperation mechanisms in the field of satellite navigation, coordinates compatibility and interoperability efforts, and carries out active cooperation and exchanges with other countries on navigation satellite systems and satellite-based augmentation systems, in a bid to achieve common development of all navigation satellite systems around the world.

Carrying out coordination and consultation on the utilization of frequency and orbital slot resources. Abiding by the International Telecommunication Union rules, China works to safeguard the international order in terms of satellite network application and coordination and to facilitate coordination and consultation on navigation satellite frequencies and orbital slots through bilateral and multilateral negotiations. China is also an active participant in technological research and standards formulation led by international organizations, and joins with other countries to safeguard, utilize and expand navigation satellite frequency and orbital slot resources.

2. Promoting International Cooperation and Exchanges

China continues to expand the circle of international BDS friends and improve its global applications through measures such as strengthening cooperation mechanisms, increasing cooperation channels, and establishing cooperation platforms and windows.

Stepping up participation in international satellite navigation affairs. China has attended activities under the framework of the United Nations, and hosted ICG meetings. It also participates actively in research projects and proposes cooperation initiatives in this area, and works with other countries to promote global satellite navigation through extensive consultation.

Carrying out bilateral and multilateral cooperation and exchanges. China conducts cooperation and exchanges with regional organizations such as ASEAN and the League of Arab States, and countries in Africa, Latin America and elsewhere. It holds BDS/GNSS cooperation forums and provides application scenarios and solutions, so as to expand international applications of BDS.

Extending cooperation in testing and assessment. China collaborates with other countries to conduct testing and assessment on the performance of BDS and other global navigation satellite systems in positioning, navigation, timing, short message communication, international search and rescue, and other areas. It issues testing and assessment reports to increase users' knowledge and confidence about the conditions and performance of navigation satellite systems, strengthening cooperation in this area.

Establishing international education and training platforms. China continues to promote academic education of international students, especially at master's and doctoral levels, in disciplines related to satellite navigation. Relying on platforms such as the Regional Center for Space Science and Technology Education in Asia and the Pacific (China) affiliated to the United Nations, the BeiDou International Exchange and Training Center, and various BDS/GNSS centers, China actively carries out satellite navigation training activities to cultivate talent and build professional capacity in the field for the international community and in particular for developing countries.

Conducting international academic exchanges. Through strengthening international exchange platforms such as the China Satellite Navigation Conference and the International Summit on BDS Applications, China has constantly expanded the global influence of BDS. China also takes an active part in international academic exchange events in the field of satellite navigation and makes contribution to advances in satellite navigation technology worldwide.

3. Promoting the Ratification of BDS by International Standards

China is making every effort to have BDS ratified by international standards organizations and standards organizations in the industrial and specialized application sectors, so that the system can better serve global users and support relevant industries.

International civil aviation standards. The technical indicators of BDS have passed the authentication of the International Civil Aviation Organization, indicating that the system conforms with international civil aviation standards and is qualified to provide positioning, navigation and timing services for global users in the civil aviation sector.

International maritime standards. BDS has become an integral part of the global radio-navigation system and gained legal status in maritime applications worldwide. China has released the official standards for BDS shipborne receiver equipment, providing criteria on the design, production and testing of relevant maritime equipment for global manufacturers. The BDS short message communication service is making steady progress in aligning with the global maritime distress and safety system of the International Maritime Organization.

International search and rescue standards. China has issued an international standard for satellite emergency locators. It is also endeavoring to enable the BDS return link service to be ratified by the Cospas-Sarsat, and working on international compatibility and joint application of the return link service.

International mobile communication standards. The 3rd Generation Partnership Project has issued technical, performance and consistency testing standards that support BDS signals, enabling 2G, 3G, 4G and 5G networks and terminals to use BDS to achieve aided positioning and high-accuracy positioning.

International data exchange standards. China is working to incorporate BDS into international general standards for data receivers in fields such as high-accuracy differential positioning services, general data exchange formats, and positioning information output protocols.

4. Enabling BDS Development to Benefit the Whole World

China is working to expand and extend the international application of BDS products, services and industries, and accelerate the large-scale application of BDS worldwide, for the purpose of boosting economic and social development and improving public wellbeing across the globe.

Increasing the contribution of BDS products to the world. China is speeding up the integration of BDS products such as chips, modules and terminals into the international industrial system, enabling them to meet international requirements and align with international standards. Efforts are also made to give full play to the unique strengths of BDS products and enable them to integrate into local industries, upgrade services, and boost economic and social development.

Promoting BDS services overseas. China has set up an international satellite navigation application and service network, and joined with other countries to build satellite navigation service platforms and provide international services and applications such as global search and rescue, short message communication, satellite-based augmentation, and ground-based augmentation to meet the diverse demands of global users.

Expanding international cooperation on satellite navigation. China engages in active cooperation with other countries and international organizations on technology R&D and the satellite navigation industry. It has set up overseas BDS application and industrialization promotion centers, and strives to build solid foundations for the satellite navigation industry. It is strengthening cooperation with regional organizations such as ASEAN, the African Union, the League of Arab States, and the Community of Latin American and Caribbean States, and releasing BDS-based solutions in the fields of smart cities, public security, precision agriculture, digital transport, and disaster prevention and mitigation, which are being piloted in Asia, Africa, and Latin America.

Conclusion

To explore the cosmos has been the dream of the Chinese nation for millennia. From observing Beidou (Chinese pinyin for the Big Dipper) to developing and using BDS, from gazing at the stars to utilizing the space, the Chinese people have shown their great potential and created a promising future. China is committed to independent innovation, building a comprehensive spatiotemporal system that is more extensive, more integrated, and more intelligent on the next generation of BDS, and continuing to advance human progress in exploring the universe.

The universe is vast enough to accommodate exploration and utilization by all countries; by the same token, it demands global cooperation. China is ready to share its achievements in developing BDS, and it will work with all countries to promote the development of navigation satellite systems, venture into deeper space, and make an even greater contribution to building a global community of shared future and a better world.