

Current Status and Transformation of Satellite Navigation Industry Policies in China

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Abstract: Satellite navigation is an emerging industry of strategic importance in China. Targeted and powerful industrial policies can help to optimize and upgrade the satellite navigation industry, as well as promote the scaled, industrialized, and international development of the BeiDou Navigation Satellite System. They can also help to establish a comprehensive spatiotemporal system that is integrated, ubiquitous, and intelligent. The present study focuses on the transformation of China's satellite navigation industry and the role industrial policies play in its development. Moreover, it summarizes the current status and main problems of the industrial policies at the country, industry, and region levels, and analyzes the objectives, basic ideas, and measures for the transformation of these policies. The present study demonstrates that a policy system has been preliminarily established for the navigation satellite industry in China. However, the legalization level of the industrial policies is low; these policies are fragmented, the policy instruments have not been scientifically combined, targeted policy support is urgently required for the core technology research of the industry, and the application of international rules and standards is inadequate. To promote the high-quality development of the satellite navigation industry in China, we suggest that the legislation of the industry be accelerated, and policy support and dominating methods for the industry be adjusted. Moreover, comprehensive and targeted policy implementation should be promoted, the coordination mechanism should be improved, and China's satellite navigation industry should participate in the formulation of international standards and rules.

Keywords: satellite navigation industry; industrial policy; transformation; rules and standards; BeiDou Navigation Satellite System (BDS)

1 Introduction

The satellite navigation industry is an emerging high-tech sector consisting of the manufacturing industry of satellite positioning, navigation and timing, and user terminal systems, as well as the operation and maintenance of satellite positioning systems and navigation information services [1]. As a strategic emerging industry, the satellite navigation sector not only demonstrates the direction of a new round of scientific and technical revolution and industrial transformation but also presents a key field for the world's major powers to compete for the commanding heights of future development. It is highly significant vis-à-vis driving scientific and technological

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progress, promoting the upgrading of the industrial structure, and maintaining national security. In the late 20th century, with the support of the three-step strategy for the construction of a national satellite navigation system, China's satellite navigation industry grew out of nothing and developed rapidly. According to the 12th Five-Year Plan, China issued the *National Satellite Navigation Industry Medium- and Long-Term Development Plan (2013)*, with the aim of implementing a second-generation satellite navigation system in 2020, which reflected a national macro policy guidance regarding the development of the satellite navigation industry. Notably, in 2020, the global service of the BeiDou Navigation Satellite System (BDS) was launched, the *National Satellite Navigation Industry Medium- and Long-term Development Plan* was completed, and the plan to "build and improve a more ubiquitous, more integrated, and smarter integrated space-time system until 2035" was hatched. Furthermore, China's satellite navigation industry is confronted with new contradictions and challenges. On one hand, promoting the upgrading of domestic-related industries and building an emerging industrial chain based on space-time information are urgent. On the other hand, it is essential that the BDS compatibly competes and develops with the U.S. Global Positioning System (GPS), the Russian Global Navigation Satellite System (GLONASS), and the European Galileo satellite navigation system (GALILEO) on the same platform. Therefore, the new opportunities and challenges of China's satellite navigation industry raise new demands for the related industrial policies.

An industrial policy is the sum of various policies by which the government intervenes in the formation and development of industries to achieve certain economic and social goals [2]. Industrial policies not only create favorable conditions for the cultivation and growth of the satellite navigation industry on the supply and demand sides of the market but also guide the implementation of economic laws and open up space for economic laws by creating a favorable market environment. The research on China's satellite navigation industry policy focuses on three aspects: analyzing policies, sorting out problems, and constructing systems. Specifically, the research finds that environment-based policy tools account for the largest proportion (59.61%), followed by demand-based (21.15%) and supply-based (19.23%) tools, and that the application structure of policy tools is unreasonable, using policy analysis tools to quantitatively analyze China's satellite navigation policies [3]. These studies have also analyzed the situation of China's satellite navigation industry development and proposed a framework of related industrial policy systems [4]. Furthermore, a dynamic model of the satellite navigation industry policy system has been established, and the trend of the industry according to different policy assumptions has been simulated [5]. However, the domestic research on the satellite navigation industry policy remains in its infancy, and the research on the demand and supply of the satellite navigation industry policy under the new development pattern is insufficient.

To construct the national comprehensive positioning–navigation–timing (PNT) system and build a national strategic pillar industry, China's satellite navigation industry policy system needs to be optimized and transformed to more widely promote the satellite navigation industry at a higher level. Thus, in the present study, we take the effect of industrial policies on the development of the satellite navigation industry as the starting point, comb the current situation of industrial policies, summarize the existing problems of industrial policies, and propose suggestions for the transformation and development of industrial policies to provide a theoretical reference for building the competitive advantage of China's satellite navigation industry and entering the international market in an all-encompassing manner.

2 Analysis of the effect of industrial policies on the development of the satellite navigation industry

2.1 Promoting the flow of market elements to the satellite navigation industry

There are uncertainties in the technology and supply chains in the satellite navigation industry. From a technical perspective, the satellite navigation industry is based on innovation, solidification, and application of satellite navigation-related technologies, while the technological innovation of the satellite navigation industry is complex, which is prominently manifested in the long-term complexity of core technology breakthroughs and the coupling with related technological breakthroughs. From the supply chain viewpoint, in the early stage of the development of the satellite navigation industry, owing to the limited market capacity of its products/services, companies cannot obtain the high-quality and newly-trending raw materials from the market, and the equipment and parts rely on self-research; with the expansion of the market, more supporting enterprises have emerged, but the possibility of the unsynchronized development of various links in the industrial chain still exists, and this constitutes a bottleneck to industrial development [6].

Compared with other traditional industries, this uncertainty leads to large investment, long cycle, weak anti-interference ability, and high overall risk in the satellite navigation industry. Regardless of being “hard” elements, such as labor or capital, or “soft” elements, such as technology, knowledge, and information, the flow to the satellite navigation industry is slow, and this is not conducive for seizing the best opportunities in the international market. Therefore, the government can lead and directly participate in the basic technology development and infrastructure construction of the satellite navigation industry, thereby reasonably increasing the tilt support in terms of resource input, talent introduction, and technology transformation to win the necessary production factors and resources, as well as to foresee the flow of market elements to the satellite navigation industry.

2.2 Expanding and enriching the market demand of the satellite navigation industry

The development of the industry directly relates to market demand. To add value, market demand pushes producers to mobilize various production factors and resources to create technologies, products, and services that meet market needs. Market demand is the external motivation for the development of the satellite navigation industry. The government can cultivate and broaden the market demand through standardization, public procurement, and foreign trade policies, as well as other tools. For example, on one hand, standardization policies can clarify the satellite navigation technology standards or application in the industry, facilitate the listing of related satellite navigation technologies, products, and services on the certification list of the International Civil Aviation Organization, the International Maritime Organization, and the International Standards Organization for Mobile Communications, and obtain access to the satellite navigation international market. On the other hand, public procurement policies use government contracts to purchase satellite navigation technologies, products, and services, thereby stimulating the market demand for the satellite navigation industry and guiding the optimization and adjustment of the industrial structure.

Considering the U.S. satellite navigation industry policy as an example, since the GPS has been operationalized in the 1990s, the United States has focused on the application of the standardization and public procurement policies of the satellite navigation industry, established GPS and its enhanced functions as an international standard through legislation, and embarked upon the governmental procurement of GPS-related technologies, products, and services in accordance with the *National Defense Authorization Law*. These industrial policy tools have significantly expanded the internal and external market demands of the US satellite navigation industry and promoted the rapid development of the satellite navigation industry.

2.3 Improving the development environment of the satellite navigation industry

The rule of law is an inherent requirement of the market economy, and the satellite navigation industry should be located in a law-based environment. The law has delineated two types of rules for the market, namely, the government’s intervention in the market and the activity rules of the market entities. Under the combined effect of these two rules, there are three results. The first is to promote the scientific and organized formulation of macro-control policies for the satellite navigation industry, as well as to strengthen the responsibility system and incentive guarantee measures for the implementation of macro-control policies; the second is to better guide and standardize market order, as well as create a fair competition environment for the development of the satellite navigation industry; the third is to better protect the legitimate rights and interests of various market players.

The satellite navigation industry also has its unique characteristics. The location service based on satellite navigation generates and applies a large amount of personal location data, and it needs to establish refined data security regulations, strictly implement data protection management responsibilities, prevent the leakage of location data, and protect personal rights and public security. Technological innovation and application are the core competences of the satellite navigation industry. It is necessary to strengthen policies and measures for the protection of intellectual property rights, regulate the conversion and application of intellectual property rights, and prevent the illegal loss of related technologies, thereby better stimulating the innovation vitality and investment willingness of enterprises.

3 Current policy status of China's satellite navigation industry

3.1 The successive promulgation of national macro policies

China has issued a series of policies and documents related to satellite navigation development plans, such as the *Notice on Accelerating the Application of the BeiDou Navigation System* and *National Satellite Navigation Industry Medium- and Long-Term Development Plan*. These policy document systems expound the development conception and policy propositions of China's BDS, clarify the important position of BDS in national information infrastructure and strategic emerging industries, and deploy the development direction, target tasks, and overall arrangements of China's satellite navigation industry. Meanwhile, China has comprehensively applied several policy tools, such as target planning, infrastructure investment, as well as public technology and service procurement, which provide necessary resources, funds, and technical support, for the development of the satellite navigation industry.

For over a decade, relying on industrial policies, China initially formed a satellite navigation industry chain covering basic devices, such as chips and modules, software, data (upstream), terminals, system integration (midstream), and application services (downstream). However, now the performance of the BDS has reached an internationally advanced level, its core technology system has been basically established, and it is being widely used in many fields. For example, the BDS comprehensively serves transportation, public security, disaster relief, agriculture, forestry, animal husbandry and fishery, urban governance, and other industries, and it has been integrated into the construction of national core infrastructure, including electricity, finance, and communications; related products are exported to more than 120 countries and regions, and the scale of user services has reached a level of 100 million [7].

3.2 Industry policy continues to advance

Since 2007, the national industry authorities have issued a series of industrial policy documents related to satellite navigation, focusing on transportation, surveying and mapping, emergency management, agriculture, forestry, animal husbandry, fishery, and civil aviation. The following points are notable in this regard: (1) The transportation industry is one of the largest industry users of BDS. The "*13th Five-Year*" *Modern Comprehensive Transportation System Development Plan*, *Guiding Opinions on the Promotion and Application of the BeiDou Satellite Navigation System in Industries*, and the *Guiding Opinions of the Ministry of Transport on the Construction of New Infrastructure in the Transport Field* are the guiding documents for promoting the application of the BDS in the transportation industry during the 13th and 14th Five-Year Plan periods. (2) The BDS is an important part of the surveying and mapping geographic information infrastructure. Industrial policies strongly support the BDS to play an important role in the monitoring of geographic conditions, digital cities, and the national geographic information public service platforms. For example, the *Surveying and Mapping Law*, newly revised in 2017, clearly requires the promotion of the structural adjustment and optimization and upgrading of the geographic information industry, supporting the development of various geographic information products, and promoting the use of safe and reliable geographic information technologies and equipment. (3) The BDS plays an important role in rescue activities in sparsely populated areas, such as oceans and mountainous areas, as well as during natural disasters, such as earthquakes, floods, and others. *The 13th Five-Year Plan for the Construction of National Emergency Response System* and *National Comprehensive Disaster Prevention and Mitigation Plan (2016–2020)* fully deployed the application of the BDS in disaster reduction and relief and regulated technical standards for disaster reduction application platforms, disaster information direct reporting terminals, emergency rescue information terminals, and vehicle navigation monitoring information terminals to promote the standardization of the BDS application. (4) *Guiding Opinions on the Implementation of Subsidies for the Purchase of Agricultural Machinery (2013)* issued a financial subsidy policy for the "agricultural BeiDou terminals (including fishing boats)." The terminal and system integration of the integrated BeiDou basics can be widely used in the fields of agriculture, forestry, animal husbandry, and fishery, and the BeiDou Marine Fishery Application Demonstration Project (2012) proposes the equipment of fishing boats with BeiDou navigation terminals, which significantly improves the application coverage.

3.3 Close follow-up of regional industrial policies

The satellite navigation industry has formed industrial agglomerations in five major regions of Beijing–Tianjin–

Hebei, Yangtze River Delta, Pearl River Delta, Hubei–Henan–Hunan, and Western Sichuan–Shaanxi–Chongqing. In 2019, the output value of these five major regions achieved 267.1 billion CNY, which accounted for 77.4% of the national total output value [8]. Many provinces in these regions have issued regional policies and documents to guide the development of the regional navigation industry.

3.3.1 Beijing–Tianjin–Hebei Region

Beijing adopts the promotion policy of “apply BDS as much as possible,” and encourages new informatization projects to adopt domestic positioning timing technology through the government informatization technology review mechanism. In addition, it has established the BeiDou new format fund to provide support on technical innovation, financial support, application promotion, industrial support, and talent introduction [9]. *Beijing's Implementation Plan for Promoting the Development of BeiDou Navigation and Location Services Industry (2012–2015)* propounds the goal of building an internationally leading navigation and location service integrated application demonstration city, while *Beijing's Implementation of Promoting BeiDou Technology Innovation and Industrial Development Plan* proposes the development goals, key tasks, and safeguard measures for advancing the satellite navigation industry. The Beijing–Tianjin–Hebei region has jointly formulated the *Beijing–Tianjin–Hebei Coordinated Action Plan for the Development of the BeiDou Navigation and Location Services Industry (2017–2020)* to support the construction of satellite navigation industry clusters.

3.3.2 The Yangtze River Delta

The *Shanghai's Implementation Plan for Promoting the Special Project of Strategic Emerging Industries Satellite Navigation (2012–2015)* presents the development ideas of “being compatible, focusing on both ends, cultivating leaders, as well as demonstrating and driving,” clarifies industry positioning, formulates special promotion plans to guide the development of industrial technology, supports policies to improve the business environment, accelerates market expansion through various social means, and supports the development of the BDS application industry. Shanghai takes the lead in implementing the *Satellite Navigation Application Demonstration Project in the Yangtze River Delta*, focusing on promoting the demonstration application and industrialization of the BDS in the Yangtze River Delta region. The *Outline of the Yangtze River Delta Regional Integration Development Plan* proposes the realization of the interconnection and intercommunication of the satellite navigation and positioning reference service systems and support the prior application of the BDS [10].

3.3.3 The Pearl River Delta Region

Guangzhou, Shenzhen, Zhongshan and other cities in the Pearl River Delta region have the most comprehensive industry chain supply capacity of electronic information in China, and the industrial structure of introducing, assembling, and manufacturing satellite navigation terminal products is relatively mature [11]. As the main production area of China's satellite navigation and location service terminal equipment, the Pearl River Delta region has a strong supporting capacity and mature application market for the satellite navigation industry. Its total output value in 2019 is 77 billion CNY, ranking first in the country. The release of *Guangdong's Special Plan on the BeiDou Satellite Navigation Industry Development (2013)*, *Guiding Opinions on Promoting the Development of Satellite Navigation Application Industry (2016)*, *BeiDou Satellite Navigation System Application Industrialization Implementation Plan (2012)*, and other policies guide and support BDS application, thereby contributing to the uniqueness of the satellite navigation industry.

3.3.4 Hubei–Henan–Hunan Region

The Hunan and Hubei Provinces have advantages in scientific research and talents in the field of surveying and mapping science. The Hubei Province has issued the *Opinions on Promoting the Development of the BeiDou Satellite Navigation Application Industry (2014)*, the *Hubei's BeiDou Satellite Navigation Application Industry Development Action Plan (2015–2020)*, and *Opinions on Promoting the High-Quality Development of the Province's Ten Key Industries (2019)*, with the proposition to develop innovative industrial clusters of geospatial information and application services with global influence and build a geospatial information and application service industry ecosystem. Changsha City of the Hunan Province has issued the *Opinions on Accelerating the Development of the BeiDou Satellite Navigation Application Industry (2014)*, with the plan to build a BeiDou satellite navigation industrial base in Lugu High-tech Zone; *Changsha's Development Plan for the BeiDou Satellite Navigation Application Industry (2014–2020)*; and *Changsha's Three-Year Action Plan for Accelerating the Development of the Satellite Navigation Industry (2016–2018)*, all geared toward the development of Changsha

into the “BeiDou City.”

3.3.5 Sichuan–Shaanxi–Chongqing

The related industries in this area are mainly based on Xi’an. Owing to the technology, equipment, and talent from the aerospace industry, while relying on many development policies, such as the development of the western region and the industrialization of new and high technologies, Xi’an has formed an industrial pattern dominated by satellite component manufacturing. The *Shaanxi’s Special Plan for the Development of the Satellite Application Industry during the 12th Five-Year Plan (2011)* proposes the acceleration of the cultivation of the core satellite application industry and creation of a world-class satellite application industry highland. Chengdu and Mianyang are key cities for the development of the satellite navigation industry in Sichuan Province. The *Mianyang’s Development Plan for the BeiDou Satellite Navigation Industry* proposes to develop into first-class domestic and internationally advanced satellite navigation industry clusters in the southwest.

4 Problems existing in China’s satellite navigation industry policy

Albeit China’s satellite navigation industry policy system has been basically formed, it is still relatively extensive and quantitative, the ratio of policy resource input and benefit output is not high, and it is out of the actual development needs of the satellite navigation industry. The main problems are as follows: first, the policies issued by various industries and regions are highly protective and fragmented; second, the selection and combination of industrial policy tools are unscientific and unsuitable; third, the supply of targeted policies urgently needed for key core technology innovation is insufficient; and fourth, policies and regulations lack overall coordination, which leads to implementation failure.

4.1 The degree of legalization of industrial policies is relatively low

Currently, more than 90% of China’s published policies related to the satellite navigation industry are regulatory documents or “red-head documents,” and only a few are departmental or local regulations. Being the basic law of satellite navigation, the *Regulations on Satellite Navigation of the People’s Republic of China* has been included in the State Council’s legislation plan since 2016, but it has not yet been promulgated. Therefore, most of the satellite navigation industry policies are not included in the legal level, leading to difficulties in the formulation and implementation of industrial policies.

First, the lack of a statutory authority for the BDS and navigation industry leads to the lack of overall coordination and implementation of industrial policies. During the construction phase of the BDS, the state established a BDS major special project leading group to promote the construction of the Beidou system and achieve the proposed goal. As the BDS enters into the stage of promotion and application, the model of “overall deployment–application of national security and key industry–commercial use in the mass consumer market” should be adopted to drive the marketization process; however, the current management model remains that of the construction phase, lacking a high-level, permanent overall management organization, thereby leading to many constraints in functional connection, task docking, and work collaboration, which apparently fails to meet the requirements of higher-level industrial development.

Second, owing to the lack of enforcement of the law, it is difficult to achieve the expected effects in the implementation of satellite navigation industry policies. Industrial policies are related to the medium- and long-term goals of the entire economy, and the relationships involved are long-term and extensive. Therefore, under the macro background of emphasizing the rule of law, it is evidently insufficient for the satellite navigation industry policy to exist only in the form of a “pure” policy, which needs corresponding legal adjustments to enforce the industrial policies [5].

Third, from the construction experience of the world’s satellite navigation system, early construction was mostly driven by policy, while application development was mostly incorporated into the regulation of law. As the BDS has been applied more comprehensively, guiding policies fail to establish the complex system of right and duty. Thus, it is urgent to strengthen the legislation and build a satellite navigation legal and regulatory system.

4.2 Fragmentation of industrial policies is prominent

The GPS was first applied in the field of national defense and security, and then comprehensively promoted in industrial applications, and gradually realized the large-scale application of mass consumption. Conversely, the

development model of China's satellite navigation industry is promoted simultaneously in three aspects. Although the *National Satellite Navigation Industry Medium- and Long-Term Development Plan* has planned the key directions and main tasks for the development of the satellite navigation industry, the policy design is relatively general and lacks specific implementation and promotion rules. National defense, civilian use, industries, regions, and localities have intensively introduced many satellite navigation industrial policies based on their respective needs, but the lack of a top-level overall design has resulted in obvious competition in the market, squeezing of resources, and disorderly competition.

There are over 40 satellite navigation industrial parks in various places, but most of them lack clear industrial plans and specific implementation plans, and the comprehensive utilization efficiency is low. Some industrial parks have been left undeveloped for a long time, and a few parks have even been converted to land for real estate development, which has affected the overall effect of the implementation of the satellite navigation industry policy. Furthermore, the homogeneity of related products is prominent, and the technological content is not high [12], while the application market is severely squeezed. For example, in the field of transportation, the homogeneity of navigation services provided by most companies is serious, and the price war is fierce and inevitable, which is not conducive to relevant companies and other market players to maintain continuous investment in the industrialization of satellite navigation application.

4.3 The combination of policy tools is not sufficiently scientific

The difficulty in formulating industrial policies lies in the selection and coordination of policy tools, and the selection of tools has phased features, which usually change with different stages of industrial development. The theory of industry lifecycle [13] indicates that during the introduction period, the industry generally shows that the number of enterprises is small, the degree of concentration is high, the technology is immature, the market scale is small, the demand growth is slow, the industrial profit is meager or even minus, the barriers to entry are not high, and competition is weak. Judging from the development practice of China's satellite navigation industry, in the early stage of capacity expansion, the resource tilt brought by industrial policies can indeed promote output growth in the short term, and the satellite navigation industry has achieved good results with the government intervention and industrial policy. After a period of rapid development, satellite navigation technology and the market have matured and entered a new stage of steady development. The competition among industries (enterprises) has been fierce, and the market structure has stabilized.

Presently, the growth rate of the output value of China's satellite navigation industry has continued to decelerate, indicating that the original government-led and project-driven method has a limited role and insufficient overall driving force when confronted with changes in the country's macroeconomic situation. This is because there are too many policy-related micro interventions in the market, squeezing the market's role in resource allocation. For example, the selective preferential policies (sometimes even against market law) for specific projects, technologies, and companies in the satellite navigation industry actually disrupt the market's rules regarding resource allocation. Thus, neither good companies nor projects receive special preferences, and it is rather difficult for them to get necessary support, which consequently affects the companies' enthusiasm to participate in market competition. Additionally, some satellite navigation industries or industrial applications can only survive and develop under the support of policies. Once the preferential policy declines, it will be difficult for them to survive independently in the application market. The full support of fiscal policy can easily affect the decision-making and judgment of companies, thereby leading companies to underestimate market risks, blindly expand investment, and tend to gain competitive advantage through scale rather than technology. It may also lead to the failures of the due supervision mechanism, rent-seeking of enterprises, and policies.

4.4 Lack of targeted support for core technology research and development

The development of emerging industries depends on the mastery and application of advanced technologies. Only through continuous industrial technological transformation and accumulation can a core technology system with independent intellectual property rights be formed, and only then can the economic benefits of industrial development be shared [14]. Correspondingly, the basic technology of the satellite navigation industry is the foundation for the sustainable development of the industry and the maintenance of market competitiveness. However, the long investment cycle and low rate of return for the related technology research and development, coupled with the positive external effect of basic technology research, makes private enterprises less active in basic

technology research and development. The research and development of core and key technologies in the satellite navigation industry, especially basic technology research and development, requires reasonable support from industrial policies. However, existing industrial policies focus more on the middle- and back-end chain of the satellite navigation product manufacturing, infrastructure construction, and other industries, which lack the support of the front-end industrial chain.

4.5 Deficiencies in the use of international rules and standards

The industrialization and internationalization of satellite navigation complement each other. China's satellite navigation applications account for a relatively low proportion of the international market, the number of users remains relatively small, and the willingness to participate globally is still relatively weak. One of the important reasons is that, in industry-related international organizations, such as the International Telecommunication Union, the International Civil Aviation Organization, the International Maritime Organization, and the International Standards Organization for Mobile Communications, China's influence is still relatively weak, and the leadership in international rules and standards needs further improvement. For example, only a few Chinese companies have joined the 104th Professional Committee of the International Maritime Radio Technology Committee, which is responsible for the formulation and revision of standards, such as the differential global navigation satellite system protocol and the independent data exchange format of the receiver, that are closely related to the satellite navigation industry.

Technical standards are a non-tariff barrier measure permitted by the rules of the World Trade Organization. The satellite navigation industry is built on a large number of advanced technological innovations and applications, and its development is significantly affected by technical standards. Countries and regions with traditional advantages in the satellite navigation industry actively use technical standards to build technical trade barriers, and this has become the main means and advanced form of implementing trade protectionism in related industries. The internationalization of China's BDS standards started late, which implied that many international standards resources had been occupied by the GPS, GLONASS, GALILEO and other systems, resulting in China's weak leadership in international rules and standards regarding satellite navigation.

5 Suggestions

5.1 Accelerate the legislation of the satellite navigation industry and strengthen the legal guarantee for the development of the industry

Through the rule of law, the effects of industrial policies can be better realized, and the status and role, management relationships, construction requirements, departmental responsibilities, mandatory application norms, etc. of satellite navigation can be clarified by relying on national laws and regulations, which is also the common practice of world powers. China's BDS-III satellite navigation system has been fully completed and has entered a critical stage of application promotion and industry cultivation. It is recommended to accelerate the legislative process of *Regulations on Satellite Navigation of the People's Republic of China* and clarify the legal status of the BDS as a major national space infrastructure. Policy documents on centralized management, system construction, operation services, promotion and application, and safety supervision should be upgraded to corresponding regulations as soon as possible. It is also recommended to further demonstrate the compilation of the satellite navigation industry development cycle map, technology development road map, and policy implementation road map in accordance with the issued *Regulations on Satellite Navigation of the People's Republic of China* to guide the sustainable development of China's satellite navigation industry. Moreover, government should start the project demonstration of the PNT law at the appropriate time, and promulgate it when conditions permit, as well as incorporate the PNT system and industrial development into the rule of law, unify the national time and space benchmarks, and ensure full coverage, thus improving the overall service performance and investment benefits.

5.2 Adjust policy-supporting and industry-leading methods to stimulate market dynamics

Thanks to the cultivation of industrial policies, China's satellite navigation industry has grown rapidly in the bud and early stages of development; however, it lacks the strict choices of the natural market and its market competitiveness is weak. In the new era, under the "new development pattern with the domestic cycle as the main body and the domestic and international double cycles mutually promoting each other, it is recommended to

rationally adjust the policy to more actively guide the marketization, scale, and internationalization of BDS applications, as well as deepen the refinement of the domestic market, while actively participating in international market competition. The satellite navigation industry policy should focus on the inherent advantages of the domestic super-large-scale market, guide the expansion of satellite navigation applications to aviation and other high-end user markets, improve consumer solutions and application scenarios, and build a satellite navigation industry chain that covers the whole country and radiates globally. It is recommended to make necessary adjustments to the industrial policy by shifting from the government's main role in the past to relying mainly on the market mechanism in the future and gradually reduce the government's direct intervention in the satellite navigation industry. It is recommended to reasonably adopt indirect guidance methods, such as finance, taxation, banking, foreign trade, and government procurement, give priority to the administrative and information guidance methods, such as publishing research reports and advice, and comprehensively use various policy tools, such as laws, standards, and technologies. It is also recommended to actively create a legalized market environment for the development of the satellite navigation industry, prevent improper micro-intervention by industrial policies on the satellite navigation industry and the market, encourage fair competition in the market, and promote satellite navigation technology, products, and services to provide more options for the receiving market.

5.3 Carry out comprehensive and targeted measures to enhance industrial technological innovation

The satellite navigation industry has a special position and an important role. Thoroughly solving the problems in the development process depends on the construction and improvement of the industrial ecological environment, as well as the enhancement of technological innovation capabilities and core competitiveness. It is recommended to focus on targeted and comprehensive measures, establish a timely and efficient transformation mechanism for technological innovation results, cultivate new motivation and new pattern for industrial development, and promote the enhancement of industry core competitiveness, while implementing the transformation, upgrading, and independent innovation of the satellite navigation industry. Policy formulation should focus on the frontier areas of the satellite navigation industry, the key nodes that hinder the development of the industry, emphasize the foresight and inclusiveness of policies, and plan the continuation and transformation of existing satellite navigation industry policies and future PNT system industrial policies. Relying on policy guidance, it is recommended to support the integration of the BDS and network information systems, as well as the compatible development with low-orbit navigation enhancement systems and underwater, inertial, and pulsar navigation systems to promote the integration and innovation of satellite navigation and big data, blockchain, cloud computing, artificial intelligence, and other technologies. The government should continue to cultivate high-value patents in the satellite navigation industry, pay attention to the transformation and operational use of authorized patents, thereby effectively improving the supporting role of intellectual property rights for the sustainable development of the satellite navigation industry. The government should also improve the industrial "hematopoiesis" function, enhance the ability to resist market risks, thus forming an application ecology of a virtuous circle among technology, industrial, and value chains.

5.4 Deeply participate in the formulation of international standards and rules to enhance international competitiveness

Satellite navigation services and industries are global, and China's industrial policy formulation must consider the use of international resources and the development of international markets. The development of the satellite navigation industry can be combined with the Belt and Road initiative to give it the attributes of global public service products, expound the policy propositions of the BDS serving global users, and expand the scale of effective user groups. It is recommended that standards and regulations should be addressed first. China should participate in the formulation and revision of relevant international rules for satellite navigation in an all-encompassing and multi-channel manner, and actively participate in technical discussions on multilateral platforms, such as the International Committee on Global Satellite Navigation Systems; China should recommend Chinese programs and standards, and strive to incorporate these into relevant international rules and the technical standard systems of relevant international organizations to promote the effective convergence of domestic and international standards. It is recommended to strengthen communication and coordination among management agencies, academic groups, and industry forces; reasonably increase the number of Chinese representatives in international satellite navigation organizations and various professional organizations; and actively organize

satellite navigation international conferences to effectively improve China's right to speak and influence in international satellite navigation rulemaking.

5.5 Improve the overall coordination mechanism to ensure the effective operation of industrial policies

The experience of developed countries has shown that for the satellite navigation system, which is a typical dual-use system for military and civilian purposes, the effectiveness of policy implementation can be ensured by rationalizing the satellite navigation management system and considering the interests of all parties when formulating policies [15]. China can also take effective measures to break the dual separation mechanism between the military and civilians in the field of satellite navigation, while improving the military and civilian coordination mechanism of the satellite navigation industry policy system, which is one of the key issues that need to be resolved in satellite navigation legislation. It is recommended to establish a high-level and permanent national satellite navigation management organization or conceptualize a national comprehensive PNT system construction leadership organization. The legal organization and management agency for the construction, application, industrial development, upgradation, and transformation of the national satellite navigation system should be responsible for implementing the national satellite navigation emerging strategic industry deployment, coordinating the development of the military and civilians in the satellite navigation field, taking the lead in formulating and coordinating the implementation of the policy system, studying and formulating special support policies, and coordinating and solving major problems. It is recommended to build a pragmatic and efficient work promotion mechanism, and gradually establish and improve various levels of work institutions for the development of the satellite navigation industry; clear the management system and work model; establish the responsibility system covering the departmental consultation, information exchange and sharing, third-party participation and evaluation, as well as supervision and inspection mechanisms in addition to the stepwise implementation of relevant policies, thereby forming a cross-regional, cross-field, and cross-sectoral collaborative industrial development model.

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