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Latecomer's strategy: An assessment of BDS industrialization policy

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ABSTRACT

The successful launch of the Chinese Beidou (Compass) Navigation Satellite System (hereafter refers to as BDS) makes it the third operational navigation satellite system capable of offering regional services after GPS and GLONASS in the end of 2012. Yet considering the dominant role of GPS in global GNSS market, it's a great challenge to maximize the utilization of other systems and cultivate competitive domestic navigation industries for all latecomers in the GNSS community. This paper analyzes the current strategy of BDS industrialization by a detailed review of current policy documents from both central and local government, examines the progress of BDS industrialization based on statistical data and expert interviews, and summarized the current strategy of BDS industrialization as indigenous in key domains and compatible in commercialization. Then a stakeholder analysis is conducted to analyze the consideration behind current strategy. This paper also comes up with several policy recommendations for Chinese decision makers' reference to improve BDS related policies in the future from a latecomer's perspective based on detailed comparison analysis of BDS's advantages and disadvantages.

1. Introduction

Like the Internet, satellite navigation systems are essential element of the global information infrastructure, which is now in everything from cell phones and wristwatches to bulldozers, shipping containers, and ATMs [1]. The well-known and widely used US NAVSTAR Global Positioning System (GPS) and Russian GLONASS system are currently in operation global satellite navigation systems [2]. The successful launch of the Chinese Beidou (Compass) Navigation Satellite System (hereafter refers to BDS) makes it the third operational navigation satellite system capable of offering regional services in the end of 2012 [3].

The Chinese government has made great efforts to promote the application and commercialization of BDS. As early as 2007, related ministries had established satellite navigation industry as a national strategic high-tech industry [4]. The release of the National Medium- and Long-Term Development Plan on Satellite Navigation Industry [5] by the State Council in 2013 further reiterated the practical and long term strategic significance of BDS for adjusting economic structure, increasing productivity, improving social welfare, and strengthening national competitiveness. The Plan also raised the goal of cultivating a 400 billion RMB navigation market with the contribution from BDS based products and services counting for more than 60% (the percentage is expected more than 80% in key domains), as well as a strong global competitiveness.

Though China raised an ambitious plan to industrialize BDS, it is still under a lot of uncertainty and difficulty. According to the European GNSS Agency, the global GNSS market size exceeded 150 billion Euros in 2012, and the installed base of GNSS devices will increase four-fold, almost one GNSS receiver for every person on the planet over the coming decade [6]. Yet currently more than 70% of models available on the market are GPS-SBAS capable (SBAS comprising WAAS, EGNOS, and MSAS). In Chinese market, the market share of BDS based products only counted a negligible share of less than 10% by the end of 2013. With the construction of European Union's Galileo global positioning system, Japanese Multi-functional Transport Satellite Satellite-based Augmentation System (MSAS) and the Quasi-Zenith Satellite System (QZSS) and the Indian Regional Navigation Satellite System (IRNSS), a severe competition in the future is foreseeable.

Current studies on BDS industrialization lag behind the practice of the government and industry. Literature on BDS mainly focuses on the technological aspect of the system, and very limited number of studies considered the policy issues of its industrialization. Li (2013) reviewed the development and decision process of GNSS in China from a historical perspective, and analyzed the policy issues of China's satellite navigation industry [7]. Some domestic scholars summarized the current status and development trends of satellite navigation, especially BDS based industry, such as Han et al. (2010)

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[8], Sang (2012) [9], Wu et al. (2013) [10] and Zhang et al. (2013) [11]. Some attentions are also paid to the experiences and lessons learned from the industrialization of other major GNSS systems, like Wang and Wu (2011) [12], Shi (2013) [13]. But in general, a holistic assessment of industrialization policy of BDS in the context of global cooperation and competition is absent. The release of the National Medium- and Long-Term Development Plan on Satellite Navigation Industry by the State Council of China in 2013 provides an opportunity to follow and discuss the policy issue of BDS industrialization.

This paper tries to shed some light on the problem by taking a policy assessment on BDS industrialization strategy as a latecomer. Three research questions are raised to understand the industrialization strategy of BDS: (1) what strategy is China currently taking to promote the industrialization of BDS; (2) why the strategy is taken? and (3) what measures may be taken to improve the strategy in the future. The research setting is that China attempt to cultivating a BDS based industry under the context that GPS is holding an existing dominant position in both domestic and international market, as well as the emergence of some other global and regional satellite navigation systems. Within this setting, there is no doubt that BDS is a latecomer to the international GNSS community in terms of constellation construction, industry cultivation and market penetration.

The paper is organized as follows. We start with a detailed description of data collection and analysis methodology. We then summarize the progress of BDS industrialization to explain its industrialization strategy in terms of governance, market and international cooperation. Based on interviews and expert meetings, we discuss concerns of major stakeholders on BDS industrialization, and come up with alternative strategies and policy suggestions for its future development. We conclude by discussing the major findings and possible future research directions.

2. Research methodology

Given the nature of the research question and data availability, an exploratory case study method is hired to investigate the current BDS industrialization strategy. The case method has long been accepted as an important method to develop an understanding of the dynamics that occur within single settings [14]. Especially an exploratory case study focuses to understand what happened within a case by looking beyond descriptive features and studying surround context [15]. Stakeholder analysis and latecomer strategy analysis will be conducted to answer the *why* and *how* questions of the case study. Stakeholder analysis is a widely applied method used to investigate entities such as communities, NGOs, government and the private sector who have a ‘stake’ or an interest to affect, or will (potentially) be affected by a certain decision-making processes [16]. It will be taken into analysis the stakeholders' concerns, networks and their relations which may affected or be affected by the industrialization of BDS, with a view of understanding the current strategy and give a clue for the future development.

Latecomer theory is widely applied to explain the rapid development completion strategy to catch-up of latecomer economies. Literature indicate that advantages of first-mover/incumbent mainly derive from technological leadership, preemption of scarce assets, and switching costs and buyer choice under uncertainty [17]. Studies on consumer behaviors also suggest that the purchasing behavior of consumer is a learning process, within which the brand reputation and previous purchasing experiences are more likely to bring first-mover advantages [18,19]. Besides, distance from major markets is also identified for latecomer firms which are always firms in developing countries [20]. Literature, on the other hand, indicate that the first-mover advantage may be undermined by means of “free-rider” affects, resolution of technological or market uncertainty, shifts in technology or customer needs, and incumbent inertia [21]. At the same time, latecomers in developing countries always benefit from a cheap and well-trained labor supply [22], export promotion policies and indigenous technological development efforts within local firms [23]. Practical evidences show that rapid catching up even overtaking to incumbent multinational enterprises (MNEs) may be acquired in some emerging technology industries if appropriate strategies are taken, such as the cases of consumer electronics and semiconductors industry in Japan and Korea [24], and the telecom equipment industry in China [25]. We will take the methods suggested by latecomer's strategy to catch up to analysis major advantages and disadvantages of BDS, and come up with alternative strategies for the future.

To conduct these analyses, a variety of data collection methods are used. In-depth interviews with related experts, including government officers, industrial experts, entrepreneurs, technical expert, and researchers in China as well as their counterparts in the United States and EU are taken. All interviews take a semi-structured questionnaire to lead the conversation, and we also encourage the interviewees to raise new policy issues. Besides, two expert meetings are held to discuss the concerns of major stakeholders, BDS industrialization strategy, and policy suggestions. Six types of public archival data are also collected and analyzed to support the study, namely: (1) major legal and policy documents issued by Chinese government at both national and provincial level; (2) major legal and policy documents issued by the United States on GPS; (3) international GNSS industry reports and BDS industry reports; (4) official GNSS websites; (5) websites of major GNSS enterprises, both local and MNEs; and (6) journal articles and research reports on GNSS commercialization and industrialization.

3. Strategy of BDS industrialization

As mentioned above, the intention to promote GNSS industry development in China dates back to 2007, and the release of 2013 National Plan make the strategy more clear and comprehensive. Current strategy of BDS industrialization can be summarized as indigenous in key domains and compatible in commercialization, which is implemented by a mixture of three interrelated measures: top-down push, bottom-up pull, and inside-out promotion. The strategy and its progress will be depicted with a descriptive elaboration based on official publications and investigation data.

3.1. Top-down push from government

Top-down push refers to the promotion and introduction of BDS industrialization from both central and local governments, by means of various policy measures, such as construction of industry parks, R&D funding, and government procurement, etc.

The application and industrialization of BDS is governed and regulated by a multi-agency mechanism. Major departments and agencies get involved in BDS industrialization including National Development and Reform Commission (NDRC), Ministry of Science and Technology (MOST), Ministry of Industry and Information Technology (MIIT), State Administration of Science, Technology and Industry for National Defense (SASTIND), General Staff Department (GSD) and General Armament Department (GAD) [26]. The Management Office of Satellite Navigation System is the executive authority to promote the application and industrialization of BDS, which are in charge of the formulation and release of Interface Control Documents, coordination of standard and IPR issues, and promotion of international cooperation. Besides, a Technological

Committee on BDS Standardization is formed to manage the national and international standardization issues of BDS system management, construction, operation, application and services, whose members come from government, industry, universities, and research institutions [27].

Chinese government put great emphasis to the application and industrialization of satellite based navigation. Several national policies take the development of GNSS industry as a priority. Taking the 12th Five-year Plan for National Strategic Emerging Industries [28] for an example, it identified satellite navigation as an important area under high-end equipment manufacturing (one of seven strategic emerging industries), put forward the development and promotion of BDS compatible navigator and digital comprehensive application terminals, and encouraged private capital to invest in satellite navigation industry.

The first policy document on satellite navigation dates back to 2007, when the former Commission of Science and Technology and Industry for National Defense (COSTIND) and NDRC issued Several Opinions Relevant to Promoting the Development of the Satellite Application Industry, which put forward to transform the applied satellite industry of China from "testing and application-based" to "business and service-based" by 2020. Key policy measures concerning satellite navigation including accelerating the construction of BDS, coordination the construction of augmentation system, promote the development of large-scale and normalized navigation service industry, and encourage the development of chips, key components, digital maps, user terminals with indigenous intellectual property rights [29].

The National Medium- and Long-Term Development Plan on Satellite Navigation Industry issued by the State Council in 2013 is the key guiding document in force for the industrialization of BDS. The Plan raised a goal of cultivating a 400 billion RMB navigation market with the contribution from BDS based/compatible products and services counting for more than 60% (the percentage is expected more than 80% in key domains), and forming the pattern of industrial innovative development. The Plan clarified four basic principles of industry development: (1) overall planning and interagency coordination; (2) play the dominant role of the market and the promotion role of the government; (3) strengthen technology and application innovation, business model innovation, industrial organization innovation; and (4) insist long-term, stable, open and compatible international service policy. To achieve the industrialization goals, the Plan also set up 6 major tasks and 5 major projects. Its 6 tasks include: improve the navigation infrastructure; break through core key technologies; guarantee the timing in key areas; promote innovative applications; enlarge application scales; and exploit the overseas markets. The 5 major initiatives include: "fundamental initiative" to enhance the performance of BDS; "innovation initiative" to improve technological capacity; "security initiative" to promote the implication of BDS based products in key areas; "public initiative" to promote large scale industrial development; and "international initiative" to exploit global market [30]. However, the Plan is still just an outline which requires related ministries and local government and industry to implement in accordance with responsibilities and status quo [31].

In addition to the State Council, several departments and agencies also released policies to promote the industrialization of BDS. For example, MOST formulated and released the Twelfth S&T Plan for Navigation and Positioning Service, which raised measures for basic research, system platform development, common technology development, application and demonstration projects and standard system building. NDRC and MOF, in consulting with related agencies, funded industrialization projects for satellite application, and navigation satellite, which mainly focus on the development and application of new generation BDS compatible navigator and its core components, as well as the development and application of smart positioning service, indoor and outdoor positioning, and high accuracy displacement measurement, etc. [32] Ministry of Transport issued technical regulations files on BDS compatibility for road transport vehicles to promote the car navigator industry. Besides, Ministries such as MIIT, MOA, SFA, and NASMG have taken measures to promote and support the application of satellite navigation in their respective fields. Key policies of major ministries on BDS industrialization are listed as follows (see Table 1)

Local governments are also actively get involved in the industrialization of BDS. Coastal areas such as Beijing, Shanghai, Guangdong has issued their provincial plan for BDS industry development before the national policy release. Since BDS-II put into operation in the end of 2012, more provinces have joined the competition to the 400 billion RMB business. Beijing, Shanghai and Hubei province raised ambitious goals of achieving a 100 billion RMB BDS industry; some other provinces and cities also set goals of 10 billion level industry volumes towards 2020. To meet these goals, package measures such as funding of pilot and demonstration projects, construction of industry parks, financial guidance and support, and foundation of industrial alliance, are also taken at local level. According to a rough estimate, around 40 BDS related industry parks were established within the past a few years. Though some experts criticize that some local government take advantage of BDS industrialization for real estate business rather than developing high-tech industry, the burst of BDS industrial parks partially reflect the enthusiasm of local government to cultivate BDS industry.

3.2. Bottom-up pull by the market

Bottom-up pull refers to domestic and global market requirements for BDS based/compatible products and services which attract commercial investment in BDS businesses. With the completion of BDS-II constellation at the end of 2012, it acquired the ability to offer regional services. Especially since the release of the Interface Control Document (ICD), a growth spurt of BDS industry is witnessed in 2013.

The market scale of positioning, navigation and timing (PNT) sector in China experienced a significant increase in recent years. According to the statistics of Chinese Association of Satellite Navigation and Positioning, The accumulation of PNT terminal equipment in China increased from 205 million to 348 million (among witch smartphone counted for 330 million, and automotive navigation equipment accounted for around 10 million), while BDS bases products increased from 230 thousands to 1.3 million from 2012 to 2013. Though the proportion of BDS based products is still low comparing to GPS based ones, the percentage is increasing dramatically. Accordingly the sales of whole PNT products and services increased from 81 billion RMB to 104 billion RMB from 2012 to 2013, with an annual growth rate of 69.8% (in comparison of 15.7% from 2011 to 2012). At the same period the market share of BDS based products also increased from less than 5%–9.8% [33].

BDS enabled products and services boomed in various areas. In 2013, around 100 thousand vehicles, mainly tour buses and dangerous goods transportation vehicles were equipped with BDS receivers for cost reduction and safety concerns. 10 thousand public service vehicles in Guangzhou are equipped with BDS receivers to avoid abuse for personal purposes, which brought 30% of cost saving. Nearly 50 thousand fishing boats have taken BDS based equipment to ensure their property safety. BDS's short text function also plays significant roles in forest fire prevention, weather forecasting, and hydrologic monitoring, etc. [34].

Table 1
Key policies of major ministries on BDS industrialization.

Ministries	Key policies
MOST (2012)	The Twelfth S&T Development Plan for Navigation and Positioning Service
NDRC & MOF (2012–2014)	Industrialization Initiative for Satellites and Their Applications
MIIT (2012)	The Twelfth Development Plan for High-end Equipment Manufacturing Industry
MOT (2013)	Technical Regulations on BDS Compatible Satellite Navigator for Road Transport Vehicles; Technical Regulations on Communication Protocols of BDS Compatible Satellite Navigator for Road Transport Vehicles
MOA (2011)	The Twelfth National Development Plan for Fishery
SFA (2011)	The Twelfth National Development Plan for Forestry Informationization
NASMG (2014)	Several Opinions on BDS Promotion and Application
NDRC, MOF & *SASTIND* (2015)	The Medium and Long Term Development Plan on the National Civil Space Infrastructure (2015–2025)
Others	Pilot and demonstration projects

Note: MOST (Ministry of Science and Technology), NDRC (National Development and Reform Commission), MIIT (Ministry of Industry and Information Technology), MOF (Ministry of Finance), SFA (State Forestry Administration), NASMG (National Administration of Surveying, Mapping and Geo-information), SASTIND (State Administration of Science, Technology and Industry for National Defense).
Source: composed by the author

In addition, the trend of application in consumer electronics industry, the largest share of GNSS commercial sector, was also emerging. In 2010, BD Star Navigation, a leading navigation products and system provider located in Beijing, released its Nebulas chip, which was claimed as the first BDS based multi-system, multi-frequency navigation SoC (System on Chip) compatible with GPS, GLONASS, and Galileo system [35]. Major domestic electronic manufacturers, like Huawei, Datang, Hisense and Konka, are also cooperating with BDS compatible chip manufacturers to develop SoCs for their smart phones.

Navigation industry clusters and supply chains are growing. A batch of domestic enterprises are rising rapidly, and drive the formation of supply chain of GNSS industry which covers chips, antennas, terminals, system integration and operation services. Geographically a pattern of five major clusters of BDS industry have gradually emerged, namely area surrounding Bo Sea centering on Beijing, Pearl River Delta region centering on Guangzhou, Shenzhen and Zhongshan, Yangtze River Delta region centering on Shanghai, Central China area (mainly Hubei and Hunan province) and Western area (mainly Sichuan, Chongqing and Shanxi province) [36]. Take the Pearl River Delta region as an example, this area has sophisticated industrial clusters and strong capabilities of production, processing and supporting of manufacturing. More than 60% of civil car navigator is manufactured by this area.

Some multinational enterprises, both end product manufactures and chip suppliers, have also shown a keen interest in BDS compatible products. In 2013, the Qualcomm from the United States collaborated with consumer electronic products manufacture Samsung from South Korea to employ BDS Network to enhance location-based mobile data and services for smartphones. The Samsung GALAXY Note® 3 (WCDMA 3G version SM-N9006 & TD-LTE 4G version SM-N9008V) were claimed using the first integrated tri-band location platform to provide more accurate and responsive location data to mobile users mainly in China by concurrently processing signals from multiple satellite networks [37]. Another international semiconductor manufacturer, Broadcom, also developed new GNSS location chip compatible with BDS. The Broadcom BCM47531 was claimed a GNSS chip that generates positioning data from five satellite constellations simultaneously (GPS, GLONASS, QZSS, SBAS and BDS), and "utilizes BDS signals for up to 2x improved positioning accuracy" [38].

3.3. *Inside-out promotion for internationalization*

The internationalization effort of Chinese GNSS starts with the cooperation with Europe on the Galileo program. China and EU signed the "Sino–European Galileo Plan Technology Cooperation Agreement" in 2003, with the Chinese contributing about $265 million to the program [39]. But the cooperative effort failed due to the European side failed to provide China the privilege of joining the Galileo consortium as a partner according to the previous agreement. After that China turned to develop the BDS independently.

In accordance with the 3-step strategy of BDS constellation construction, the internationalization of BDS industry also follows the pattern from demonstration, regional application to international services.

Regional collaborations are booming with the rapid development of domestic capacity and market. On the one hand, BDS is introduced to neighbor countries by means of demonstration projects, training services and joint research programs for their better understanding and acceptance. For instance, China continuously carries out the BDS/GNSS Application Demonstration & Experience Campaign (BADEC) and has negotiated with related countries to jointly establish BDS/GNSS Centers. Those centers will implement BDS/GNSS popularization, exhibition, application demonstration, and user experience activities, as well as system performance testing and assessment, academic exchanges, training and R&D, to jointly promote the compatibility and interoperability among multiple navigation satellite systems, boost technologies diffusion, and improve satellite navigation applications and industrial development [40]. Through international S&T aid projects, BDS's Continuously Operating Reference Stations (CORS, ground enhancement facilities of GNSS) are constructed in several neighbor countries to support local government and institutions to conduct demonstration projects. It is worth mentioning that the Pakistan CORS network is funded and built by BD Star Navigation, a private navigation products and system provider company located in Beijing we mentioned above. On the other hand, neighbor countries also show keen interests in BDS. Countries like Pakistan, South Korea, Thailand, Mongolia, Indonesia, Malaysia, the United Arab Emirates, and Australia have expressed their interests in collaboration with China in the application of BDS [41].

Besides, Chinese government actively promotes the compatibility and interoperability of BDS with other systems. China and the United States concluded technical coordination discussions on radio frequency compatibility between BDS and GPS at the operator-to-operator level since 2007 under the auspices of the ITU. The two sides also discuss broader cooperation issues during meetings of the International Committee on Global Navigation Satellite Systems (ICG) [42]. The 2014 Joint Statement U.S.-China Civil Global Navigation Satellite Systems (GNSS) Cooperation further identified the willingness of both side to strengthen cooperation, to enable extensive applications of BDS and GPS worldwide [43]. China and

Russia, under the framework of comprehensive strategic partnership, signed the Memorandum of Understanding on Cooperation in the Field of Satellite Navigation in 2014, which laid a concrete foundation for further cooperation. The cooperation between BDS and Galileo has also been integrated into the China-EU 2020 Strategic Agenda for Cooperation.

4. Why the strategy: a stakeholder analysis

With the context of globalization, the industrialization policies of BDS will influence, on the one hand, stakeholders in China as well as their international cooperators and competitors; on the other hand, influenced by them. The analysis of the concerns and postures of various stakeholders on BDS industrialization can bring us a better understanding of the current strategy. Nonetheless we are not attempting to be exhaustive in addressing all concerns from all stakeholders case by case but focus on the major players. In general, five groups of stakeholders are identified who may benefit or harm from the policies and have the ability to influence the policies, by which the strategy of BDS industrialization is finally shaped.

4.1. Chinese government

GNSS is of great importance to national interests to its builders as well as users, especially its defense and national security significance. But under the premise of guaranteeing the basic applications, Chinese government has strong motivations to promote the industrialization of BDS.

From an economic point of view, industrialization of BDS is essential to economic development. As an important information infrastructure, GNSS can be applied widely in almost every aspect of economy and society. Decades of application of GPS in China has made the Chinese decision makers fully aware of the economic significance of GNSS. Especially under the context of China's attempting to transform its economic development pattern and optimize the industrial structure, BDS is given high expectation to play a role in improve the productivity, social welfare and industrial competitiveness.

From a domestic political point of view, guarantee a significant economic and social achievement is important to the justice of huge investment to BDS construction. Successful industrialization of BDS is supposed to bring China better economic development and more jobs, which is followed by a positive feedback from investment to reinvestment. The involvement of large amount of enterprises to develop more innovative application is of positive significance to enhance social and national security application. Imagine the situation that BDS is only serving military and national security purpose while the large commercial market is dominated by GPS or other GNSS, will no doubt undermine the rationality of the whole BDS decision.

From an international relation point of view, widely application of BDS can serve as a positive message to establish China's image as a responsible power. Offering the world navigation and positioning services for free with negligible marginal cost is definitely a good choice to improve the international environment. Promotion through diplomatic agreement is of course important, but the success of widely commercial use of consumer electronics such as smart phones and car navigators, can fulfill the mission better.

4.2. Domestic commercial sector

In comparison to its international counterparts, GNSS industry in China is highly decentralized. It is estimated that more than 100 companies are specialized in R&D, production and sale of BDS related products and services; more than 6000 companies and research institutions and more than 300 thousands employees get involved in GNSS related business. The majority of domestic players is recently founded or transformed from other industry, which have huge gap with multinational enterprises in terms of R&D capacity, supply chain integration and brand reputation, etc. In general, the domestic commercial sector response positively to policies with a view of getting more supports from the government.

From the perspective of industrial development stages, the majority of domestic players are still at their infant or early stage, with typical characteristics of focusing on technological capacity accumulation and market exploitation, and strong requirement to government support on R&D and procurement. The current top-down strategy of Chinese government by means of funding basic research, common technologies development and demonstration projects, fulfills the general policy demands of domestic commercial sector to a large extent.

A small number of leading companies with larger scale and stronger R&D capabilities prefer the government to create a fair competition environment which is conducive to long-term development of GNSS industry. Though there are still gaps in comparison with major MNEs in terms of technology and brand, those leading domestic players have better understandings of domestic market demands. Their policy demands accordingly are beyond direct government subsidies, such as fair competition environment, complete technological standards, testing and certification system, protection to intellectual property rights and innovative products, supportive financial and taxation incentives, and certain amount of regulatory measures to protect domestic industries from international competition.

4.3. Other GNSS providers

Other GNSSs are the potential competitors and partners of BDS. On the one hand, the majority of GNSS satellites is distributed in the medium and geosynchronous orbits with very limited plots, and competes for very limited orbit and frequency resource. On the other hand, compatibility and interoperability is essential to the commercial success of all GNSSs. Here we focus only on the cooperative and competitive relationship of BDS with GPS, GLONASS and Galileo, without concerning other regional GNSS augmentation systems.

There is no doubt that GPS is the most successful commercialized GNSS, and the potential cooperator and competitor BDS will have to confront in its industrialization process. As a successful first mover and incumbent, GPS has accumulated unique experience and competitive advantages in both system construction and market share. In fact, GPS has become the de facto standard of GNSS. Other latecomers may make value only by joining and taking the game rules established by GPS.

Yet government agencies and the industry community in the U.S. hold diversified concerns and mixed feelings about the industrialization of BDS. Economically speaking, guarantee fair opportunities and equal entry during BDS industrialization conforms to the interests of US enterprises to maintain their competitiveness at the one hand; successful industrialization of BDS may erode the dominance position of GPS on the other hand. From a security point of view, more systems always mean more risks of interference and complicated to coordinate. So it's a better choice to “keep the club small and manageable” for the very first and once the only GNSS services provider. Wide range of commercial application of BDS may bring troubles to frequency coordination even interference. Generally the civil and commercial sectors hold a relatively open attitude towards BDS industrialization while the military and security sectors are more cautious.

The recent Sino-US joint statement announced that two sides are going to promote cooperation on compatibility and interoperability of civil signals between BDS and GPS, their respective augmentation systems and civil aviation applications, monitoring and assessment, spectrum protection, interference detection and mitigation. It's no doubt good news for industry from both sides to enhance mutual understanding through dialogue, and to strengthen possible cooperation concerning BDS industrialization in the future.

GLONASS and Galileo, also latecomers in comparison with GPS, hold a common position with BDS to some extent. Both of them take similar willingness and strategies to maximize the global acceptance and utilization of their own system, actively foster domestic industry and cooperate to avoid marginalization. But for BDS industrialization, Russia and Europe may have different considerations.

Though Russia kept investing on the modernization of GLONASS in recent years, the process of GLONASS industrialization is dragged down by problems like system instability, domestic market volume, and the maturity of supporting industries, etc. Maximize cooperation with China in GNSS is in the interests of both sides. Under the framework of comprehensive strategic partnership, China and Russia established a Committee on GNSS Strategic Cooperation Projects to promote mutual cooperation on compatibility and interoperability, augmentation systems, monitoring and evaluation, application and promotion. The cooperation will leverage the advantage of BDS in low latitude and equatorial regions and the advantage of GLONASS in high latitude regions, and promote the application of both systems through compatibility and interoperability [44].

Galileo has originally claimed and positioned itself as a civil/commercial GNSS. By construction and operation of EGNOS, Europe has accumulated years of experiences in terms of navigation system construction and operation. The sign of cooperation agreement on the civilian part of GNSS with the United States, has also laid a good foundation for its industrialization. In addition, similar to China, the huge internal market and strong industrial base of Europe, add scores to industrial application of Galileo. But due to the lagging construction progress, though the Galileo program is launched earlier than BDS, BDS is almost certainly going to acquire capability of global services earlier than Galileo. This situation brought European policymakers a strong concern of latecomer to take its share of the global GNSS downstream market, and make them initiate action plans to promote the application of Galileo before the system becomes operational [45,46]. Considering the unpleasant experience in the previous cooperation on Galileo project, although the two sides will have to cooperate in the existing system, intense competition between the two systems can be expected in the future on the downstream GNSS market currently dominated by GPS.

4.4. International commercial sector

International commercial sector refers to the component suppliers, product manufacturers and service providers using GNSS based positioning and navigation as a significant enabler [47]. They will not only directly participate in the industrialization of BDS, but also exert influence on BDS industrialization process by means of lobbying and affecting domestic government decision-making. The key to take a new system or not is business logic, though influenced by political factors more or less. To international commercial sector, more satellites always mean more opportunities, especially when they are free.

BDS provide commercial service is definitely good news for downstream enterprises for at least three reasons: firstly, China has a huge and rapidly growth LBS and car navigation market, embrace BDS means the possibility to have a finger in the big pie; secondly, exist products shows that integration BDS can significantly improve the performance of GNSS products currently in Asian-Pacific area, such as the time-to-first-fix, accuracy and availability; thirdly, integration a new GNSS system brings acceptable cost increase. So some multinational firms, both end equipment manufactures and chip suppliers have released BDS compatible products as mentioned above.

At the same time, international manufacturers have also some concerns about large-scale investment on BDS compatible products. First of all, BDS constellation and ground infrastructures are still in the construction phase, and their long-term reliability and stability have to be tested. Concerns also come from the expectation of policy stability and continuity. The third concern is about possible regulatory measure opposed to foreign firms, such as mandatory use of domestic products, monopolistic and oligopolistic certification to domestic manufactures, mandatory technology transfer requirements, tariff protection, etc.

But until now, Chinese authorities haven't taken any discriminatory protection measures in favor of domestic industry in domains not concerning national security. On the contrary, Chinese government has been committed to improve the investment environment for foreign capitals. The recent released Thirteen's Five Year plan stressed to build an institution mechanism in accordance with the international investment and trade rules, and to promote the post-establishment national treatment and negative list for foreign investment which are currently been applied only in four Pilot Free Trade Zones [48]. It is witnessed that some GNSS receiver manufacturers closed their Chinese operations recently. Yet it is not a unique phenomenon of GNSS industry itself, but decisions made by all firms based on their business logic. For example, the new Enterprise Income Tax Law ends the preferential tax rate to foreign firms, which will be raised from 15% to 25% in five years; at the same time reduces the tax rate of domestic firms from 33% to 25%. Besides, the labor cost advantage of China is fading away in comparison with India and ASEAN countries.

4.5. International organizations

International organizations related to the industrialization of BDS including International Committee on Global Navigation Satellite Systems (ICG), International Telecommunication Union (ITU) and main users of GNSS, the International Civil Aviation Organization (ICAO) and International Maritime Organization (IMO). As one of the major GNSS providers, BDS actively promote international cooperation through the platform of international organizations. For instance, through the ICG Provider Forum to increase coordination and cooperation with other providers to improve overall service provision, and promote the use of GNSS to support sustainable development, particularly in developing countries; through the ITU platform to strengthen cooperation on compatibility and interoperability among systems.

By introducing new GNSS services, user international organizations, like ICAO and IMO, could increase the stability and the redundancy of the navigation service, and avoid solely dependence on the GPS system. Of course the decision of accepting a new GNSS provider is very cautious, and a long and complicated evaluation process is required to ensure the new system could fulfill the performance requirement.

BDS has made great progress to be accepted as a new common standard. In November 2014, the China Maritime Bureau, on behalf of the Chinese government, submitted the government commitment letter to IMO Maritime Safety Committee (MSC). The 94th session of the MSC has formally recognized BDS as a component of

the World-Wide Radio navigation System (WWRNS), which marks a premise and necessary condition for international development and application of BDS in the maritime domain [49]. ICAO has also agreed BDS joining into the ICAO standard framework gradually, which is at the same stage with Galileo. In the field of mobile communication, the technical standard supporting BDS services has been approved by the third generation mobile communication standard partnership project (3GPP) of ITU [50].

5. What's in the future: from latecomer strategy perspective

To meet the goal raised by the State Council to cultivate a 400 billion industry by 2020, BDS is faced both opportunities and challenges from not only business strategy, but also complicated security and international relation concerns. In this section we will analysis the advantages and disadvantages of BDS industrialization as a latecomer, and come up with alternative strategy advices from latecomer perspective.

5.1. Latecomers' advantages and disadvantages

Look forward to the future, the industrialization of BDS is faced with a situation where challenges and opportunities coexist. This paper analyses the advantages and disadvantages of BDS industrialization as a latecomer from three aspects, namely infrastructure, industry attributes and institutional environment.

5.1.1. Infrastructure

Successful construction and operation of the system is the prerequisite and basis for industrialization. As a latecomer, BDS could learn from first mover system to avoid possible problems like construction delay and system instability. The three-step construction strategy of BDS is proven to be a wise choice, which could accumulate management and operational experience at regional level for its global operation after 2020.

5.1.1.1. Advantages. Stable and continuous investment is the key to success to any project. After nearly three decades of sustained and rapid economic growth, China has become the second largest economy in the world, which laid a concrete foundation for space exploration activities. Sufficient budget ensures the construction of BDS constellation as scheduled.

BDS could take lessons from incumbent system about system design and infrastructure construction. The construction of GPS Ground-Based Augmentation System (GBAS) is a continuous exploration and improvement process. Aviation, marine, surveying and mapping and several other agencies have their own augmentation system. Although different application fields have various requirements on navigation and positioning in terms of accuracy, availability, integrity and reliability, redundant investment and construction are inevitable, and more frequency resources are needed. BDS could learn from the experience of GPS to “build a comprehensive national ground augmentation system, and to establish a comprehensive national positioning data service system” as the State Council planned. Besides, the construction of BDS augmentation system could upgrade existing GPS stations rather than build new ones, which would save cost and improve efficiency.

As a latecomer, the design of BDS considers the integration issues of multi system, and integrated some unique functions the other systems don't have. For example, the unique design of high-orbit constellation could improve the satellite availability in city area for its great anti-blocking ability, especially in circumstance like multi-layer flyovers, urban canyons and tree shaded environment [51]. Another unique feature is its short message service, which has been widely used in remote rescue, geological disaster monitoring, marine fishery industry and other fields. These advantages provide a sound basis for BDS commercial application.

5.1.1.2. Disadvantages. System technical uncertainty is a big barrier to market acceptance faced by BDS as a latecomer. GNSS is one of the most sophisticated and complicated artificial system, which involves coordination issues between space segment, a large number of space-based facilities and hundreds and thousands of end users. The long term stable operation capacity of the system still remains to be proven, especially considering the high standard set by GPS. It is no doubt that reputation and confidence building will be a long term process. Bounded rationality is another possible obstacle to build a sophisticated and one-time investment system. The pre-designed comprehensive national ground-based augmentation system, which will integrate basic information like geographic information, remote-sensing data, traffic information, weather information and environmental information, may encounter with requirements inconsistency problems among agencies, organization and coordination difficulties.

5.1.2. Industry attributes

As shown by literature, industrial attributes decide whether a latecomer of a certain industry could catch up and how to catch up. Industry attributes are mainly featured by innovation and technological learning, market volume, manufacturers' switching costs, consumer habits, etc.

5.1.2.1. Advantages. The integration trend of GNSS capabilities with ICT brings BDS opportunity to expand its market acceptance. In comparison with early stage of the industry, the most important change of the GNSS industry is it's highly integration with consumer electronics. Mobile phones, tablet computers and other personal mobile terminals are all integrated with navigation and positioning capabilities. According to the investigation by the European GNSS Agency, the market share of location based service (LBS) devices account for nearly half of the global GNSS revenues [52], and the share seems increasing for LBS devices in diverse applications. Furthermore, information technologies change very fast, which means new products and applications replace the old ones with a high frequency. Short life cycle means more opportunities for latecomers to catch up, as argued by Cho et al. (1998) and Gao (2011).

The huge domestic market brings unique advantage for BDS industrialization. In 2014, mobile internet users in China reached 838 million, and motor vehicles reached 264 million, which are all potential users of GNSS industry. Compared with large multinational enterprises, local manufactures lag behind in terms of technology and management, but they have advantage on understanding and meeting diversified local demands faster and better. In addition, government procurement on BDS compatible products concerning national security and government public affairs will be a large enough demand for domestic manufactures. It's crucial to technological learning and capacity building for local manufactures in their early development stage.

The huge market demand and consumer behavior cultivated by two decades of GPS service is also a big fortune for latecomers including BDS. The key issue is how to make consumers accept other GNSS products and services with GPS still working, or how to solve the path dependence problem for latecomers. The good news is that end users don't need to pay too much cost and effort on learning how to switch GPS-based services to others. Due to the

integration of GNSS capabilities with consumer electronic devices, PNT services from different systems are homogeneous to end users, as long as terminal manufactures integrate BDS compatible chips into their products, and they offering similar services.

5.1.2.2. Disadvantages. After ICD document of BDS issued, transnational navigation chip manufacturers like Qualcomm and Broadcom have joined the development of BDS compatible products. These international commercial giants have great competitive advantages in terms of R&D capacity, manufacturing technique, brand reputation as well as market experience.

Facing these leading multinational competitors, it's a big challenge to cultivate domestic navigation industry. Integrated circuit has long been a weak link of Chinese ICT industry. The primary challenge of BDS industrialization also lies in chip design and manufacturing capability, which is the key of navigation devices. The majority of domestic chip manufactures focus on car navigation terminal, and a few of them join the value chains of key smart phone manufacturers. The average cost of BDS/GPS dual-mode chips of local manufacturers have significantly declined from 150 to 170 RMB in 2012 to 70–80 RMB in 2014, while the integrated chips of international competitors is around 50 RMB [53]. Due to the big cost-benefit efficiency and other performance indicators like power consumption and chip size, local chips are blocked outside the application in smart phones.

Domestic GNSS industry is highly decentralized, which lead to fierce homogeneous competition at low level and hinder the rise of leading local enterprises with strong technological capabilities and supply chain dominant position. According to the statistics of China Semiconductor Industry Association, 22 local enterprises are capable of providing BDS chips in 2012, but their total revenue are only 768 million RMB (around 120 million USD), with an average of 5.5 million USD. If we count the terminal devices manufacturers and component suppliers in, there are more than 6000 institutions are involved in BDS related manufacturing. Only car navigation terminal original equipment manufacturers (OEMs) reached a peak number of 500, most of them located in Guangdong province in southern China [54]. Since lack of innovation capacity and own brand, these OEMs may suffer from intellectual property and international trade disputes in future market competition.

5.1.3. Institutional environment

Institutional environment is an important guarantee of BDS industrialization. This paper analyses the institutional advantages and disadvantages of BDS industrialization mainly from the perspective of domestic law and policy, international cooperation and competition.

5.1.3.1. Advantages. From the previous analysis we can find that BDS industrialization get strong promotion from both central and local governments. The medium and long term plan issued by the State Council draws the blue print of BDS industry development till 2020. Local governments actively promote the application of BDS by means of funding pilot and demonstration projects, construction of industry parks, financial guidance and support, etc. Besides, Chinese government has accumulated sophisticated regulation experience on ICT industry, which will be helpful to the regulation of BDS industry, especially considering their convergence trend. In addition to domestic institutional environment building, Chinese government actively market BDS in neighbor countries with strong economic and trade ties, like Pakistan and ASEAN countries, and promote the acceptance of BDS by international organizations. All of these efforts together create a favorable environment for the industrialization and internationalization of BDS.

5.1.3.2. Disadvantages. Within an open and competitive international business environment, the governance of such a high decentralized industry is a major challenge to Chinese government in a couple of ways. Firstly, as a latecomer, BDS related laws, regulations, policies and standards are far from complete. The State Council plan is a good start, but more supporting policies and implementation details are required to make it operable. Lack of space legislation and the absence of national space policy and national GNSS policy would influence even hinder the process of confidence building for international promotion and commercial investment in the long run [55]. Secondly, the governance structure of BDS industrialization is still to be complete, especially the coordination issues of various agencies, and excessive and homogeneous competition at local level which may lead to "over capacity". Thirdly, the institutional environment for international space cooperation needs to be improved. Compared with other high-tech area, space cooperation between China and other space powers are weak in terms of quantity and quality, which may bring obstacles in achieving consensus and settling differences on issues like compatibility and interoperability negotiation.

5.2. Policy recommendations for BDS as a latecomer

The core strategy of latecomers to catch up is amplifying the advantages and surmounting the disadvantages to the largest extent. Four policy recommendations are proposed as follows from latecomer strategy perspective.

5.2.1. Recommendation 1: take a good advantage of fulfilling the needs of huge domestic market

The goal of BDS industrialization is to maximize its adoption and market uptake in downstream applications. Globally speaking, GNSS industry has entered into a stage of stable development, which is featured that the market volume and product structure is relatively stable, and the value chain is shaped by several key multinational players. Yet domestic GNSS industry in China is still in its infancy or rapid growth stage.

On the one hand, multinational manufacturers have entered and dominated the fast growing consumer electronics market. They are important force of promoting the industrialization of BDS with significant technology advantages and decades of transnational operation experiences, and will promisingly gain a substantial return along with BDS industrialization process.

On the other hand, a large number of local enterprises are rising rapidly, and they mainly focus on government procurement requirement and low-end links in the global value chain at present. Their opportunity to grow and develop lies in whether they can effectively meet the needs of the huge domestic market. To grasp these market needs, the short term strategy of local enterprises should take full advantage of the government procurement opportunities for technology learning and absorption, and talents and capital accumulation; in the long run these latecomer players should invest more on R&D and innovation, try to make breakthroughs in chip design and manufacturing technologies to gradually get close to their international counterparts in terms of product cost and performance.

5.2.2. Recommendation 2: BDS industrialization should be integrated into and serve national strategies

BDS industrialization should be discussed in a more strategic and comprehensive background rather than just an industrial development issue, considering GNSS as a national fundamental infrastructure and its widely application.

China is currently experiencing a process of rapid urbanization,

industrialization and informatization. With a view of building an innovative country and a moderately prosperous society by 2020, it is dedicated in cultivating 7 strategic emerging industries,[1] constructing smart cities, and upgrading the information infrastructure all over the country. BDS could play an important role in implementing these strategies as a key enabler.

In this regard, government authorities should pay more attention to the widely application of GNSS technology and products to improve the whole economy and society development level, when pursuing the cultivation of BDS industry itself. Lessons should be taken from ICT industry that thought the chips and operating systems are still mainly rely on import, the widely application and popularization of computers and the Internet are boosting in almost all aspects of the economy and society.

5.2.3. Recommendation 3: take appropriate policy portfolios in accordance with the industrial development stage

Fiscal policies are preferable in short term. Current policy measures of both central government and local governments are mainly fiscal policies (which are also preferred by enterprises), including funding of infrastructure construction and operation, R&D programs, pilot industrial demonstration programs, government procurement of navigation terminals, etc. As mentioned before, several national departments and agencies as well as local governments have issued policy documents about BDS industrialization. But at least two types of coordination are still needed to maximize the effectiveness of these fiscal policies. One is to promote coordinative efforts among departments and agencies to optimize resource allocation at national level. The other is to build a mechanism to strengthen the coordination among local governments with a view to amplify the respective advantages of different regions and to prevent possible overcapacity.

Selective regulatory measures should be evaluated and taken prudently. Historical experience shows that regulatory measures (for example, mandatory use of certain products, monopolistic and oligopolistic certification to certain actors, or tariff protection on domestic industry, etc.) have positive effects on protection and cultivation of underdeveloped domestic industries in short term. But at the same time it may conflict with existing international trade rules and hinder the international acceptance. A moderate and operable way is all critical infrastructures concerning national and public security should be mandated to take BDS-enabled products (at least BDS-enabled multi-constellation products). Some other key domains, such as public transportation, personal safety, electrical power system and financial systems, should also be regulated by means of a negative list, which is helpful to confidence building of commercial investors, and at the same time in accordance with international regulatory regime.

In the long run, the key to BDS industrialization is the formation of favorable institutional environment and framework conditions, namely: (1) a national GNSS law or policy, which explicitly demonstrates Chinese government commitment to a long-term free and open system to both domestic and international users with a view to shore up confidence of business investment; (2) a fair competition and market environment to attract more private and foreign players investing in BDS industry; (3) a complete standard system for worldwide interoperability and compatibility covering software and hardware interface, testing and monitoring, infrastructure, and location service issues, etc.; (4) more universal policy measures to promote industry development, such as intellectual property right protection, and tax incentives to GNSS related R&D, production and services; (5) in addition to supply side policy measures, pay more attention to demand side measures to BDS products and services, i.e. promote the diffusion and penetration of BDS capacity to downstream sectors, not only related industries but also societal applications.

5.2.4. Recommendation 4: stick to the strategy of open competition and international cooperation

Current trends of BDS industrialization shows the compatibility and integration strategy is the right direction to be continued. The authorities should keep promoting the coordination and cooperation between BDS and other GNSS operators, and promote the uptakes of BDS by more international organizations and users. During the internationalization process, more attention should be paid to the ongoing Silk Road Economic Belt and the 21st-century Maritime Silk Road Initiative (or the Belt and Road Initiative) and the Asian Infrastructure Investment Bank (AIIB). These two initiatives match the idea of BDS industrialization well which could bring mutual improvement, especially to the uptakes of BDS in a large number of countries around the Belt and Road.

BDS should also strengthen the communication and cooperation with other stakeholders on policy issues, such as legislation, policy making, organizations and their coordination mechanisms as well as program funding issues. It is also vital to leverage the investment from enterprises, and involve as much players as possible, including government, enterprises, universities, research institutions, and users.

6. Concluding remarks

GNSS industry is gaining increasing attention from all over the world as an emerging industry which is featured by highly dependent on public space infrastructure, highly substitutability among systems, highly integration with information technology and highly embeddedness into broader socio-economic settings. Considering the huge public investment on the construction of satellite constellation and large scale ground facilities, system application and cultivation of a competitive domestic GNSS industry is critical issue not only faced by China, but also all GNSS operators. This paper, from a perspective of latecomer theory, discusses the industrialization strategy of BDS with a macro view, analyses the factors behind the strategy, and comes up with policy recommendations for the future development.

We define the current strategy of BDS industrialization as a portfolio strategy, which can be summarized as indigenous in key domains and compatible in commercialization. This strategy is further implemented by a mixture of three interrelated measures: top-down push, bottom-up pull, and inside-out promotion. After examining the current progress of BDS industrialization, a preliminary conclusion is drawn that the strategy is a success evidenced by the rapid expansion of domestic BDS industry volume and widely application of BDS-enabled products and services from both domestic and international users.

From a stakeholder analysis, this paper further argues that the current portfolio strategy is shaped by joint interactions of all stakeholders, not only the endeavors of Chinese government to achieve economic and social gains of BDS and to cultivate a BDS based industry, but also the active involvement of both domestic and transnational enterprises, as well as the interactions of BDS with international institutions, including related international organizations and other GNSS providers. Within this complicated

[1] These 7 strategic emerging industries are selected by the State Council in the 12th Five-Year Plan for National Strategic Emerging Industries, namely new energy auto industry, energy-saving and environmental protection industry, new generation information technology industry, biology industry, high-end equipment manufacturing industry, new energy industry, and new material industry. Satellite and its application industry is one of the priorities under the high-end equipment manufacturing industry.

stakeholder network, BDS has to deal with a couple of relations, namely domestic and international, military, civil and commercial use, government and market. Considering its unique characteristics, the development of such a highly decentralized domestic GNSS industry is a great challenge for Chinese government in an open competition environment.

Based on the perspective of latecomer's strategy, this paper analyses the advantages and disadvantages of BDS industrialization from three key aspects of GNSS, namely infrastructure, industry attributes and institutional environment. The result turns out to be, not surprisingly, a situation where challenges and opportunities coexist. Finally four recommendations are raised to amplify the advantages and to surmount the disadvantages for BDS as a latecomer to catch-up its predecessors: take a good advantage of fulfilling the needs of huge domestic market, integrate into and serve national strategies, take appropriate policy portfolios in accordance with the industrial development stage, and stick to the strategy of open competition and international cooperation.

We should keep the fact in mind that the BDS is still under construction, the national plan on BDS industrialization is just released in 2013 and detailed implementation plans and policy measure are still to be issued. We are aware that the assessment of policy effects requires a long term following up and observation. But still it's meaningful to understand the current progress, to identify the key policy issues, and to come up with suggestion for future development, as what this work is trying to do. Those recommendations been raised from the perspective of latecomer's strategy, neither necessarily effective nor operatable in practice, shed some light on the further discussion on BDS industrialization issue. It provides the policy makers in China a theoretical and macro way to view this issue. We also suggest future works could extend to industrial and firm level analysis, such as a detailed BDS industrial value chain analysis and the typical enterprises case studies with the evolvement of the local GNSS industry.

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References

[1] GPS.gov. GPS Applications. http://www.gps.gov/applications/. (Accessed 25 May 2014).
[2] International Committee on Global Navigation Satellite Systems, Current and Planned Global and Regional Navigation Satellite Systems and Satellite-based Augmentations Systems, 2010.
[3] Beidou Navigation Office. http://www.beidou.gov.cn/. (Accessed 25 May 2014).
[4] NDRC & COSTIND. Several Opinions Relevant to Promoting the Development of the Satellite Application Industry, 2007. http://www.cnsa.gov.cn/n615708/n620168/n620180/130839.html.
[5] The State Council. National Medium- and Long-Term Development Plan on Satellite Navigation Industry (the Office of the State Council issued, No. 97 2013). http://www.gov.cn/zwgk/2013-10/09/content_2502356.htm. (Accessed 25 March 2014).
[6] European GNSS Agency, GNSS Market Report (Issue 3), 2013.
[7] C. Li, The Chinese GNSSdSystem development and policy analysis, Space Policy 29 (2013) 9–19.
[8] H. Han, X. Zhao, L. Ye, Development situation and strategic choice of Chinacs satellite navigation industry, J. WUT Inf. Manag. Eng. 32 (6) (2010) 81–84.
[9] Y. Sang, Current Status and Future Trend of Beidou Satellite Navigation Chip Industryin China. Guide to Business, vol. 17, 2012, pp. 70–71.
[10] H. Wu, Z. Li, Y. Zhang, Current status analysis of Beidou satellite navigation industry, Satell. Appl. 4 (2013) 8–11.
[11] D. Zhang, W. Liu, C. Zhao, J. Wei, Discussion on the construction of national policy system of satellite navigation industry, Satell. Appl. 5 (2013) 36–39.
[12] J. Wang, W. Wu, An policy analysis of foreign satellite navigation systems, Space Int. 3 (2011) 1–6.
[13] L. Shi, IPR disputes of satellite navigation signals between UK and US and its influence to Chinese Beidou patent stategy, Digit. Commun. World 12 (2013) 16–19.
[14] K.M. Eisenhardt, Building theories from case study research, Acad. Manag. Rev. 14 (4) (1989) 532–550.
[15] R.K. Yin, Case Study Research: Design and Methods, second ed., Sage Publications, Thousand Oaks, 1994.
[16] B.R. Agle, R.K. Mitchell, J.A. Sonnenfeld, Who matters to CEOs? An investigation of stakeholder attributes and salience, corporate performance, and CEO values, Acad. Manag. J. 42 (5) (1999) 507–525.
[17] M.B. Lieberman, D.B. Montgomery, First-mover (dis)advantages : retrospective and link with the resource-based view, Strat. Manag. J. 19 (12) (1998) 1111–1125.
[18] G.S. Carpenter, K. Nakamoto, Reflections on consumer preference formation and pioneering advantage, J. Mark. Res. 31 (1994) 570–573.
[19] F.H. Alpert, M.A. Kamins, An empirical investigation of consumer memory, attitude, and perceptions toward pioneer and follower brands, J. Mark. 59 (4) (1995) 34–45.
[20] M. Hobday, Innovation in East Asia: the Challenge to Japan, Edward Elgar, Aldershot, 1995.
[21] M.B. Lieberman, D.B. Montgomery, First-mover (dis)advantages : retrospective and link with the resource-based view, Strat. Manag. J. 19 (12) (1998) 1111–1125.
[22] A.H. Amsden, Asia's Next Giant: South Korea and Late Industrialization, Oxford University Press, 1992.
[23] L. Kim, Imitation to Innovation: the Dynamics of Korea's Technological Learning, Harvard Business Press, 1997.
[24] D.S. Cho, D.J. Kim, D.K. Rhee, Latecomer strategies: evidence from the semiconductor industry in Japan and Korea, Organ. Sci. 9 (4) (1998) 489–505.
[25] X. Gao, Effective Strategies to Catch up in the Era of Globalization: Experiences of Local Chinese Telecom Equipment Firms, vol. 1, 2011, pp. 42–49.
[26] National Development and Reform Commission. Promote information consumption: accelerate the development of BDS industry. http://www.gov.cn/zwhd/2013-10/17/content_2509413.htm. (Accessed 15 April 2014).
[27] The Management Office of Satellite Navigation System. National Technological Committee for BDS Standardization is founded in Beijing. http://www.beidou.gov.cn/2014/04/28/20140428bfbdf2e7d77e499b89a5165a23ded6c3.html. (Accessed 17 August 2014).
[28] The State Council. The 12th Five-year Plan for National Strategic Emerging Industries (the State Council issued No. 28, 2012). http://www.gov.cn/zwgk/2012-07/20/content_2187770.htm. (Accessed 15 August 2014).
[29] NDRC and COSTIND. The Several Opinions Relevant to Promoting the Development of the Satellite Application Industry(NDRC issued No 3057, 2007). http://www.sdpc.gov.cn/zcfb/zcfbtz/200711/t20071123_174233.html. (Accessed 15 August 2014).
[30] The State Council. National Medium- and Long-Term Development Plan on Satellite Navigation Industry (the State Council issued, No. 97 2013). http://www.gov.cn/zwgk/2013-10/09/content_2502356.htm. (Accessed 15 August 2014).
[31] Cao C. Interview to the expert of National Medium- and Long-Term Development Plan on Satellite Navigation Industry. http://www.beidou.gov.cn/2013/10/22/2013102291fbc7b558a74edbaf80518a656e287c.html. (Accessed 02 March 2015).
[32] NDRC and MOF. Inform on Organizing and Implementing Industry development Project of Satellite and Its Application (NDRC issued, No. 895 2012). http://www.xadrc.gov.cn/websac/cat/545/545493.html. (Accessed 02 March 2015).
[33] Chinese Association of Satellite Navigation and Positioning. White paper on Chinese satellite navigation and positioning services industry (2012/2013).
[34] The trend of satellite navigation market in 2014 (2014 Weixing Daohang Shichang Fazhan Qushi). http://industry.beidou.gov.cn/WebUI/News?NewsId=378&NewsTypeId=4. (Accessed 15 March 2015).
[35] BD Star navigation. Nebulas SoC. http://www.unicorecomm.com/products/201146/n36107770.html. (Accessed 15 March 2015).
[36] Chinese Association of Satellite Navigation and Positioning, White paper on Chinese Satellite Navigation and Positioning Services Industry, 2012.
[37] Qualcomm. Qualcomm Collaborates with Samsung to be First to Employ China's BeiDou Satellite Network to Enhance Location-Based Mobile Data and Services for Smartphones. http://www.qualcomm.com/media/releases/2013/11/21/qualcomm-collaborates-samsung-be-first-employ-chinas-beidou-satellite (Accessed 05 April 2015).
[38] Broadcom. Broadcom Announces New GNSS Location Chip with Support for Chinese BeiDou Satellite System. http://www.broadcom.com/press/release.

php?id=s812465. (Accessed 05 April 2015).
[39] BBC News. China joins EU's satellite network. http://news.bbc.co.uk/1/hi/business/3121682.stm. (Accessed 15 September 2016).
[40] Wang Li, Directions 2015: BeiDou Belongs to China, and to the World. GPS World, December 1, 2014 (Accessed 05 April 2015), http://gpsworld.com/directions-2015-beidou-belongs-to-china-and-to-the-world/.
[41] Ran C. BDS operate well after one year's service. http://industry.beidou.gov.cn/WebUI/News?NewsId=315&NewsTypeId=1 (Accessed 06 April 2015).
[42] National Coordination Office for Space-Based Positioning, Navigation, and Timing. International Cooperation of GPS. http://www.gps.gov/policy/cooperation/#china (Accessed 20 April 2015).
[43] GPS.gov, Joint Statement U.S.–China Civil Global Navigation Satellite Systems (GNSS) Cooperation, 19 May 2014 (Accessed 25 April 2015), http://www.gps.gov/policy/cooperation/china/2014-joint-statement/.
[44] Wang L. Cooperation between China and Russia lays foundation to improve the internationalization of BDS(Zhong E Hezuo Wei Tisheng Beidou De Guojihua Fazhan Shuiping Dianding Jichu). http://www.beidou.gov.cn/2014/10/30/20141030c2b2d7851def45fbb9105b15642495a5.html. (Accessed 25 April 2015).
[45] European Commission, Action Plan on Global Navigation Satellite System (GNSS) Applications, 2010 (Accessed 28 April 2015), http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52010DC0308.
[46] European Commission. Update of the Action plan on GNSS Applications including securing market uptake of Galileo to ensure a return on the investments in the EU GNSS systems and the European non-dependence on other GNSS systems. http://ec.europa.eu/smart-regulation/impact/planned_ia/docs/2013_entr_012_gnss_en.pdf. (Accessed 28 2015).
[47] The European GNSS Agency (GSA). GSA GNSS Market Report. http://www.gsa.europa.eu/market/market-report. (Accessed 28 April 2015).
[48] National People's Congress. The 13th Five-Year Plan for National Economic and Social Development. http://news.xinhuanet.com/politics/2016lh/2016-03/17/c_1118366322.htm. (Accessed 15 September 2016).
[49] An Interview to the Director of China Maritime Bureau. http://www.beidou.gov.cn/2014/11/24/20141124d3786325609e467480873560508ad0f0.html (Accessed 02 May 2015).
[50] Won the power of discourse to international standard amendment, BDS application entered the fast lane. http://www.beidou.gov.cn/2014/11/06/20141106a6e2f76e8013408cbc8994036b0ef9aa.html. (Accessed 02 May 2015).
[51] C. Ran, BDS Works Well after its First Year Regional Service, Dec 27, 2013 (Accessed 08 May 2015), http://industry.beidou.gov.cn/WebUI/News?NewsId=315&NewsTypeId=1.
[52] The European GNSS Agency (GSA), GNSS Market Report 2013, 2013 (Accessed 08 May 2015), http://www.gsa.europa.eu/sites/default/files/GNSS_Market%20Report_2013_web.pdf.
[53] Luo K., Xian J. Several domestic BDS mobile companies entered the market. http://industry.beidou.gov.cn/WebUI/News?NewsId=357&NewsTypeId=4. (Accessed 08 May 2015).
[54] MIIT Software and Integrated Circuit Promotion Center. Integrate circuit industry Studies: special issue on BDS. http://www.csip.org.cn/. (Accessed 08 May 2015).
[55] R. Mu, Y. Fan, An overview of Chinese space policy, in: K.-U. Schrogl, et al. (Eds.), Handbook of Space Security: Policies, Applications, and Programs, Springer, 2015, pp. 413–430.