DOI 10.15302/J-SSCAE-2020.02.017

# Research on the Development Strategy of Real-Time and Intelligent Space-Based Information Service System in China

**Li Deren** [1, 2], **Shen Xin** [1, 2]

1. State Key Laboratory of Information Engineering in Surveying, Mapping and Remote Sensing, Wuhan University, Wuhan 430079, China
2. Collaborative Innovation Center of Geospatial Technology, Wuhan 430079, China

**Abstract:** Real-time and intelligent space-based information service system is a next-generation system that integrates satellite communications, satellite navigation, and satellite remote sensing. The system delivers space-based information in real time to civil and military users, relying on multi-load integration, multi-satellite collaboration, and interconnection between space and ground networks. In this study, we first analyze the strategic requirements for real-time and intelligent space-based information services. Subsequently, we review the development status of satellite communications, navigation, and remote sensing in China and abroad and summarize the existing problems. Moreover, we expound the basic concept, objectives, and technical architecture of the real-time and intelligent space-based information service system and analyze the relationship between this system and the existing (or planned) space-based information systems, thereby demonstrating the feasibility of its construction. The real-time intelligent space-based information service system can be developed and launched in three steps: (1) locally, (2) regionally, and (3) globally. This system should be incorporated into the overall planning for national science and technology development and should be constructed and shared mutually by civil and military parties. During the construction of this system, communication and integration with the existing and planned satellites for communication, navigation, and remote sensing, as well as with the ground communication systems, should be strengthened.

**Keywords:** space-based information; real-time intelligent service; system construction; technical architecture; strategic requirements

## 1 Introduction

The space-based information system observes natural and human activities on the Earth's surface in real time using satellite communication, satellite navigation, and satellite remote sensing. This system obtains knowledge from data to meet the needs of the economy, national defense, and people's livelihood. At present, China's satellite communication, navigation, and remote sensing systems have progressed significantly; however, several problems remain, such as system isolation, information separation, and service lags [1]. Consequently, the space-based information system services cannot adequately meet the requirements of military programs and disaster management because of problems with timeliness, wide areas, and continuity. Therefore, the pattern of space-based information public service needs to be formulated.

**Received date:** September 19, 2019; **Revised date:** January 15, 2020

**Corresponding author:** Li Deren, professor of Wuhan University, member of the Chinese Academy of Sciences and the Chinese Academy of Engineering. Major research field is geomatics. Email: drli@ whu.edu.cn

**Funding project: Funding project:** CAE Advisory Project "Strategic Research on the Development of Space-Based Information Real-Time Service System (PNTRC)" (2017-ZD-01)

**Chinese version:** Strategic Study of CAE 2020, 22 (2): 138–143

**Cited item:** Li Deren et al. Research on the Development Strategy of Real-Time and Intelligent Space-Based Information Service System in China. *Strategic Study of CAE,* https://doi.org/10.15302/J-SSCAE-2020.02.017

In 2017, the Chinese Academy of Engineering launched the consulting project "Research on the Development Strategy of Real-Time Space-Based Information Service System." This paper presents the results of that project. First, the major strategic needs of China's real-time and intelligent space-based information services are reviewed. Next, the state-of-the-art and the latest progress in the construction of space-based information systems are examined, the gaps in knowledge are identified, the objectives of the construction of China's real-time and intelligent space-based information service system (positioning, navigation, timing, remote sensing, and communication (PNTRC)) are explained, the feasibility and technical architecture of the system construction are detailed, and strategies for the development of China's future PNTRC are suggested.

## 2 Strategic requirements

With the continuous growth of China's national strength, national strategic interests are extending from local to global contexts. To safeguard and protect national interests, China should establish information dominance in the global scope. Strategically, to develop the real-time space-based information intelligent service, it is necessary to strengthen the combination of civil and military functions of space-based systems and deeply integrate the existing communication, navigation, remote sensing satellites, and ground communication networks. The necessity of PNTRC construction is explained by the following four reasons.

(1) The construction of PNTRC is necessary to cope with the increasingly complex international situation and meet the major requirements of real-time tracking of global moving targets and real-time monitoring of fixed targets. China's strategic interests extend from local to global contexts, and it is urgent to monitor the situation and change the hotspots and key targets (both locally and globally) in real time. However, the existing space-based information system in China responds at the hourly level, which is insufficient to satisfy the aforementioned requirements. The technology gap between China and the world's aerospace power is evident. PNTRC has a data transmission link with high-orbit and low-orbit communication satellites. After data acquisition, PNTRC can provide fast and accurate space-based information services for military and civilian users using the satellite communication network and ground network through on-orbit intelligent processing [2].

(2) The construction of PNTRC can effectively solve the problem of a limited overseas presence of foundation strengthening stations of the BeiDou system (BDS), and it can significantly improve the efficiency of BDS. To improve the real-time positioning accuracy of a satellite navigation system, the main approach is to use ground-based navigation enhancement technology [3], which can achieve real-time navigation accuracy at the decimeter level. However, the construction of BeiDou ground-based enhancement stations abroad has been blocked by competing countries for a long time. The PNTRC spacecraft carries the satellite-based enhanced navigation payload, which can enhance the BDS signal to provide the navigation service at the decimeter level and allow China to conduct military and civilian operations within the global scope.

(3) The construction of PNTRC can significantly advance the science and technology that integrates communication, navigation, and remote sensing. Moreover, PNTRC can ensure China's fast progress in the field of space science and technology. At present, the competition among the space powers in the fields of satellite communication, satellite navigation, and satellite remote sensing is unprecedented. However, there is still no space-based information system that would integrate communication, navigation, and remote sensing. China should take advantage of this rare opportunity, plan PNTRC construction, and take an integrated application of communication, navigation, and remote sensing as the core breakthrough direction. This would lay the foundation for comprehensively improving China's global competitiveness and leadership in space science and technology.

(4) The construction of PNTRC is important for promoting the innovative development of China's satellite communications, navigation, remote sensing, and other industries, and for promoting the formation of new momentum for the development of the space economy. PNTRC will reinvigorate and open new directions for the development of China's satellite industry. It will also comprehensively drive the development of emerging industries, such as remote sensing applications, mobile navigation terminals, location services, and low-orbit satellite communications. Moreover, PNTRC will promote the formation of a new industry type of "Internet + aerospace" [4], with an annual output value expected to reach a trillion yuans.

## 3 Development status

### 3.1 Development status abroad

Space-based systems with satellites for communication, navigation, and remote sensing have been built by

DOI 10.15302/J-SSCAE-2020.02.017

space powers such as the United States, Europe, and Russia. In recent years, low-orbit mobile communication satellites and commercial remote sensing satellites have become emerging hotspots in space-based systems due to their good performance and efficiency. Through dislocation competition, they have initially formed a tripartite confrontation with traditional satellite systems in terms of technology and markets. The progress of satellite mobile broadband communication can be described as follows: (1) Since the 1990s, high-orbit satellite mobile communication system represented by Thuraya, Inmarsat, and TerreStar have been successively built in foreign countries [5]; (2) Iridium and Globalstar are traditional low-orbit mobile communication satellites. These satellites mainly work in L and S frequency bands, at low and medium rates. The service supports handheld mobile communication and low-power miniaturized Internet-of-things services. (3) At present, low-Earth-orbit communication networks are developing toward multiservice broadband satellite mobile communication systems. Companies such as OneWeb and Space X have designed low-orbit broadband communication constellations [6]. The working frequency band adopts Ku and Ka high-frequency bands. These systems have a large number of satellites, mainly for medium- and high-speed services. They support Internet access, network node interconnection, base station backhaul, and other services.

Satellite navigation systems can be divided into global systems, regional systems, and satellite-based augmentation systems. The difference between global and regional systems is their service coverage. Satellite-based augmentation systems use satellites to provide enhanced services. Examples of global systems are the U.S. global positioning system, Russian global satellite navigation system, and European Galileo satellite navigation system under construction. Examples of regional systems include Japan’s Quasi-Zenith Satellite System and India’s Regional Navigation Satellite System. Examples of satellite-based augmentation systems include the American Wide Area Augmentation System, Russian Satellite Differential Correction Monitoring System, European Geostationary Satellite Navigation Overlay Service System, and Japanese Multifunctional Transport Satellite Augmentation System [7,8].

High-resolution remote sensing satellites can be divided into optical imaging and synthetic-aperture radar imaging. Since the successful commercial launch of Ikonos-2 satellite in 1999, the technology and applications in this field in foreign countries have advanced significantly [9]. Relevant industries are concentrated in the United States, Europe, Japan, and other aerospace powers or regions, and the applications tend to mature. Representative satellite systems include IKONOS, Geoeye, Spot, TerraSAR, and ALOS. The highest imaging resolution has reached the sub-meter level.

### 3.2 Development status in China

After more than 60 years of development, China’s aerospace industry has built various satellites for communication, navigation, and remote sensing. With the strong promotion of the national science and technology major project “High-Resolution Earth Observation System” (shortly: “High-Resolution Project”) and the “Medium- and Long-Term Development Plan of the National Civil Space Infrastructure” (2015–2025) (shortly: “Medium- and Long-Term Development Plan”), the number of satellites in orbit in China has exceeded 200 in 2020.

The progress of mobile satellite communication can be described as follows: (1) in August 2016, Tiantong-1-01 satellite was launched into orbit, taking the first step in the construction and application of China’s regional satellite mobile communication system; (2) In April 2017, China’s first high-throughput communication satellite Shijian 13 was launched into orbit, providing the access of mobile communication base stations in remote areas to many industrial applications; (3) The national “Science and Technology Innovation 2030” major project has deployed the “Space and Earth Integrated Information Network” project, aiming to build the space and Earth integrated information network system [6]. At present, satellite communication is mainly used in satellite broadcasting and fixed services, while satellite mobile communication is mainly used in voice and narrowband communication. Users are distributed in national defense, emergency industry, field operations, etc., with a high application cost and less popular applications.

In terms of satellite navigation, China has become the third country with its own satellite navigation system after the United States and Russia after the construction of BDS. After providing services to China and the Asia Pacific region starting from 2000 and 2012, China is expected to provide global navigation services in 2020 [2]. At present, large-scale industry applications of BDS are under development. Driven by mobile communication technology, the market of public applications has a potential.

In terms of high-resolution remote sensing satellites, the series of satellites related to “Resources” and

"Environment" has been launched into orbit. With the support of the "High-Resolution Project," the development and application technology of high-resolution remote sensing satellites has made breakthroughs, and the Earth observation resolution has reached the level of meters (sub-meter resolution). The highest resolution of the advanced remote sensing satellite is better than the sub-meter level, and the processing speed of remote sensing information has reached the minute level. The large-scale application of relevant achievements is mainly concentrated in the fields of national defense, national land, planning, forestry, agriculture, power, water conservancy, petrochemical, and other industries. However, the application mode is still based on providing basic data; the direct output value is lower than that of navigation and communication applications, and the popular application mode remains in the exploration stage.

### 3.3 Existing problems

China has made remarkable progress in space technology and applications, but there is still a gap compared with the world's space powers. China could not provide "fast, accurate, and flexible" space-based information integrated services on a global scale.

(1) There is a gap between real-time space-based information services in China and the world's level, as well as the requirements of economic and social development. It is not yet possible to fully guarantee the timeliness of key information for major actions such as national security, emergency rescue, disaster relief, and remote dispatching.

(2) The existing space-based information system has limited support for continuous monitoring of wide areas. Moreover, it cannot comprehensively track and monitor the global key moving targets and the change of fixed targets.

(3) The construction of BDS ground-based enhancement stations is blocked overseas, which restricts the precision of the China's autonomous navigation system in overseas navigation and positioning. Therefore, the existing system cannot meet the information requirements of the Belt and Road program.

(4) The existing communication, navigation, and remote sensing satellite systems are all independent systems, with a significant bottleneck in the transmission of space-based information data, which severely restricts the efficiency of information acquisition and processing. Mobile satellite communication cannot ensure the high-speed transmission of space-based information, which creates problems with fragmented information and lags.

## 4 Analysis of PNTRC construction

To provide real-time space-based information services for military and civilian purposes, PNTRC includes the following components: hundreds of small low-orbit high-resolution optical and radar satellites with remote sensing and navigation enhancement functions, which cooperate with high-resolution remote sensing satellites in-orbit, BDS, and the satellite communication network under construction, which are integrated with terrestrial Internet and mobile network. With the joint support of space-based big data, cloud computing, artificial intelligence, and fifth-generation mobile communication technology, PNTRC provides military and civilian users (including professional and mass users) with fast access from satellites to smart terminals with accurate, intelligent, real-time space-based information services.

### 4.1 Construction goals

The construction goals can be described as follows. (1) To provide accurate remote-sensing information, the spatial resolution should reach the decimeter level, the temporal resolution should reach the minute level, and the data processing speed should less than 1 minute. (2) In terms of real-time navigation and positioning accuracy, it should reach the decimeter level. (3) In terms of coverage and communication capability, it is necessary to have global voice, video, and image communication functions, and the transmission time of space-based information from satellites to intelligent terminals should require less than 1 minute. (4) In terms of service capability, it is necessary to provide users with a fast, accurate, and intelligent air-space information service function, supporting information connectivity, time-space integration, and smooth service of various satellite systems.

### 4.2 Technical system

The construction of PNTRC involves seven key technologies in the three aspects of platform and payload, information transmission and processing services, and support and security: (1) enhanced low-orbit satellite-based navigation, (2) space-Earth integration network communication, (3) on-orbit processing of imaging data from

DOI 10.15302/J-SSCAE-2020.02.017

multiple sources, (4) space-based information intelligent services, (5) space-based resource scheduling and network security, (6) multiload integration platform, and (7) air-space-Earth integration of space-time benchmark construction.

As an enhanced system of BDS, PNTRC can improve the real-time navigation and positioning accuracy of BDS; as an access node of the space-based communication network, it uses the inter-satellite and satellite-ground links of the space-based network to transmit data and provide effective space-based communication satellite applications; as a useful supplement to the high-resolution satellite system, it can further improve the timeliness of the response of remote-sensing information. The relationship between the proposed system and the on-orbit system is shown in Fig. 1.

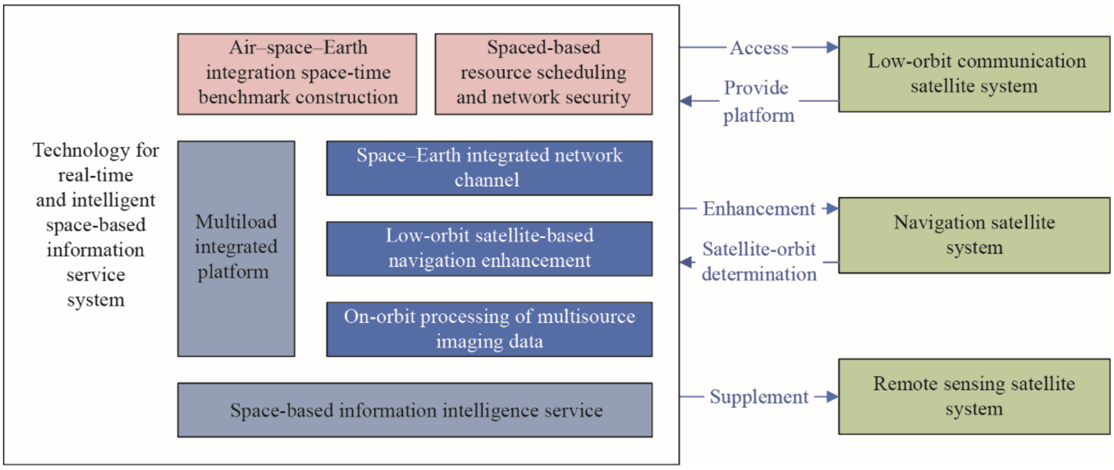


**Fig. 1**. Logical relationship between PNTRC and other space-based systems.

4.2.1 Correlation with the satellite navigation systems

PNTRC is not only a user of the existing Global Navigation Satellite System (GNSS) but also an extension and supplement of the existing GNSS. On one hand, the low-orbit satellite navigation enhancement system and the imaging data on-orbit processing system must receive the satellite navigation signals transmitted by the navigation satellites to calculate the precise orbit and time synchronization; on the other hand, the low-orbit satellite navigation enhancement system can also generate the ranging signal autonomously and provide joint positioning with the existing satellite navigation signal to further improve the service performance of the existing satellite navigation signal system. The low-orbit satellite is close to the ground, signal spatial attenuation is small, and geometric position changes rapidly; these help shorten the convergence time for precise positioning.

4.2.2 Correlation with the satellite communication systems

During the Thirteenth Five-Year Plan period, the major national project "Space–Earth Integration Information Network" started to be implemented. China Aerospace Science and Technology Group Co., Ltd. is building a "Hongyan" network, and China Aerospace Science and Industry Co., Ltd. is building a "Hongyun" network. Such satellite communication networks will provide the key space-based data transmission channels for PNTRC. The PNTRC satellite is equipped with an inter-satellite transmission link, which can be used as an access node of a satellite communication network for the fast transmission of massive high-resolution data.

The low-orbit communication satellite can provide a platform for enhanced navigation loads of PNTRC: the orbit height is approximately 1000 km, and it is easy to cover the ground seamlessly; the enhanced navigation load is small in volume, low in power consumption, and has little constraints on the platform. The aim is to take advantage of the orbit distribution and platform characteristics of the low-orbit communication satellite constellation, and to conveniently carry the satellite-based enhanced navigation load, so that the communication-navigation enhanced function integration has good engineering implementation.

4.2.3 Correlation with the existing high-resolution remote sensing satellite systems

As an effective supplement to the existing high-resolution remote sensing satellite system, PNTRC can alleviate or even eliminate the problems of the existing systems caused by a limited number of satellites and the poor timeliness caused by the reliance on transit transmission, thereby significantly improving the response speed of the national satellite remote sensing information system. Simulation experiments show that for the global coverage and coverage requirements of the areas along the Belt and Road, 200 and 80 remote sensing satellite constellation schemes can be used to rapidly acquire high-resolution remote sensing information in minutes. In addition, PNTRC satellites are equipped with inter-satellite links, on-orbit data compression, and fast processing functions, which enable them to access the satellite communication network to achieve the rapid return of remote sensing data.

### 4.3 Construction feasibility

From the preliminary judgment of key technologies, supporting systems, national policies, etc., the conditions for China's PNTRC construction are basically complete. The construction of relevant systems is expected to accelerate China's progress in the field of space technology.

(1) The technology of development, processing, and application of the sub-meter high-resolution remote sensing satellites in China is mature, providing core technical support for the construction of PNTRC. In recent years, a series of breakthroughs have been made in relevant technical fields. For example, the highest resolution of civil remote sensing satellites reaches 0.5 m, which is sufficient for large-scale business applications. The acquisition and processing technology of high-resolution space-based information has been verified on-orbit and has entered the engineering application stage.

(2) Breakthrough progress has been made in the low-orbit satellite-based navigation enhancement technology, which provides a new way to enhance the navigation accuracy, integrity, and real-time work of BDS. Further, it broadens the global service capabilities that the BDS has formed. "LuoJia-1" low-orbit enhanced navigation on-orbit technology verification showed [10] that the use of low-orbit satellites for enhancing the BDS can significantly improve its real-time positioning accuracy.

(3) With the rapid development of low-orbit satellite communication networks, it not only provides a data transmission channel for the rapid transmission of space-based information, but it also provides a good platform for the enhanced navigation load. The PNTRC satellite can be used as an access node, relying on the satellite communication network under construction to achieve mass high-resolution fast transmission. The orbit height of approximately 1000 km provides convenient conditions for the task design of carrying the load and the function integration design of communication-navigation enhancement.

(4) With the rapid development of China's satellite research and application systems, the national policy prioritizes new directions, which has given the prerequisites for the construction and industrialization of PNTRC. With the steady advancement of the "High-Resolution Project" and the "Medium- and Long-Term Development Plan," China's application satellite system becomes more advanced. In addition, the latter plan clearly proposed "supporting private capital investment in satellite development and system construction" and "encouraging and supporting qualified enterprises to invest in the construction of satellites." State-owned and commercial capital has entered the space field, and commercial satellites have entered a new round of a rapid development stage. This marks a new stage in the aerospace industry's full-scale industrialization development and also provides market-oriented resources for the commercial operation of PNTRC.

## 5 Development recommendations

### 5.1 Three-step launch: local, regional, and global

Step 1: From 2020 to 2022, the plan is to launch approximately 40 low-orbit high-resolution remote-sensing and enhanced navigation satellites for the real-time service of space-based information in the South China Sea region and Guangdong–Hong Kong–Macao Greater Bay Area. The satellites are planned to be integrated with the existing space-based communication network and the terrestrial mobile communication network. The satellites will send real-time space-based information to military and civil user terminals according to the requirements of national defense and economy in specific regions. Furthermore, in response to the urgent need for the construction of a future global system, we should gather resources and teams to perform integrated research and on-orbit verification of PNTRC stranglehold technology.

Step 2: From 2023 to 2025, 120 new intelligent remote sensing and enhanced navigation satellites will be launched to build a regional PNTRC service system, covering the periphery of the country and along the Belt and Road.

Step 3: From 2026 to 2035, 200 new intelligent remote sensing and enhanced navigation satellites will be launched to build a global PNTRC service system; it will be connected and integrated with other space-based

DOI 10.15302/J-SSCAE-2020.02.017

systems in China to meet the military and civilian demands for space-based information, thereby helping in global popularization and commercial applications of space-based information.

### 5.2 Incorporate into the overall planning for national science and technology development. Jointly construct and share by civil and military stakeholders.

In the context of the integrated development of military and civilian equipment, PNTRC's demonstration construction is incorporated into the state's overall management strategy to strengthen the coordination of space-based information services for military and civilian users and the top-level design of the system. The recommendation is to innovate the project mechanism, attract superior units, take advantage of the opportunity for development, and complete and launch the system as soon as possible. Another recommendation is to pay attention to the market rules and form a system operation mode of "ordinary procurement and wartime requisition." The aim is to ensure national defense, better serve domestic economic construction and social livelihood, and simultaneously develop a larger global application market.

### 5.3 Strengthen the communication and integration with the existing and planned communications, navigation, and remote sensing satellites as well as with the ground communication systems

The channel should be broadened for carrying satellite-based enhanced navigation loads. The system should perform functional docking with the satellite platform of the low-orbit space-based system that has been planned and is still under planning. Moreover, the new system should be integrated with the BDS to provide high-precision real-time navigation services, solve the problem of limited construction of foundation enhancement stations overseas, and comprehensively improve the military-civilian application efficiency of the BDS. Another recommendation is to strengthen the interface docking and application scenario integration with the next-generation mobile communication network, the Internet, and the integrated positioning, navigation, and time service information network of the next generation. The focus should be on ensuring the ability of real-time transmission of space-based remote sensing information to smart terminals of military and civilian users. The service of "space-based information on mobile phones" should provide convenient and ubiquitous communication, navigation, and remote sensing information services for worldwide users.

## References

[1] Li D R, Shen X, Li D L, et al. On civil-military integrated space based real-time information service system [J]. Geomatics and Information Science of Wuhan University, 2017, 42(11): 1501–1505. Chinese.

[2] Li D R, Shen X, Gong J Y, et al. On construction of China's space information network [J]. Geomatics and Information Science of Wuhan University, 2015, 40(6): 711–715, 766. Chinese.

[3] Zhou J H, Chen J P, Zhang J Y. Service performance enhancement technologies for BeiDou navigation satellite system along the Belt and Road [J]. Strategic Study of CAE, 2019, 21(4): 69–75. Chinese.

[4] Li D R. The "Internet Plus" space-based information services [J]. Journal of Remote Sensing, 2016, 20(5): 708–715. Chinese.

[5] Wang J, Fan J, Sun Z G. Development status and trend analysis of high orbit mobile communication satellite [J]. Satellite Application, 2019 (11): 52–57. Chinese.

[6] Wu X G. Overview and consideration of the development of LEO constellation satellite communication system [C]. Beijing: Proceedings of the 15th Annual Satellite Communication Academic Conference, 2019. Chinese.

[7] Liu C B. Overview of the development of foreign navigation satellites in 2018 [J]. Space International, 2019 (2): 42–47. Chinese.

[8] Liu C B. Overview of the development of foreign navigation satellites in 2017 [J]. Space International, 2018 (2): 31–36. Chinese.

[9] Kong C, Cao S B. Analysis of the current situation of the world commercial satellite remote sensing industry [J]. Aerospace China, 2019 (12): 70–74. Chinese.

[10] Wang L, Chen R Z, Li D R, et al. Quality assessment of the LEO navigation augmentation signals from Luojia-1A satellite [J]. Geomatics and Information Science of Wuhan University, 2018, 43(12): 2191–2196. Chinese.