Journal of Global Change Data & Discovery. 2024, 8(4): 347-355
www.geodoi.ac.cn

Global Change Research Data Publishing & Repository

Progress of High-resolution Earth Observation Systems

Wu, J. J.[1] Li, M.[2] Liang, L.[2] Liu, Q. H.[1*] Zhong, B.[1] Yang, A. X.[1]

1. Aerospace Information Research Institute, Chinese Academy of Sciences, Beijing 100101, China;
2. School of Geography, Geomatics and Planning, Jiangsu Normal University, Xuzhou 210023, China

Abstract: With the rapid development of science and technology, high-resolution Earth observation systems have become an indispensable tool in modern society. Not only do they provide us with detailed information about the Earth's surface, but also play a vital role in numerous fields of applications, and there is an increasing demand for high-resolution Earth observation systems. In order to cope with this growing demand, scientists have made unremitting efforts, and high-resolution Earth observation systems have made continuous progress and improvement in technology and applications, providing important support for environmental monitoring and resource management. In this paper, the development status and application of high-resolution Earth observation systems in China and abroad are summarized, the advanced products and applications of spaceborne high-resolution sensors are investigated, and the future development trend is discussed.

Keywords: high-resolution; Earth observation system; remote sensing satellite; high-grade products; development trend

DOI: https://doi.org/10.3974/geodp.2024.04.02

CSTR: https://cstr.escience.org.cn/CSTR:20146.14.2024.04.02

1 Introduction

A high-resolution Earth observation system can provide high-resolution and high-precision Earth surface information, including terrain, vegetation cover, soil type, urban distribution and other information, and provide important data support for scientific research and decision-making in land use planning, resource management, environmental monitoring, disaster prevention and other fields.

Since the 21st century, various countries individually or in collaboration, have vigorously developed space remote sensing technology geared to build a new generation of high-resolution Earth observation systems. The United States, France, Russia, Japan, European Space Agency (ESA) among others are at the frontier of this endeavor, aiming to achieve high-precision, real-time and large-scale monitoring of the Earth's surface through advanced space technology. Some of the well-known high-resolution Earth imaging observation systems include WorldView and SBIRS from the United States, the French SPOT series, the Canadian Radar Sat series, the German TerraX-SAR series, just to name a few[1]. Military, civilian and

Received: 02-09-2024; **Accepted:** 02-12-2024; **Published:** 24-12-2024

Foundations: Ministry of Science and Technology of P. R. China (2021YFE0117400); National Natural Science Foundation of China (42371322); Xuzhou City (KC23079)

***Corresponding Author:** Liu, Q. H., Aerospace Informafion Research Institute, Chinese Academy of Sciences, liuqh@aircas.ac.cn

Citation: Wu, J. J., Li, M., Liang, L., *et al*. Progress of high-resolution Earth observation systems [J]. *Journal of Global Change Data & Discovery*, 2024, 8(4): 347–355. https://doi.org/10.3974/geodp.2024.04.02. https://cstr.escience.org.cn/CSTR:20146.14.2024.04.02.

commercial remote sensing satellites are being launched exuberantly worldwide, witnessing increased detection capabilities expanding applications both in breadth and in depth[2].

The mission of the Major Project of high-resolution Earth Observation System (Gaofen Project for short) of China is to accelerate the development of the nation's spatial information and application technology, enhance self-reliant innovation capability, and build an advanced high-resolution Earth observation system to meet the needs of economic growth, social development and national security[3]. China's has also made continuous progress in this area. The momentum in developing high-resolution remote sensing satellites is going strong, and a stable and matured high-resolution Earth observation system has been formed[4].

Through literature research and information analysis, this paper discusses the development, application and future prospects of high-resolution Earth observation systems both in China and abroad, to provide useful information for scientific research and application in related fields.

2 Progress of High-resolution Earth Observation Systems in the World

Generally, high-resolution Earth observation satellites can be divided into two categories, military and civilian, both share the same imaging principle, the main difference is reflected in the sensor electromagnetic spectrum as well as the differences in desired ground resolution.

2.1 Civil High-resolution Earth Observation Systems

With regards to civilian high-resolution optical Earth observation systems, France spearheaded by launching the SPOT satellite series from 2002, bringing high-resolution optical images to the realm of Earth observation. SPOT series are the world's first multi-spectral high-resolution remote sensing satellites with stereoscopic imaging capabilities. Shortly after, in 2005, India launched the IRS-P5 (Cartosat-1) satellite, designed primarily for topographic mapping and resource survey in India. South Korea successfully brought into orbits the KOMPSAT satellite series in 2006, enabling high-precision territorial mapping and elevation modeling. Subsequently, Digital Globe of the United States launched a constellation of 5 satellites from 2007, which is currently the world's highest spatial resolution civilian Earth observation system with a global coverage. The spatial resolution of the panchromatic mode increased from 0.5 m of WorldView1 to 0.31 m of WorldView3 and 4. The German Rapid Eye constellation was also successfully deployed in 2008, providing continuous, stable high-resolution data for environmental monitoring and urban planning on a global scale. Soon followed was the launch of the US Planet Scope and Sky Sat constellations, both of which consist of multiple small satellites capable of rapidly responding to and capturing changes on the Earth's surface. Contemporarily, the French-Italian Pleiades constellation, designed as dual civil/military system, composed of two very-high-resolution optical Earth-imaging satellites, providing a complete global coverage in 26 days.

In the series of civilian high-resolution radar imaging remote sensing satellites, Canada began to develop RADARSAT series satellites in the 1970s and 1980s, laying the foundation for the subsequent RADARSAT Constellation Mission (RCM). The National Aeronautics and Space Administration (NASA) and the Jet Propulsion Laboratory (JPL) began to develop and apply SAR technology[5], such as the Magellan spacecraft's exploration of the surface region of Venus. On January 24, 2006, the Japan Aerospace Exploration Agency (JAXA) launched the Advanced Land Observation Satellite ALOS-1. The satellite carries three sensors, including a L-band SAR sensor PALSAR. TerraSAR-X was launched on 15 June 2007 by the German Aerospace Center (DLR) and EADS Astrium. TerraSAR-X's companion, TanDEM-X, was launched on June 21, 2010, and the pair are flying in tandem mainly engaged in topographic survey, surface deformation monitoring and earthquake research. In 2013, the Korea Aerospace Research Organization (KARI) successfully launched KOMPSAT-5, with a payload of X-band COSI sensors for high-resolution SAR imaging. On May 24, 2014, Japan launched ALOS-2 satellite, carrying only PALSAR-2 sensor, significantly improving the stability and data transmission of the platform. On April 3, 2014, the ESA launched Sentinel-1A satellite as a successor to ERS-1/2 and EnviSat. The Sentinel-1B satellite was also successfully launched on April 25, 2016, a constellation was thus formed, reducing the revisit period to just 6 days. The 2019 RCM was successfully launched by SpaceX on June 12, 2019, and consists of three satellites resembling characteristics of RadarSAT-1/2, to ensure continuity of C-band data for the next decade.

2.2 Military High-resolution Earth Observation Systems

The highest resolution military Earth observation satellite is the Key Hole (KH) satellites of the United States. The spatial resolution of the KH-12 reached 0.1 m, and the new generation of Key Hole satellites is expected to reach 0.05 m. The next generation space-based infrared system (SBIRS) being developed by the United States Air Force is an important part of the missile defense system, which provides infrared data of thousands of non-missile-related events every year[6]. Helios2A and 2B satellites, funded by France with contributions from Belgium, Spain, Italy and Greece reached a spatial resolution of 0.35 m, system in addition to high-resolution observation capability in the visible spectrum, the constellation also has the infrared night vision capability. The optical image resolution of Helios-2B satellite reaches 0.25 m, and the resolution of military and civilian dual-purpose optical imaging remote sensing satellite Pleiades reaches 0.7 m. Israel's Horizon9 small optical imaging remote sensing satellite has a resolution of 0.5 m, and Japan's "intelligence gathering satellite" has a comparable resolution of 0.6 m.

With regard to military high-resolution radar imaging satellites, the United States "Lacrosse" series of satellites, with a resolution of 0.3 m, can not only work all weather and all day, but also detect disguised weapons and identify false targets, even penetrate dry surface to find facilities hidden beneath, and have a certain tracking ability for moving targets. The FIA radar satellite series, which has been sequentially launched since 2010, the replacement model of the current "Lacrosse" satellite, has improved the radar power and its Earth observation performance. The spatial resolution of the latest FIA radar satellite has reached 0.15 m. The German military satellite "Synthetic Aperture Radar-Magnifying Glass" series and the Italian military and civilian dual-purpose "Cosmo-Mediterranean" series satellites were designed to operate at both 0.5 m and 1 m resolution. Other imaging satellites with a sub-meter resolution include the second generation of radar imaging "intelligence gathering satellite", Israel's "technical synthetic aperture radar" satellite, India's dual-use radar imaging satellites, etc.

3 Progress of High-resolution Earth Observation Systems in China

Driven by the major project "National High-resolution Earth Observation System", China made a series of breakthroughs in key technologies, improved the performance of high-resolution remote sensing satellites by leaps and strides. The resolution of civilian remote sensing satellites narrowed to a sub-meter level, comparable to that achieved by countries leading in this field of technology[7].

Since launched jointly with Brazil the CBERS-02B satellite in 2007, China has made remarkable progress in the field of high-resolution remote sensing satellites. The CBERS-02B satellite, jointly built by the two nations, is equipped with a 2.36 m high-resolution camera[8]. The satellite was decommissioned in April 2010. From the Ziyuan 02C satellite in 2011 to the Gaofen multi-mode satellite in 2020, China has independently developed and launched a number of high-resolution remote sensing satellites, including the Ziyuan 3, Gaofen 1–7, and hyperspectral observation satellites, etc. These satellites have demonstrated China's Earth observation capability, and applications of satellite remote sensing have been widely advocated in many fields such as natural resources survey, disaster prevention and reduction, ecological environment monitoring, agriculture, forestry and water conservancy, and major national infrastructure and ecological restoration projects. Gaofen-2 has achieved a sub-meter resolution, Gaofen-3 is the first C-band multipolar SAR satellite, Gaofen-4 is the first geosynchronous orbit remote sensing satellite, and Gaofen-5 is a hyperspectral observation satellite for comprehensive observation of the atmosphere and land, signifying major leaps in China's remote sensing satellite technology. In addition, China also launched its first civilian high-resolution satellite constellation, consisting of three satellites, Gaofen-1 02/03/04, to achieve global coverage and rapid revisit imaging capabilities. These achievements demonstrate China's determination striving for satellite imaging technology development of, and have provided important data support for national economic construction and social development.

For a long time, China's remote sensing industry has been state-dominated, with limited spillover effects on the industrial chain, making it difficult to drive economic growth. Due to high R&D costs and long investment cycles, the civilian satellite sector has faced commercialization challenges. In recent years, to transform its economic model and build an independent, reliable national civil space infrastructure, China has vigorously promoted the commercial satellite industry and its applications[9].

In 2014, China's State Council issued guidelines to promote private investment in key sectors, marking the start of commercial remote sensing satellite development. Since then, the industry has grown rapidly, with major players like Chang Guang Satellite, the Chinese Academy of Sciences' Micro-Satellite Institute, and China Aerospace Science and Technology Corp. emerging. Table 1 summarizes China's commercial remote sensing satellite constellations.

With the increasing demand for remote sensing information in the fields of natural resource management, urban planning and construction, agricultural production optimization and ecological environmental protection, the information and data service capability of commercial remote sensing satellites will be significantly boosted. Thanks to the guidance of national policies and continuous investment, coupled with the continuous acceleration and maturity of technological innovation within the industry, the number of commercial remote sensing satellites in China will usher in explosive growth, promoting the entire industrial chain into a long-term stable and vibrant prosperity and development.

Table 1 The operating constellation by Chinese commercial remote sensing satellite companies

Company	Horoscope	Number of planned satellite launches	Note
Changguang Satellite Technology Co., Ltd.	Jilin-1	300 satellites in orbit by the end of 2025	The largest sub-meter commercial remote sensing satellite constellation in the world
Twenty First Century Aerospace Technology Co., Ltd.	"Beijing" series	Currently 8 satellites in orbit	Built through a combination of independent investment and international cooperation
China Siwei Surveying and Mapping Technology Co., Ltd.	"Gaojing" Series, High Score Multimode	Plans to launch more than 20 commercial remote sensing satellites of international leading level in the next five years	The agent of 17 foreign mainstream commercial remote sensing satellites such as WorldView
Zhuhai Aerospace Microchips Science and Technology Co., Ltd.	Zhuhai-1	The whole constellation consists of 34 satellites, and the constellation currently has 12 satellites in orbit	The first satellite constellation built and operated by a private company in China
Spacety China	Tianyi SAR	The total number of satellites in the Tianyi SAR constellation is 120, and the company has launched a total of 30 satellites so far	One of the pioneers of international light and small commercial SAR remote sensing satellites
Beijing MinoSpace Technology Co., Ltd.	"Taijing" series, etc.	The company has launched a total of 24 satellites so far	A leading enterprise with satellite manufacturing as its core business
Piesat Information Technology Co., Ltd.	"Nvwa"	54 satellites in the first phase of the project, consisting of 44 radar satellites and 10 optical satellites	Currently has 8 SAR satellites in orbit
Ellip Space (Beijing) Technology Co., Ltd.	"Star Pool" program	Plans to launch more than one hundred intelligent satellite	Currently has 4 satellites in orbit with Star Pool I

4 High-level Products and Applications of High-resolution Earth Observation

High-level Earth observation products refer to a series of products that use the data obtained by high-resolution Earth observation satellites to extract the specific information of surface objects through advanced processing and analysis. High-resolution Earth observation data is widely used in agriculture, forestry, water resources management, urban planning, environmental protection, disaster warning and response and other areas with its ability to capture fine details of features on the ground. It not only provides accurate data support for the aforementioned fields, but also greatly promotes the scientific and efficient decision-making.

In the field of meteorology and climate change research, High-resolution Earth observation data, including satellite imagery, temperature, precipitation, humidity, and wind speed measurements, significantly enhance weather forecasting accuracy. Their fine spatial and temporal resolution allows for better tracking of weather systems, improving predictions of extreme events like hurricanes and heavy rainfall—reducing risks and damages. For climate change research, such data provide critical insights into ocean temperatures, ice melt, vegetation shifts, and atmospheric aerosols. This enables more precise climate trend analysis and supports evidence-based policymaking[10].

High-resolution Earth observation data can be used to invert a variety of surface parameters, such as soil moisture, surface temperature, vegetation index and topography. These parameters are important inputs to meteorological and climate models. Soil moisture data are particularly important for atmospheric water cycle and drought monitoring. For example, the normalized microwave reflection index and soil moisture obtained by Hu[11] based on the SNR of Global Navigation satellite system interferometric reflection technology can reflect changes in vegetation water content and soil moisture. High-precision vegetation index data can help understand the response and adaptation mechanism of ecosystems and assess the feedback of ecosystems to climate change. For example, Zhang[12] used Sentinel-2A and Sentinel-2B data and combined with a variety of vegetation indices to study the characteristics of tobacco mosaic disease in Fujian Province.

High-resolution Earth observation data plays a pivotal role in agriculture and rural development, contributing greatly to the fine-grained management of modern agriculture by providing detailed information on crop growth, soil characteristics, pest and disease monitoring, and disaster loss assessment. These high-precision data inform farmers the health of their crops in real time, optimize irrigation and fertilization strategies, and effectively control pests and diseases to reduce yield losses. Additionally, high-resolution data can be used to quickly produce loss maps after disasters, providing scientific basis for post-disaster recovery. For example, Zhao *et al*.[13] estimated winter wheat yield in Beijing based on HJ small satellite images. With the continued progress of technology heading towards the direction of forming constellations and finer resolutions, the data will continue to benefit the sustainable development of agriculture and rural areas.

High-resolution remote sensing technology plays a vital role in disaster management by capturing detailed images of affected areas in real time, allowing rapid assessment on the scope and severity of disasters, and providing valuable first-hand information for emergency relief and disaster management. For example, based on multi-source remote sensing data, Gao *et al*.[14] used data coordination to conduct time-series monitoring and analysis of inundation range, so as to reproduce the scenarios of flooding. By comparing the remote sensing data before and after the disaster, key information such as damages to housing, road traffic conditions and farmland can be accurately analyzed to provide scientific basis for post-disaster reconstruction planning. In addition, the technology can also effectively monitor potential natural hazards, such as identifying disaster-prone areas through long-term data analysis, risk assessment and early warning, so as to take targeted prevention and response measures. For example, when natural disasters such as floods and earthquakes occur, high-resolution remote sensing technology can quickly generate spatial distribution maps of inundation extent and geological damage, providing decision support for emergency response and subsequent recovery.

The application of high-resolution remote sensing technology in the field of geological exploration and engineering investigation has greatly stimulated the progress of this field, and it has become an indispensable technical means because of its high efficiency and accuracy. Through the acquisition and analysis of high-resolution images, remote sensing technology provides geological explorers with abundant surface and subsurface information, improving the efficiency and accuracy of resource exploration. In railway engineering geological investigation, remote sensing technology combined with 3D visualization tools makes the interpretation and delineation of unfavorable geologic formations and substrates more accurate, provides scientific basis for route selection, and effectively reduces the workload of field investigation. For example, Liu[15] combined high-resolution remote sensing with three-dimensional remote sensing in geological investigation of Menghua Railway to carry out structural geology interpretation and delineation, which provided a practical guideline for railway route selection. Zhang[16] produced a reconstruction of three-dimensional environment by making a large stereoscopic image model, effectively reduced the workload of field investigation, and provided important information support for the route selection and survey design of Sichuan-Tibet Railway. Lu *et al*.[17] used remote sensing and digital photogrammetry technology to establish 3D real terrain and geographical environment and virtual railway track selection, and achieved satisfactory results. In geological environment monitoring of mining sites, remote sensing technology finds different magnetic fields through infrared radiation to achieve accurate monitoring, and refined data processing through computing platforms, providing strong support for managing excavation sites. These examples demonstrate the comprehensive, objective and rich information support for resource management and environmental protection, and promote the continued progress in the field of geological exploration and investigation.

High-resolution remote sensing data plays a vital role in urban planning and management. Its detailed information on land cover, topography and water resources management provides a solid foundation for sustainable urban development. These data not only support the formulation of land use and urban planning, help decision makers optimize urban spatial layout and resource allocation, but also widely used in urban pollution monitoring and management. High-resolution remote sensing enables precise identification of pollution sources (air/water/solid waste) and analysis of contamination patterns, supporting effective mitigation strategies. For urban infrastructure, it efficiently maps and monitors roads, bridges, buildings, and large projects, offering real-time data for planning. In building inventories, it provides critical insights into structural density and typology, informing urban renewal decisions.

With its wide coverage, timeliness, low cost and highly authentic and rich information content, high-resolution remote sensing data plays a pivotal role in the transportation industry and shows a very broad application prospect. It can capture and monitor the impact of natural disasters and human factors on the transportation network in real time, providing critical information for rapid and effective response to disasters. In the field of highway survey, design and traffic mapping, high-resolution remote sensing data can accurately depict topography, geological structure and land cover characteristics, and provide scientific basis and detailed information for highway route selection, engineering geological survey and traffic network planning. At the same time, it can also effectively support highway traffic survey, including traffic flow, traffic congestion, etc., to provide a strong help for traffic management and optimization. In addition, high-resolution remote sensing data can monitor environmental changes of road networks in real time, such as vegetation cover, water quality, soil erosion, etc., providing an important information for environmental protection in road construction, operation and maintenance.

5 Capacity Building and Policy Decision Support for High-resolution Earth Observation Systems

Substantial progress has been made in building capacities to support high-resolution Earth observation systems both in China and abroad in terms of computing platforms and software systems. In terms of computing platforms, earth science engines such as GEE Cloud platform, PIE-Engine and GEOVIS, provide powerful geospatial data processing, analysis and visualization capabilities, and are widely used in environmental monitoring, agricultural management, urban planning and other fields.

High-resolution Earth observation technology reflects a nation's scientific prowess and global competitiveness. Various countries and organizations have introduced relevant policies to improve automated observation capabilities purposely to meet application needs in multiple fields, promote scientific and technological innovation and industrial upgrading, and strengthen international cooperation and exchanges. The Group on Earth Observations (GEO) has introduced policies to support the use of high-resolution Earth observation systems in four priority areas, i.e., climate change, disaster prevention and mitigation, resilient cities and sustainable development. In terms of climate change, international agreements such as the Paris Agreement aim to accurately monitor climate change through high-resolution remote sensing systems, control the rise in global average temperatures, and promote green and sustainable development. In the field of disaster prevention and reduction, global policy frameworks such as the Sendai Framework for Disaster Reduction 2015–2030, emphasize the use of high-resolution remote sensing technology to deeply understand and assess disaster risk, strengthen disaster reduction investment and capacity building, and reduce natural disaster losses. The United Nations Sustainable Development Goals (SDGs) regard high-resolution remote sensing technology as a key tool to achieving the rational use and protection of resources and promoting sustainable development. In terms of the construction of resilient cities, various governments and relevant institutions have issued a series of policy to encourage the application of high-resolution remote sensing technology in urban flood control, earthquake resistance, disaster prevention and other fields, to improve the resilience of cities to cope with natural disasters, and ensure the quality and comparability of remote sensing data through the formulation of international standards. These policy decisions have promoted the development and application of high-resolution Earth observation technology, and provided strong support for the global response to climate change, disaster prevention and reduction, sustainable development and resilient city construction.

In order to support the application of high-resolution Earth observation platforms, countries have also introduced data sharing policies and provided data sharing platforms to provide users with rich Earth observation data resources and analysis services. The commonly used international remote sensing data sharing platforms include NASA Earth observation system data sharing platform, Copernicus Open Access Hub, etc. In China, the commonly used remote sensing data sharing platforms include the National Integrated Earth observation data sharing platform, and the satellite remote sensing cloud service platform of the Ministry of Natural Resources. The main remote sensing data sharing platforms both in China and abroad are shown in Table 2.

6 Development Prospects and Trends of High-resolution Earth Observation Systems

With the continued progress of science and technology, high-resolution Earth observation systems are developing in the direction of higher spatio-temporal resolution, multi-spectral observation, intelligent and automated processing, providing strong support for sustainable economic and social development. In the future, the integration of communication, navigation and remote sensing will become a leading trend in the development of satellite systems. By integrating bidirectional communication of the Internet of Things, space-based navigation and positioning enhancement, and homologous multi-mode remote sensing functions, the performance of satellite systems will be improved comprehensively, and real-time wide-area integrated sensing services will be provided for multiple fields. PNTRC, a real-time intelligent service for space-based information, will become the core of the next generation

Table 2 List of remote sensing data sharing platforms (part)

Category	Name	Website
International Platforms	EOSDIS	https://earthdata.nasa.gov/
	Copernicus Open Access Hub	https://scihub.copernicus.eu/
	USGS	https://www.usgs.gov/
	Geo Platform	https://www.geoplatform.gov/
	G-Portal	https://gportal.jaxa.jp/
	CSA	https://www.asc-csa.gc.ca/eng
	ISRO	https://www.isro.gov.in/
	CNES	https://regards.cnes.fr/
	Roscosmos	http://www.roscosmos.ru/
Domestic Platforms	China GEOSS Data Sharing Network	http://chinageoss.cn/
	Natural Resources Satellite Remote Sensing Cloud Service Platform	http://www.sasclouds.com/
	National Platform for Remote Sensing Data and Application Services	https://www.cpeos.org.cn/
	National Earth System Science Data Center	http://www.geodata.cn/
	National Tibetan Plateau Data Center	https://data.tpdc.ac.cn/

of space-based information systems, integrating positioning, navigation, timing, remote sensing and communication functions through multi-satellite collaboration and multi-network interconnection, and providing fast, accurate and flexible integrated space-based information services. The development of on-board data processing technology will reduce the load of data transmission, improve the efficiency of remote sensing data use, and provide real-time processing and analysis capabilities for real-time response application scenarios. In addition, remote sensing intelligent interpretation technology uses computer technology and artificial intelligence algorithms to analyze and interpret remote sensing images to realize automatic identification, classification and extraction of Earth surface features. With the continuous optimization of technology, more refined interpretation requirements will be realized and interpretation efficiency and accuracy will be improved. In the face of technical challenges and financial needs, it is necessary to strengthen technology research and development, policy support and financial investment, promote sustainable and healthy development of high-resolution Earth observation systems, thus improving global Earth observation capabilities.

7 Conclusion

The development and application of high-resolution remote sensing satellites in China and the world else are reviewed in this paper. Great progress has been made in the development of high-resolution remote sensing satellites, signifying that Earth observation technology has entered a new era of development. These advances are not only reflected in the continuous improvement of satellite design, manufacturing and launch technology, but also in the performance of the remote sensing equipment on board the satellite and the significant enhancement of data processing capabilities. The development of high-resolution remote sensing satellites is also rapid, and the surge in commercial high resolution remote sensing satellites has injected new vitality into this field. With their flexible launch schedules, efficient data processing capabilities and customized data services, these commercial satellites have become supplements to government projects, further enriching the diversity and practicability of high-resolution remote sensing satellite observation systems. Driven by commercial high-resolution remote sensing satellites, high-resolution remote sensing satellite observation systems are increasingly becoming abundant and matured. While improving the accuracy and timeliness of Earth observation, these systems also give rise to a series of innovative application and service models through integration with other information technologies such as the Internet of Things, big data, and artificial intelligence. In agriculture for example, high-resolution remote sensing satellites can help farmers with precise fertilizer use, irrigation, and pest control. In urban planning, satellite data can support the construction of smart cities and improve the efficiency and level of urban management. In terms of environmental protection, remote sensing technology can monitor water quality, air quality and forest cover in real time, providing a scientific basis for environmental protection and sustainable development.

Acknowledgements

Wu, J. J. and Liu, Q. H. designed the overall framework of the article review; Li, M., Wu, J. J. and Liang, L. collected and researched the progress of the high-resolution Earth observation system; Wu, J. J. and Li, M. drafted the initial manuscript; Zhong, B. and Yang, A. X. revised the article.

Conflicts of Interest

The authors declare no conflicts of interest.

References

[1] Zhou, Y. J., Qiang, L., Li, Y. X. Status and development trends of foreign space-borne high-resolution imaging remote sensing systems [J]. *Flight Control & Detection*, 2021, 4(5): 1–8.
[2] Ma, C. L. Application of high-resolution surveying and mapping satellite and its standards development [J]. *Geospatial Information*, 2020, 18(5): 8–13.
[3] Cheng, S. Y., Li, Y. J. Characteristics and application of SPOT satellites [J]. *Journal of Geology*, 2010, 34(4): 400–405.
[4] Li, D., Wang, M., Jiang, J. China's high-resolution optical remote sensing satellites and their mapping applications [J]. *Geo-spatial Information Science*, 2021, 24(1): 85–94.
[5] Zhou, J. M., He, X. F. Differential SAR interferometry and its application to monitoring of earth surface deformation [J]. *Journal of Hehai University* (*Natural Sciences*), 2005(4): 463–465.
[6] Wang, H. Research on development of American space based infrared system [J]. *Tactical Missile Technology*, 2018(3): 19–23+29. DOI: 10.16358/j.issn.1009-1300.2018.8.004.
[7] Li, J. D. Advances in high-resolution Earth observation satellite remote sensing technologies in China [J]. *Science and Technology Foresight*, 2022, 1(1): 112–125.
[8] Yuan, X., Wang, T. Block adjustment for CBERS-02 B satellite images [J]. *National Remote Sensing Bulletin*, 2012, 16(2): 310–324.
[9] Cui, S. W., Zhang, X. L., Zhang, Y. K. Overview of the development of the domestic and international commercial remote sensing satellite industry [J]. *Satellite Application*, 2024(5): 33–38.
[10] Zhang, C. L., Cao, X. Q., Ji, Q. Glacier monitoring studies of Dongkemadi basin from 1990 to 2020 [J]. *Bulletin of Surveying and Mapping*, 2024(4): 61–68. DOI: 10.13474/j.cnki.11-2246.2024.0411.
[11] Hu, X. M. Research on synchronous inversion of vegetation water content and soil moisture based on GNSS-IR and multisource data fusion [D]. Guilin: Guilin University of Technology, 2023. DOI: 10.27050/d.cnki.gglgc.2023.001070.
[12] Zhang, H. M., Wu, Z. H., Lin, M. F., *et al*. Characterization of tobacco mosaic disease based on Sentinel-2 satellite data and vegetation indices [J]. *Straits Science*, 2023(12): 17–21.
[13] Zhao, A. Z., Zhu, X. F, Li, T. Q. Estimation of winter wheat yield in Beijing based on HJ-1 images [J]. *Research of Agricultural Modernization*, 2014, 35(5): 573–577.
[14] Gao, W., Shen, Q., Li, M. F., *et al*. Analysis of time-serial monitoring of flood extent based on multi-source remote sensing data [J]. *Geomatics & Spatial Information Technology*, 2018, 41(7): 8–10+14.
[15] Liu, G. W. Application of multi-scale 3D remote sensing technology for geological investigation in railway [J]. *Journal of Railway Engineering Society*, 2016, 33(8): 40–43.
[16] Zhang, Z. Z. Key Technologies for making large scene stereo model and its application in railway survey and design [J]. *Journal of Railway Engineering Society*, 2020, 37(4): 6.
[17] Lu, X. K., Chen, J. J. Three-dimensional geological environment modeling method for digital railway alignment [J]. *Journal of the China Railway Society*, 2015, 37(8): 91–97.