Research on the International Space Development Pattern

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Abstract. Since the Space Race, a new round of space race has emerged, and space, as an important field for the future of human development, has rich resources and endless space for development, which must be explored by all countries. Space development is one of the topics of national attention today, and researchers have found that there are many countries currently involved in space development, but there are gaps in the study of the international pattern of space development. Thus, three countries, China, Japan and Russia, are selected to represent the first, second and third levels of international space development, respectively. Through the analysis of the current state of space development, cooperation, and problems and challenges faced by the three countries, the overall status of the countries in space development is clarified and appropriate recommendations are made. This research found that the current competition in international space development is intense, and the high investment in space development of countries is developing rapidly, but there are many problems, such as environmental issues, issues of the legal system, financial issues, and so on.

Keywords: Space; development; international cooperation; international competition.

1. Introduction

Space, as the fourth environment of mankind, has rich resources and broad development prospects, is a very important area for the future development of humanity. Space development began with the space race in the United States and the Soviet Union, with the collapse of the USSR, the Cold War ended, the space development situation slowed. However, in the late 20th and early 21st centuries, space exploration once again sparked a wave, with more countries participating in the competition for space development, with the United States, Russia, China, Japan, India, ASEAN, the Middle East, and the European Union having their own unique development advantages and development strategies. In this fierce competition, technological innovation and development prompted countries to acquire more development opportunities, space resources and space for activities, which are important for strengthening national integrated competitiveness, safeguarding national interests and enhancing international status. It is therefore useful to understand the current multipolar development pattern of the world and to use it as a basis for a more targeted development strategy.

Furthermore, there are few papers currently analyzing the overall pattern of space competition from multiple national perspectives, mostly on the general situation, such as "New trends in current international space strategic competition and their revelations", "International competitiveness and cooperation in the field of space". The lack of literature in the world to analyze the international space development patterns in a number of specific countries makes this study meaningful. This study looks at the status of space development in three countries, China, Japan, and Russia, including their main developments, advantages, and cooperative relations, as well as the difficulties and challenges, and ultimately gives an overview of today's international space development pattern.

2. China's Space Development

2.1. Status of Development

At present, China's space development is steadily developing and continuously achieving greater achievements. Rapid development comes from China's two major advantages in space development.

2.1.1 Technological advantages

The technological achievement stems from China's long-standing unremitting investment in space. In the field of space exploration, China has made great technological breakthroughs, such as the successful launch of Chang'e IV in 2018, and the first human soft landing and surveillance probe on the back of the moon in January 2019. In 2021, China's first scientific and technological experimental satellite for solar detection, Chinese Hα Solar Explorer, was successfully launched, marking the arrival of Chinese solar detection. Economic development is also therefore rapidly increased by technological stimulus, while the space economy has a strong investment pull-up effect, industrial drive effect, and scientific and technological progress effect, this positive feedback relationship between science and technology and the economy makes the positive cycle go on [1]. China is accelerating the development of space tourism, space biopharmaceuticals, space breeding, space debris clearance, space experimental services, and other new space economies. "Commercial space prospects are very broad, and the existing technology should be fully utilized to develop the space economy, to help the construction of space power," said Ziyuan Ouyang, Chief Scientist of China's moon exploration engineering, academician of the Chinese Academy of Sciences [2].

2.1.2 China's institutional advantages - a new type of state-leading system

With the fundamental objective of national development and national security, the new type of state-leading system will effectively leverage the benefits of resources through scientific integration, concentration of forces, optimization mechanisms, synergy and coordination in the implementation of national major projects and major strategic organizations, coordination of resource allocation, mobilization and allocation of relevant forces, including spiritual and material resources [3]. The country system will make the resource allocation of the space cause more optimized; the space government, enterprises, universities, research institutions, users and financial institutions will coordinate their role; the budget will be precisely controlled, and high returns will be achieved; and China's space cause will make it easier to connect with the world and exchange cooperation.

2.2. Cooperation Situation

At present, China has adopted a diverse foreign policy in space, and China's multilateral space diplomacy is mainly based on relevant platforms such as the United Nations, the International Astronautical Federation and the International Space Research Commission at the global level [4]. At the regional level, China mainly relies on the Asia-Pacific Space Cooperation Organization (APSCO), BRICS countries, Shanghai Cooperation Organization and other regional organizations to conduct cooperation and exchanges in space exploration and governance related fields [4].

Firstly, at the global level, China is actively involved in the multilateral diplomatic platform for space under the United Nations system, and actively participates in the exploration and cooperation of space legislative processes and processes for the peaceful use of space technology (such as low-level research, early warning of disasters, etc.) [4].

Secondly, on the regional level, it advocates and participates actively in the creation, development and transformation of the Asia-Pacific Space Cooperation Organization [4].

Thirdly, with the commercialization and civilization of many technologies in the space field, China has begun to promote the development of China's multilateral space diplomacy through the addition of space cooperation subjects under traditional mechanisms such as the Shanghai Cooperation Organization and BRICS cooperation [4].

Fourthly, with the steady advancement of the "Belt and Road" initiative, in 2016, the National Defence Technical Administration and the Development and Reform Commission of China jointly issued the "Guidelines on Accelerating the Construction and Application of the Space Information Corridor of "One Belt and One Road", and formally proposed the construction of the space information corridor "One belt and one road" - "mainly with communications satellites, navigation and remote sensing satellite resources in orbit and planning construction, properly supplementing the improvement of the sky-based resources and the ground-based information sharing network, forming a four-person space information service system, providing space information services capacity for the countries and regions along the "one belt and two roads", and achieving information interconnectivity [4]."

2.3. Challenges and Shortcomings

2.3.1 The barrier between innovation and application

The transformation and application of results of space science and technology innovation progressed slowly.

The results of space science and technology innovation themselves have the "military-civil" dual characteristics, which also led to the transformation of related technological results facing the "security-application" dual paradox. In addition, China's scientific and technological achievements transformation system itself has to be perfected, and there is a lack of the system, economy and information system that supports the transformation of the results of related space science and technology innovation.

2.3.2 Insufficient speech and topical leadership in institutional building

Globally, the number of actors in the space field has increased gradually, forming a complex group of individuals, large space enterprises, subnational actors, States and transnational organizations. A growing number of actors have joined space development, and with the expansion of this group, more problems have arisen in international space governance.

The first problem is the space environment. Since the Soviet Union launched the first Earth satellite in 1957, humankind has begun the history of settling satellites into outer space. It has been followed by the explosion of space debris, which now records more than 50,000 cases of abandoned spacecraft and space fragments near the Earth. However, their harm does not only affect the beauty of the environment, they wander in space, and once they are wrapped with satellites in operation, enough to destroy them directly, producing more fragments, even though the vastness of space is impenetrable, people should also protect the environment here. The second issue is that the competition for dominance in international space governance is also increasing. The United States has replicated the "America's Priority" strategy in the space field, strengthening the dominance of the space game with technical advantages. The United States led the International Space Station (ISS) project, a joint construction of 15 countries such as Russia, France, Germany, and more than 60 countries participate in the application and experimentation, the impact is huge. At the same time, the United States strongly rendered the "China Threat Theory" and published the "Space Security Challenges" report in February 2019, calling China and Russia’s development of space technology a "challenge" to US space security. "The international space order is entering a new phase of restructuring and adjustment of turbulence, and our country must strengthen the modernization and governance capacity of space activities," emphasized Weiren Wu, an academician of the Chinese Academy of Engineering and Chief Designer of China's Moon Exploration Engineering [5]. The international community should therefore work together to improve international law and establish rules of conduct in space. However, the current system of international space law is predominantly developed by the United States, and China is relatively passive not only in improving and updating the international space system, but also in the area of international cooperation issues.

2.3.3 Lack of domestic space law

China's domestic space law is absent. The current domestic space legislation in China is not in line with the current state of development of space science and technology in China. At present, China's space development has entered a new historical phase, namely, the advancement of innovation-driven development strategy and military-civilian integration strategy in depth, constantly putting new historic requirements on Chinese space development and Chinese space diplomacy [4]. During this period, the space activities that the Chinese government needs to manage are no longer limited to traditional space state enterprises and research institutions, but also many new private space enterprises, such as Blue Arrow Space, Interstellar Glory, Starfleet Power, and Skywalk. The emergence of these enterprises brings many new management challenges to government agencies, including rocket launch services and management, spacecraft surveillance and security, space debris management, radio frequency coordination, and so on [4]. Meanwhile, Chinese aerospace enterprises have to start "going to the market" and face more fierce market competition. The government is no longer the only customer, executive directives are not the only driving force for production development, and market customers have a higher, more varied demand for space products and services [4]. At present, however, in the field of space law, China has only documents such as "the Space Object Registration Management Measures" and "the Civil Space Launch Project Permission", which are seriously incompatible with the current level of development of China's space activities [4]. Since space technology is closely related to national security, there is no perfect domestic legal system, and it is difficult for domestic enterprises, research institutes, universities and other space actors to develop and apply their own space technology [4].

3. Japan's Space Development

3.1. Status of Development

Japan is currently at the forefront of its developmental technology and partnership in the space development race and is known for its cooperation with its military allies, the United States, and other friendly countries, in space agencies, as well as for its highly militarized development of space. Although Japan's space development did not go smoothly in its earliest years, it has proved to be a stable and reliable participant in space exploration and exploration over time and continuously in steady co-operation with other agencies. On capitalizing on its accumulated knowhow, Japan is seeking to expand human activities starting from the moon to the rest of the solar system. Japan's space achievements are mostly related to institutions, the Japanese space technology research and development agency JAXA, which is a combination of the former space development agencies such as NASA (NASDA), Space Aviation Technology Research Institute (NAL) and the Institute of Space Science Research (ISAS) [6]. Since the 20th century, the old three agencies have been raising Japan's level of space technology through technological cooperation with the developed countries of the universe. Since JAXA was founded in 2003, it has succeeded the activities of the Old Three agencies in the space technology field and expanded international cooperation in more forms [6]. One notable development plan by JAXA in collaboration with researchers at domestic universities is Smart Lander for Investigating the Moon (SLIM). It is designed to miniaturize and advance technologies for pinpointing lunar landing and to demonstrate them on the Moon's surface with a small lunar probe. It is slated to be launched and soft-landed in the 2023 fiscal year [7].

3.2. Cooperation Situation

3.2.1 Cooperation with the US

Japan attaches great importance to cooperation with the United States in the space field.

Firstly, Japan reached a strategic consensus with the US military to share space intelligence. Since 2018, the United States has provided space-technical support to Japan through its Foreign Reimbursed Military Assistance (FMS) to help the Japanese Self-Defense Force establish a space surveillance system and develop deep space detection radar. In the future, the Japanese satellite will be equipped with U.S. military space surveillance sensors [8].

Secondly, the Japanese Self-Defense Force is trained by the United States. The Government of Japan has sent Air Self-Defense Officers to the Joint Space Operations Centre at the Vandenburg Air Force Base, California, United States. Japan and the United States also consulted on the appointment of the Self-Defense Officer as the official permanent liaison officer from 2021. Further information will also be shared with the US military after Japan establishes the Space Operations Force. Japan and the United States agreed to share relevant information on other countries' satellites and space debris sharing in real time from 2023 onwards, to construct a defence system against attacks by other countries and to establish a joint space command centre with the US at the appropriate time [8].

Finally, Japan participated in the United States-led multilateral space exercises and multilateralism agreements. Japan participated in the US-hosted "Global Sentinel" and "Schriever Wargame" to seek space security and demonstrate deterrence [8].

3.2.2 Cooperation with other countries

In addition to the United States, Japan is actively seeking to cooperate with other partner countries, such as Australia, France, the European Union and Japan, to “supplementary advantages”, indirectly enhance space capabilities, compensate for its own shortcomings, and share interests and responsibilities in the space field by working with space powers [8]. Japan cooperates with the Five Eyes Alliance in space intelligence and establishes a space force intelligence network [8]. There is a bilateral "Japan-Australia Space Agreement" and a multilateral "Japan-US-Austria space agreement" between Japan and Australia, and the two countries regularly exchange views on space policy [8]. In 2020, the Japan-EU Space Policy Dialogue has been held four times. Japan and India have also held intergovernmental space dialogue [8]. On 14 October 2020, Japan signed an “Alchemy Mess” agreement with eight countries, including the United States, Canada and the United Kingdom, on exploring the moon [8].

3.3. Challenges and Shortcomings

3.3.1 Technical aspect

At the technical level, there is a small gap between Japan's current space power and that of the space powers, and Japan does not necessarily have sufficient capacity to compete with other major players, such as the United States or China, at this stage, because much of the technology relies on other countries, like the US. The high degree of dependence on cutting-edge space technology overseas has led to the vicious cycle of technology development and industrial development abroad. The weakness of the semiconductor-led technological base is linked to the fragility of the industrial base. In the "Space Industry Perspectives 2030" published by the Space Policy Commission in 2017, 40% of Japan's artificial satellite components and components depend on overseas, with 80% of the main semiconductors present abroad [6]. This component is highly dependent on overseas and is directly related to the decline in productivity, which has led to a fall in the international competitiveness of the Japanese space industry [6]. As a result, the expansion of the space industry has been restricted, making it more difficult to invest in the development and maintenance of component parts [6]. As a result, there is a vicious cycle. It is for this reason that Japan wishes to become an independent space state.

3.3.2 Financial aspect

At the financial level, space development requires considerable funding. Japan has been in economic recession since the 1990s, so the budget allocated to the space sector has a bottleneck. After the twenty-first century, the increase in Japan's space-relations budget is clearly inadequate in the context of the rapid growth in global space development and utilization. According to the data of the Cabinet, the budget for space relations in 2010 was 295.5 billion yen, in 2015 it was 27.86 billion yen and in 2020 it was only 300.5 billion yen [6]. In other words, over a period of ten years, the budget allocated to the space sector has not increased qualitatively but decreased for one year. Moreover, Japan’s space-related financial expenditure is significantly lagging behind compared to other space developers. In 2018, Japan's space-related expenditure did not even reach one-tenth of that in the United States. In order to address this problem, Japan has begun to significantly increase its space budget from 2021. For the first time, the space relations budget for 2023 exceeds 50 billion yen [6]. While the achievement of the objectives was evaluated by stakeholders, there were also indications that the increased budget allocation was problematic. If funding for basic space science and technology is not secured, the vicious cycle resulting from the fragility of the following technologies and industrial bases cannot be fundamentally addressed [6].

3.3.3 Talent aspect

In terms of talent, there is a shortage of talent in Japan's cosmic field as a whole. According to the data of the Cabinet, in 2010, the number of employees in the space sector of the world's major space developers reached more than 30,000 [6]. However, Japan, with less than 10,000, lags a long way behind other space developing countries [6]. On the one hand, the number of employees is low, and on the other, the momentum for growth is weak. According to the report summarized by the Ministry of Economic and Industrial Affairs in May 2018 “Seminary on Strengthening the Personnel Base in the Space Industry”, there were only about 9,000 employees in the Japanese Space Machinery Industry so far, while in JAXA only about 600 were employed in the space fields related to rocket, satellite and data utilization [6].

Moreover, in Japan, starting with aerospace education programmes, including undergraduates, masters, and doctoral graduates, about 2,400 students enter the labour market annually, but less than 10% of the graduates are actually employed in the space industry [6].

4. Russia’s Space Development

4.1. Status of Development

Russia currently occupies a leading position in the world in the field of carrying rockets, including the launching of spacecraft, manned space vehicles and the production of cargo rockets. Russia has a technical advantage in the following areas:

Firstly, Russia has several rocket-carrying rocket series, covering 30 to 40 per cent of the world's launch missions [9]. The Soviet Union's "Alliance" for manned space, the "Proton" for carrying large spacecraft and the "Skytop" for military satellite launches received some upgrades in terms of functionality and number, establishing not only a complete system for Russian space launch, but also a long-term advantage in the world market at a stable price of performance and low cost [9]. According to statistics, the current cost of Russia's launch into low orbit is approximately $6,300-8900 per kilogram. In comparison, the cost of operations in the United States is $12,500-18,800/kg, in EU countries it is around $11,000-13,000/kg and in China it is about $8100-10800/kilograms [9]. In addition to these Soviet-era carrier rockets, Russia has developed its own "Angara" (Ангара) rocket launch complex, which includes a carrier rocket using environmentally friendly fuel, ground launch bases, control systems and power supply stations, fully safeguarding Russia's "independent access to space" [9].

Secondly, Russia's state-of-the-art space station technology is an indispensable strength in cooperation projects [9]. Russia has jointly constructed and operated the multi-purpose space research manned complex "International Space Station Project" with the National Space Agency of the United States, the Japanese Space Agency, the Canadian Space Agency and the European Space Agency to support astronauts and scientists in long-term stays in Earth orbit and conduct scientific research activities [9]. The station's modules are built by a joint division of work between countries. Among them, Russia's "Dawn"（Заря） functional cargo cabin is the largest existing international space cooperation project to date [9]. As of 2015, a total of 1,500 scientific experiments have been carried out, with the data returned providing scientific support to 69 countries. In addition to the "Aurora", Russia has contributed to the life and work of astronauts with the "Star" （Звезда）, the "Port" (Прис), and the small research module "Search" (Поиск). Some of the modules produced by other countries have also been sent into space with the powerful carrying capacity of the "Alliance" series of rockets.

Thirdly, Russia has built the GLONOS (ГЛОНАСС) global satellite positioning navigation system, with the US GPS, China's Beidou, Europe's Galileo and known as the world's four major navigation systems. It supports the full range of navigation needs, search and rescue, geographical mapping, environmental protection, remote communications, and more, and is the only civilian global positioning signal system in the world that provides both L1 and L2 frequency bands for free [9].

4.2. Cooperation Situation

Russia has concluded 37 project agreements, 4 multilateral cooperation agreements and 49 intergovernmental committees for economic, scientific and technical cooperation with 22 countries or international organizations. Among them, the first cooperation between Russia and the CIS countries (starting on 30 December 1991) formed legal provisions and institutional safeguards [9]. With regard to the Soviet heritage, Russia was concerned about the Baikonur launch complex in Kazakhstan and the rocket and engine manufacturing technology inherited by Ukraine, and in the 1990s continued to seek the right to use the site and developed good cooperative relations [9]. Russia has established base stations of the "Glonos" system in Belarus, Kazakhstan, Armenia and Nicaragua. Russia is also conducting scientific research with the United States and the European Union on Mars' atmospheric observations, soil component analysis, telescope research and satellite research. Gagarin Space Center (Центр Подготовки Космонавтов имени. Ю.А.Гагарина) is the world's largest training base for astronauts, providing basic training and simulation of space environments to astronauts from various countries, has so far trained more than 100 domestic and foreign astronauts, and has a good reputation within the world range [9].

4.3. Challenges and Shortcomings

4.3.1 Insufficient funding in Russia

According to the Stockholm International Peace Research Institute, Russian military expenditure increased year by year from 1999 to 2016, surpassing $70 billion and $80 billion in 2015 and 2016, and has since stabilized at more than $60 billion [10]. The report entitled "Space Policy, Issues and Trends 2016-2017"released by the European Institute for Space Policy Research (ESPI) further confirms Russia's development path towards space power growth through increased funding [10]. However, in order to overcome the adverse effects of budget cuts by increasing focused investment, the Russian Space Group provided approximately 20 billion rubles in April 2016 to its important manufacturer of space launch systems, Russia's National Space Research Production Centre "Khrunichev", to repay the centre's debt [10].

In addition, the sanctions have brought Russia’s economy back into trouble, with finance once again becoming a “barrier” to Russian space sustainability. In 2019, Russia's sales of space orders decreased by 17 per cent from planned due to a decrease in advance payments, failure to complete domestic orders on time, extended spacecraft testing processes, and reduced overseas orders. However, in the context of the economic downturn and the decline in national incomes, the Russian government still gives enough attention to space, and space funding grows at a rate of 5-10 per cent annually [9].

4.3.2 Technological disadvantage

At present, Russia's relatively weak part in space technology lies in the launch of satellites. Although Russia has five launch bases – including the world's largest Baikonur Space Launch Centre – it accounts for only 2% of the total number of satellites launched globally (the United States 60%, the EU 25% and China 5% or Japan 4%), which is clearly a big gap from its world-leading target [9]. The Russian satellites not only do not dominate the world in terms of number, but they are also not sufficiently diverse to be used for navigation and military purposes. The sub-development of satellite commercial fields is not the same as the United States' ability to navigate the scope of its technology to extend its service to high-tech development and related research in astronomical sciences [9]. Russia's orbiting spacecraft account for about 9.2% of the world's share, and its share in spaceship production reached 11-12%, a growth rate higher than the world average, behind the US and China. However, up to 90% of the electronic components required by Russia to assemble spacecraft depend on foreign imports, which are not conducive to sustainable development in the long run [8].

4.3.3 Political factors

The deterioration of relations between Russia and the West following the crisis in Ukraine has also affected the normal implementation of some space cooperation projects. The US-Russian question of whether to renew the International Space Station (ISS) is a three-wave. On 3 April 2014, the United States Government announced that the United States would terminate its cooperation with the Russian National Space Company in the light of continued violations by Russia of the sovereignty and territorial integrity of Ukraine [8].

5. Conclusion

Overall, research has revealed that international space development is currently highly competitive and that countries attach great importance to space development, but high-speed development also brings many problems. It was recommended that all countries should adequately release the constraints of the domestic space exploration market and encourage enterprises that are capable and willing to develop innovative space technologies to improve legal systems and norms on this basis, thus better introducing marketization and promoting progress in the development of the space economy and technology, while balancing the horizon between open development and secrecy. With a view to the world as a whole, the establishment of rules of space conduct and related norms should be accelerated, the international space law system should be improved and international cooperation and exchanges should be strengthened, thus contributing to the development of the human space cause. This study analyzes the current state of space development in the country and helps to see the situation of international space development.

Finally, this study is only a rough introduction of the state of space development of the various countries, without a detailed analysis of the specific space industries of each country, in the future can be further refined in the aforementioned aspects, which is conducive to the in-depth study of the topic.

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