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Challenges and prospects of ensuring security in the legal regulation of space activities

Outer space has long been regarded as an important domain for human survival and development, playing a significance role in scientific and technological progress, resource utilization, and the continuation of civilization. From the stars in classical Chinese mythology to the constellations of ancient Greek mythology, human imagination and exploration of outer space have persisted for thousands of years. The article analyzes the challenges and prospects of ensuring security in the legal regulation of space activities within the framework of international law. The aim of the study is to examine existing legal mechanisms governing outer space and to identify key problems related to its security. The research methods include literature review and comparative analysis. The findings suggest that space-related research has contributed to various fields, including medicine, transportation, and the exploration of rare metals and other resources, potentially alleviating pressure caused by the depletion of Earth's natural resources. At the same time, the inherently international nature of outer space reflects the common interests of humanity and represents a significant advancement in mankind's ability to understand and transform the world. However, legal regulation remains largely national and lags behind technological development, creating both challenges and opportunities. In conclusion, effective governance of outer space requires enhanced international cooperation, improvement of existing treaties, and the development of new legal frameworks to ensure security and equitable access for all countries.

Keywords: international law, outer space law, outer space, outer space activity, outer space rule of law.

Introduction

Outer space is the fourth largest active space pioneered by human beings after land, ocean and sky [1]. The successful launch of the first artificial satellite in 1957 marked the entry of mankind into the space era, and the outer space method was born. In the subsequent nearly 60 years of development, the outer space law has gone through three stages: treaty law, soft law and post-soft law [2]. These three stages correspond to the three historical games between the United States and the Soviet Union, developed countries in space and developing countries, and the United States and Europe and emerging space countries.

The current outer space governance rules are difficult to cover new security challenges. The 1967 Outer Space Treaty did not explicitly prohibit “non-destructive” anti-satellite tests, and there was no definition of the orbit occupation and cross-border flow of data of commercial constellations. The United Nations “Guidelines for the Long-term Sustainability of Outer Space Activities” and other “soft laws” lack coerciveness, resulting in the reduction of rules such as satellite decommissioning and disposal to “paper requirements”—although most countries will stop abandoning rocket wreckage in 2024, there are still enterprises that avoid the obligation to actively deorbit. The draft of the Treaty on the Prevention of the Placement of Weapons in Outer Space proposed by China and Russia has been delayed due to the opposition of individual countries, forming a legal vacuum of “prohibiting the deployment of weapons”.

The explosive growth of commercial aerospace, along with its supervision, has not played a corresponding role, but has instead led to increased chaos. By the time of writing this article, the data survey shows that there are more than 500 private satellite enterprises in the world, but the transnational regulatory standards are not uniform. For example, the United States is relaxed in the orbit approval of the “Star Chain”, China requires satellites to have the ability to deorbit, and developing countries are completely unable to implement supervision due to technological backwardness [3]. More seriously, the allocation of high-track resources still follows the principle of “first-come, first-served”. The United States and Europe occupy more

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than 70 % of low-track high-quality resources with the first-mover advantage, and emerging countries are forced to be deployed in high-risk orbits, which further exacerbates the governance imbalance.

Methods and materials

This article has used the literature analysis method and comparative analysis method.

Literature analysis method—The research in this article is analyzed and summarized through reading international regulations, domestic and foreign references, and the introduction of various materials.

Comparative analysis method—compare and analyze the actual background and practical situation of outer space safety in the paper.

Results

1. Deepening of international multilateral cooperation

At present, the number of space debris has exceeded 128 million, the risk of orbital collision continues to rise, and there are significant differences in the technical level of debris removal and the definition of responsibilities in countries. Therefore, promoting the formulation of unified standards has become the core demand of multilateral cooperation in the field of outer space.

The ISO20893 standard released by the International Organization for Standardization (ISO) in 2021 is a key breakthrough. This standard is led by China, which clarifies the technical requirements for the emission of residual propellant in the final stage of the launch vehicle, the prevention and control of disintegration in orbit, and also stipulates that spacecraft with an orbital altitude of 700 kilometers must be off track within 25 years. At present, this standard has been included in the Space Debris Mitigation Standard Manual by the European Space Agency, and 17 countries around the world have adopted its technical indicators in the design of new launch vehicles, laying a solid foundation for global unified debris management standards. In addition, the Zero Debris Charter launched by the European Space Agency, together with global aerospace enterprises, scientific research institutions and other forces, has set the goal of achieving zero debris increment by 2030. The relevant goals of debris monitoring and cleaning proposed by it are also gradually becoming the consensus of many countries.

In addition, spectrum and orbit are the core strategic resources of space activities. With the mass deployment of satellite constellations, the contradiction of resource scarcity is increasingly prominent. At present, although the International Telecommunication Union (ITU) has a basic distribution mechanism, there are problems such as lagging actual deployment after application and some countries grabbing resources. Therefore, deepening multilateral cooperation will focus on the improvement of rules and fair distribution. ITU is promoting the revision of relevant rules, such as shortening the “occupancy period” of satellite frequencies and orbital resources, avoiding some countries or enterprises from occupying resources for a long time without carrying out substantive activities; at the same time, multilateral cooperation will promote the establishment of a “dynamic adjustment mechanism”, targeting low-orbit satellite constellation-intensive areas, through data sharing Evaluate the orbital utilization rate, guide enterprises to plan satellite layout reasonably, and reduce orbital overlapping conflicts. Taking the Artemis Plan as an example, when many countries jointly built the lunar space station, they have simultaneously negotiated and determined the spectrum allocation scheme of Earth-Moon communication. This model of “project binding resource allocation” is expected to be promoted to the fields of near-earth orbit and deep space exploration in the future.

2. Commercial legislation has become a hot topic

People have never given up the country’s exploration of outer space, and have maintained a high degree of curiosity and desire to explore for thousands of years, which has made the commercial international cooperation in the application of outer space a new boom. Commercial rocket launch, satellite application, space tourism and other commercial new business forms are accelerating, becoming the core engine of the growth of the aerospace industry. In the field of commercial rockets, the iteration of reusable technology has greatly reduced the cost of launch, and the demand for high-frequency launches and mass networking has surged; satellite applications have been extended from traditional communication and navigation to remote sensing monitoring and the Internet of Things, and the large-scale deployment of commercial satellite constellations has become a trend; space tourism has moved from concept to reality, and suborbital brigade The normalized operation of travel and the exploration of rail tourism have been steadily promoted, and the audience of various commercial aerospace services has expanded from the professional field to the mass market. With the diversified development of business forms, the scale of the commercial aerospace market continues to expand, and the number of enterprises in the upstream and downstream of the industrial chain has shown ex-

plosive growth, but the chaos in the development of the industry has also gradually emerged. Some enterprises fall into disorderly competition in order to seize market share. For example, there are excessive grabbing of orbital resources and uneven technical standards in the deployment of low-orbit satellite constellations; the high-risk nature of space activities leads to difficulties in defining accident liability. Once rocket launch failure, satellite collisions and other events occur, it is easy for enterprises to be responsible. There is no clear basis for the guarantee of tourists, third-party loss compensation and other issues. These problems are difficult to effectively regulate by enterprise self-discipline or industry conventions alone, which not only restricts market fairness, but also buries space safety hazards.

Against this background, the intervention of legislation has become an inevitable choice. Special legislation can clarify the core game rules such as market access standards, business operation norms, and responsibility division principles for the unique attributes of commercial aerospace, and draw a compliance red line for enterprises. At the same time, legislation can establish a unified competition supervision mechanism to curb malicious low-price competition, resource hoarding and other behaviors, protect the legitimate rights and interests of compliant enterprises, and enable enterprises to compete within a fair and transparent framework. More importantly, legislation can guide the transformation of the focus of industrial development from “pursuing scale expansion and grabbing market share” to “improving technological innovation ability, ensuring safe operation, and optimizing service quality”, promote the high-quality development of the commercial aerospace industry, not only releasing the vitality of commercialization, but also safeguarding space safety market.

The characteristics of high investment and high risk in the aerospace industry make it difficult for a single country to independently support the development of the whole chain. Regional cooperation has changed from single project collaboration to whole industry chain coordination, which has become an inevitable trend. For example, China and Thailand signed a memorandum of cooperation with the International Lunar Research Station to carry out all-round cooperation on lunar exploration, data sharing and personnel training, which can not only reduce costs, but also unify resources and avoid waste. However, it has to be mentioned that there is a certain implementation dilemma. Due to the large differences in the qualification requirements, responsibility identification, data ownership and other aspects of various countries in space activities, the clear division of powers and responsibilities directly hinders the promotion of regional cooperation. For example, when enterprise A participates in the regional satellite constellation project led by country B, it often faces problems such as unconstrained launch licensing standards, conflicts in the division of accident responsibility, and restricted cross-border flow of in-orbit data.

Therefore, the regional aerospace cooperation agreement in outer space needs to have clear and unified legal application rules in order to reduce compliance costs and dispute risks in cooperation, and provide stronger institutional guarantees for resource integration, technology sharing and market interoperability in the region.

Discussion

Born in the early days of the Cold War, the international rule system, which was led by the government in the aerospace stage, and took the 1967 Outer Space Treaty as the cornerstone. At a time when commercial aerospace is booming and technological updates are changing rapidly, it has been seriously disconnected from reality. The “time gap” of this rule, coupled with the difficulty of forming consensus on the key issues of outer space, together build institutional barriers to the security governance of outer space.

1. The lag of legal rules

The current institutional framework of the core space treaty is based on the era of relatively backward development. Due to the backwardness of laws and regulations and people’s lack of imagination of science and technology, the diversified development trajectory of commercial aerospace has not been predicted at all. The 1967 Outer Space Treaty only established the principle with the general expression of “outer space for the peaceful use of all mankind”, but did not take into account that in today’s 21st century, space tourism has become something that can be easily realized. Therefore, space tourism needs to draw legal boundaries—when the Virgin Galaxy suborbital vehicle carries tourists across the Carmen Line, can tourists apply the astronaut rescue clause? If the failure of the aircraft causes ground damage, is it the responsibility of the launching country in accordance with the Convention on Liability, or is the operating enterprise directly liable for compensation? These practical problems are all unsolved because the treaty does not clarify the “legal status of commercial spacecraft”.

In addition, in the era of the explosion of the commercial aerospace industry, the regulatory gap for the constellation of commercial satellites is more deadly. The treaty does not set the orbital spacing standard and frequency occupancy period of low-orbit satellites, so that giant satellite constellations such as “Star Chain” can seize space resources on a “first-come, first-served” mode. By 2025, the number of satellites in orbit has exceeded 5,000, and orbital overlaps and conflicts with China’s “thousand sail constellation” are frequent. In addition, the constraint of the 1972 Liability Convention is only limited to national behavior. For accidents such as private satellite collisions and space debris pollution, the injured party needs to pursue responsibility through diplomatic channels. For example, in 2023, the Star Chain satellite collided with the Brazilian remote sensing satellite, and it took more than two years to pursue the responsibility and still did not reach compensation. Compensation agreement.

Expressions such as “proper attention to avoid polluting outer space” in the space treaty have become a “flexible clause” that is difficult to implement due to the lack of specific quantitative standards. When the Outer Space Treaty was drafted in 1967, the issue of space debris had not yet been taken into consideration. Today, there are more than 30,000 traceable space debris worldwide, more than 40 % of which come from abandoned satellites that have not fulfilled their deorbit obligations. Although the Long-term Sustainability Guidelines for Outer Space Activities requires “de-orbit within 25 years after the end of the mission”, the document is a “soft law” and is not binding [4]. By 2024, there are still 12 commercial aerospace enterprises to avoid the cost of deorbiting by extending the satellite in orbit. What’s more serious is that the environmental protection rules of the moon, asteroids and other deep space areas are completely blank. Human beings have left 200 tons of garbage on the moon, but there is no treaty that clearly divides the “responsibility for cleaning up space waste”.

2. *Insufficient legal constraints on safety hazards*

As commercial spaceflight enters the “constellation” outbreak period, the deployment plan of the “10,000-level” satellite cluster is pushing outer space security to the edge of danger: Space X “Star Chain” plans to deploy 42,000 satellites, and China’s “Qianfan Constellation” plans to deploy 12,000 satellites. Such large-scale deployment not only aggravates the tightness of orbital resources aggravated the already serious problem of space debris. At present, in the Earth’s orbit, traceable debris with a diameter of more than 10 cm has exceeded 30,000 pieces, and about 1 million small and medium-sized debris from 1 cm to 10 cm. These “space garbage” flying at high speed of 24,000 kilometers per hour may hit the spacecraft at any time and cause chain accidents. However, in the face of such an urgent crisis [5], the governance mechanism with the existing legal system as the core is almost “invalid” and falls into the triple dilemma of “no coercive constraints, no clear responsibilities, and no effective solutions”.

From the rule-level of debris management, there is only one unified guidance document on debris mitigation in the world—the Long-term Sustainability Guidelines for Outer Space Activities adopted by the United Nations Committee on the Peaceful Uses of Outer Space in 2019 [6]. However, this guideline is essentially only a “voluntary proposal”, which is not given any legal coercive force and cannot form a rigid constraint on countries and business entities. As Aarti Holla Maini, head of relevant United Nations agencies, said bluntly: “This code is more like a “paper commitment”, and the real implementation requires countries to take the initiative to implement it. However, in the current complex geopolitical environment, it is difficult for countries to reach a binding treaty consensus on debris management, and the practical role of the code has been greatly reduced Weak [7]”.

This “soft restraint” directly leads to the complete control of the source of space debris out of control. On the one hand, the decommissioning and disposal of commercial satellites has been reduced to the arbitrary behavior of enterprises’ “independent choice”: although the “Guidelines for the Long-term Sustainability of Outer Space Activities” recommend that “deorbitation will be completed within 25 years after the end of the satellite mission”, there are still 12 commercial aerospace enterprises around the world in 2024 that will deliberately extend satellites in order to avoid the cost of deorbitation. In-orbit time, disguised increases the risk of debris. What’s more confusing is that there are still obvious differences in the regulatory standards for the decommissioning of satellites in different countries—the United States only requires low-orbit satellites to be decommissioned within 5 years, with lax standards and limited implementation; although the European Union has formulated mandatory de-orbit rules, it cannot restrain the violations of enterprises in other countries due to the lack of transnational supervision. On the other hand, the “zero accountability” mechanism of anti-satellite tests further aggravates debris pollution: the anti-satellite test carried out in India in 2019 directly produced more than 200 traceable debris, which threatens the safety of other spacecraft by staying in near-ground orbit for a long time. However, because current law does not explicitly prohibit anti-

satellite tests, there are also no corresponding sanction provisions, and India has not been subject to any international accountability. Today, such anti-satellite tests have become the third largest source of near-Gear orbit debris, but there has always been a lack of legal means to contain them.

If the lack of source control makes the debris “continue to add”, then the dilemma of cleaning up the stock of debris makes the crisis “continuously accumulate”. The existing legal system does not define core issues such as “the entity responsible for debris removal” and “the party responsible for cleanup costs”, which has led to the global stock of debris growing at a rate of 5% per year. Meanwhile, the corresponding cleanup capacity is seriously insufficient—the world can remove fewer than 10 large debris objects each year, and the costs are extremely high, while the technology remains limited. For example, the ClearSpace-1 project led by the European Space Agency is capable of capturing and removing only one defunct satellite at a cost of approximately USD 100 million. Similarly, laser-based debris removal technology developed in Japan is suitable only for very small debris with a diameter of less than 1 cm; moreover, due to the lack of clear legal authorization, it risks being misinterpreted as a space weapon, which has generated international controversy and hindered its large-scale application.

More seriously, the attribution of responsibility for “historical debris” remains an unresolved issue. Early space objects launched in the mid-20th century have effectively become “space antiques” after decades in orbit. However, in the absence of international treaties requiring launching states to assume responsibility for the removal of such legacy debris, many of these objects continue to remain in orbit.

This distorted situation, in which those who pollute are not held accountable, has trapped the space debris problem in a vicious cycle characterized by continuous accumulation and unclear responsibility for existing debris, thereby further constraining the sustainable use of outer space [8].

Conclusions

International cooperation has gradually become an inevitable path of development, and the COVID-19 pandemic has accelerated the evolution of unprecedented changes in the world. The security and legal crisis in outer space once again shows that the fate of mankind is shared, the interests of all countries are closely linked, and the world is an inseparable community of destiny. To promote the exploration of outer space, the international community must unite and cooperate to jointly deal with the crisis test of hidden security risks. At the same time, the theme of the era of peace and development has not changed, and cooperation to meet challenges is the only option for the international community. In the era of globalization, it should not be some people who oppose another part, but all people should benefit everyone.

At the level of the legal system, outer space governance will be advanced through a dual approach of “global coordination + regional linkage.” On the one hand, the United Nations framework will retain a central leading role, while foundational instruments such as the Outer Space Treaty will be supplemented and revised to address emerging scenarios and provide clear legal support for international cooperation. On the other hand, regional cooperation will serve as an important complement to global rules [9], as illustrated by multilateral technical coordination under the Artemis program and the cooperative framework of the Sino-Russian International Lunar Research Station. The rules and technical standards derived from these initiatives will further enhance the global governance system. On this basis, by harmonizing standards to reduce technical barriers and improving governance efficiency through the use of digital tools, outer space activities can transition from “disorderly competition” to “cooperative win-win” outcomes, thereby removing regulatory and environmental obstacles to the development of emerging sectors such as space tourism and lunar bases.

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Ғарыш қызметін құқықтық реттеудегі қауіпсіздікті қамтамасыз етудің қиындықтары мен перспективалары

Ғарыш кеңістігі әрқашан адамзаттың өмір сүруі мен дамуының маңызды жалғасы болып саналады және ғылыми-техникалық прогресс, ресурстарды пайдалану және өркениеттің жалғасуы үшін үлкен маңызға ие. Қытайдың классикалық мифологиясындағы жұлдыздардан бастап ежелгі грек мифологиясындағы шокжұлдыздар туралы түсініктерге дейін адамдардың қиялы мен ғарышты зерттеуге деген ұмтылысы мыңдаған жылдар бойы тоқтаған емес. Мақалада халықаралық құқық шеңберінде ғарыш қызметін құқықтық реттеу барысында қауіпсіздікті қамтамасыз етудің мәселелері мен перспективалары талданған. Зерттеудің мақсаты — ғарыш кеңістігін реттеудің қолданыстағы құқықтық механизмдерін талдау және ғарыш қызметінің қауіпсіздігін қамтамасыз етуге байланысты негізгі мәселелерді анықтау. Зерттеуде ғылыми әдебиеттерді талдау және салыстырмалы талдау әдістері қолданылды. Зерттеу нәтижелері ғарыш қызметінің қоғам өмірінің әртүрлі салаларына, соның ішінде медицина мен көлікке әсер ететінін, сондай-ақ сирек металдар мен басқа да ресурстарға қол жеткізуге мүмкіндік беретінін көрсетеді. Бұл өз кезегінде Жер ресурстарының сарқылуына байланысты қысымды азайтуға көмектесуі мүмкін. Ғарыш кеңістігінің халықаралық сипаты адамзаттың ортақ мүдделерін білдіреді және адамдардың әлемді тану мен өзгерту мүмкіндіктерін кеңейтеді. Сонымен қатар құқықтық реттеу технологиялық дамудан артта қалып отыр және көбіне ұлттық сипатқа ие, бұл белгілі бір мүмкіндіктер мен қиындықтарды тудырады. Қорытындылай келе, ғарыш кеңістігін тиімді басқару халықаралық ынтымақтастықты күшейтуді, қолданыстағы халықаралық шарттарды жетілдіруді және барлық мемлекеттер үшін қауіпсіздік пен ғарышқа әділ қолжетімділікті қамтамасыз ететін жаңа құқықтық тетіктерді әзірлеуді талап етеді.

Кілт сөздер: халықаралық құқық, ғарыш кеңістігі құқығы, ғарыш кеңістігі, ғарыш қызметі, ғарыш кеңістігіндегі заң үстемдігі.

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Вызовы и перспективы обеспечения безопасности в правовом регулировании космической деятельности

Космическое пространство всегда являлось важным продолжением существования и развития человечества и имеет большое значение для научно-технического прогресса, использования ресурсов и продолжения цивилизации. Начиная со звезд в классической китайской мифологии и заканчивая представлениями о созвездиях в древнегреческой мифологии, фантазии и стремление людей к исследованию космоса не прекращались на протяжении тысячелетий. В данной статье анализируются проблемы и перспективы обеспечения безопасности в правовом регулировании космической деятельности в рамках международного права. Цель исследования заключается в анализе существующих правовых механизмов регулирования космического пространства и выявлении ключевых проблем, связанных с обеспечением безопасности космической деятельности. В исследовании использованы методы анализа научной литературы и сравнительного анализа. Результаты исследования показывают, что космическая деятельность оказывает влияние на различные сферы жизни общества, включая медицину и транспорт, а также способствует доступу к редким металлам и другим ресурсам, что может помочь снизить давление, вызванное истощением природных ресурсов Земли. Международный характер космического пространства отражает общие интересы человечества и расширяет возможности людей в познании и преобразовании мира. В то же время правовое регулирование отстает от технологического развития и носит преимущественно национальный характер, что создает определенные возможности и вызовы. В заключение подчеркивается, что управление космическим пространством требует между-

народного сотрудничества, совершенствования существующих международных договоров и разработки новых правовых механизмов, обеспечивающих безопасность и справедливый доступ всех государств к космосу.

Ключевые слова: международное право, космическое право, космическое пространство, космическая деятельность, верховенство права в космическом пространстве.

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