Beijing Law Review, 2022, 13, 304-319
https://www.scirp.org/journal/blr
ISSN Online: 2159-4635
ISSN Print: 2159-4627

An Overview of the Situation of Small Satellites According to the United Nations Space Treaties

Chandaphan Suwijak*, Shouping Li

School of Law, Beijing Institute of Technology, Beijing, China
Email: *suwijak.cha@mfu.ac.th

How to cite this paper: Suwijak, C., & Li, S. P. (2022). An Overview of the Situation of Small Satellites According to the United Nations Space Treaties. *Beijing Law Review, 13,* 304-319.
https://doi.org/10.4236/blr.2022.132020

Received: March 22, 2022
Accepted: June 14, 2022
Published: June 17, 2022

Abstract

The growing number of small satellite systems and launches is considered to play an essential role in conducting space activities. The development of these space activities has opened up new opportunities for novel and creative uses of space systems, especially among new entrants and users from emerging economies. Small satellites have generally been launched into low Earth orbit, with the associated missions expanding access to space while requiring less time and money than traditional satellite missions. This paper is documentary research that analyzes the situation of small satellites according to the United Nations space treaties. This body of law consists of five treaties, three of which are highly relevant to small satellites, namely the Outer Space Treaty, the Liability Convention, and the Registration Convention. Even though small satellites fundamentally differ from traditional satellites, it is evident that the current space law regime applies to small satellites as "space objects" in the same way as it does to traditional satellites. Thus, as the current legal regime does not distinguish between space objects based on their dimensions, small satellite operations are not regulated differently to other space activities.

Keywords

Small Satellites, Traditional Satellites, Space Objects, United Nations, Space Treaties

1. Introduction

The growing number of small satellite systems and launches is considered to play an essential role in the development of "NewSpace" or "Space 2.0" projects.

As a consequence, private space companies have been established in countries worldwide, thereby revitalizing the previously flagging space industry. In fact, this economic sector has been said to be on course to grow into a "trillion-dollar" industry by 2014 (O'Connell, 2022). As a consequence, these emerging space activities should help to ensure the long-term viability of the global economy. Simply put, small satellites have an impact on everyone's lives (Pelton & Madry, 2020a). Thus, it is critical to discuss how technological progress, emerging technologies, modern economic space markets, and creative ambitions have fueled the most recent facets of new space activity growth and small satellite development over the last decade. Such growth and development have opened up new opportunities for novel and creative uses of space systems, especially among new entrants and users from emerging economies (Lappas & Kostopoulos, 2020).

Sputnik-1, the world's first satellite, was successfully launched by the former Soviet Union in 1957, and with a mass of just 83.6 kg, it can also be considered the world's first small satellite (Volynskaya & Kasyanov, 2016). However, that initial launch occurred over 60 years ago. Rockets developed by both the Soviet Union and the United States of America quickly became capable of launching payloads weighing thousands of kilograms and generating thousands of watts of power, rather than tens of kilograms and tens of watts (Jakhu & Pelton, 2014). Indeed, the concept of small satellites is not a new one; Explorer-1, Oscar-1, SCORE, Relay, and Syncom were all sent into space during the late 1950s and early 1960s as "small satellites". Many other historical spacecraft were also light in terms of their mass, which may explain why they were categorized as small satellites. In fact, due to the lack of heavier items to be sent into orbit, the early satellites weighed just a few tens of kilograms. Yet, as launch vehicles were improved to the point of being able to carry and hoist heavier payloads into orbit, scientists developed more complex technology for incorporation into spacecraft, resulting in the development of massive and heavy satellites (Palkovitz, 2019). The issue of whether spacecraft were "small", "medium", or "large" was never a point of contention during those pioneering years. As a result, early antennas were usually simple dipoles with limited capacities. Generally speaking, these early satellites had a volume comparable to that of a giant beach ball and a density of only a few kilograms. Thus, while the early satellites were specifically intended to demonstrate that such technology could work in orbit, little faith was placed in their ability to actually provide commercial services (Pelton & Madry, 2020b).

The significant change that has occurred in terms of satellite growth is known as technological inversion, and it refers to the fact that spacecraft have become more sophisticated and more prominent. This concept of technological inversion was vividly demonstrated from the 1960s through to 2010. For example, with each new generation of Intelsat satellites, the power, antenna size, and technological complexity all grew rapidly, as illustrated by the addition of three-axis stability. As satellites are now equipped with high-gain antennas, the satellite antenna systems can be more precisely aligned to Earth positions. While satellites increased in size, power, and capability throughout this five-decade transition period, ground stations decreased in cost and scale (Pelton & Madry, 2020). As small satellites' essential dimensions are both low in size and cost-effective, these miniature satellites make sense from the economical, organizational and technological perspectives (Lappas & Kostopoulos, 2020).

The primary purpose of this research is to analyze the situation of small satellites according to the United Nations (UN) space treaties. This paper is divided into five parts, including Introduction and Conclusion. Part 2 will examine what constitutes a small satellite and how it differentiates from a traditional satellite. Part 3 will discuss the critical applications of small satellites in low Earth orbit (LEO). Part 4 will examine small satellites according to the five UN Space Treaties. Part 5 is the conclusion and final comments.

2. The Advent and Classification of Small Satellites

An artificial satellite is defined as "a manufactured object or vehicle intended to orbit the earth, the moon, or another celestial body" (Satellite, 2022). It is generally accepted that the satellite era began with the launch of the former Soviet Union's Sputnik-1 (83 kg) (Sinelnikov et al., 2014) and the United States of America's Explorer-1 (14 kg) small satellites (Bille & Lishock, 2002). In response to the launches of these spacecrafts, numerous other small satellites were launched in the 1960s. During the 1970s and 1980s, larger satellites became desirable due to customer requests for larger payloads and additional solar panels to provide more electricity (Whalen, 2022). This development was facilitated by the increased capacity of launchers, which meant that they could lift greater masses. Larger satellites require additional fuel for orbit raising and correction, extending each satellite's lifespan. Due to the high costs associated with designing, manufacturing, qualifying, launching, and operating a satellite, the space industry has historically been dominated by large space organizations backed by governments and major industries in industrialized countries (e.g., the National Aeronautics and Space Administration [NASA] in the United States). Thus, newcomers to the industry have been pushed to devise cost-effective strategies for achieving market penetration. The current trend with regard to space systems is to obtain more significant benefits with less inputs, which has resulted in the concept of "smaller, cheaper, faster, better" (Heidt et al., 2000). To date, small satellites have almost always been launched into LEO (Kopacz et al., 2020) with their missions expanding access to space while requiring less time and money than traditional satellite missions. In fact, numerous constellation missions have been accomplished with the use of small satellites (Murugan & Agrawal, 1682).

Given the classification of small satellites in terms of advanced space technology, the differences between large and small satellites have become increasing difficult to identify. At present, this issue remains controversial and debatable due to the many possible ways to define small satellites in an effort to differentiate them from larger and less modern satellites (ITU UNOOSA, 2015). In addition, the classification ranges of small satellite masses vary by both organization and user (Murugan & Agrawal, 1682). Moreover, they are based solely on a satellite's mass, regardless of its maneuverability, shape, or other features. The most widely accepted definition, which was established by the International Academy of Astronautics (IAA) as part of its study of Earth observation satellites, categorizes small satellites into four groups based on mass: minisatellites (100 - 1000 kg), microsatellites (10 - 100 kg), nanosatellites (1 - 10 kg), and picosatellites (less than 1 kg) (Jakhu & Pelton, 2014).

3. Small Satellites and Their Applications

As a result, the growth and launch of small satellites are continuing to accelerate. Around 90% of small satellites already reside and operate in LEO, and there are hundreds more scheduled to be launched in the future (Ritchie & Seal, 2020). Thus, the world is paying attention to these small satellites and the dangers they pose to space safety. All types of orbital debris, including small satellites, will have a detrimental effect on all areas of future space missions (Virgili & Krag, 2015). Yet, the space industry is currently in the process of transitioning to the use of small satellites for appropriate applications. The following sections will discuss the critical applications of small satellites.

1) Earth observation

The critical need for Earth observation missions is clearly illustrated by the numerous ongoing initiatives concerning international cooperation in the field of the environment, where measurements from Earth-observing satellites represent an essential component (Young & Onoda, 2017). This is especially true when it comes to acquiring, analyzing, and utilizing data that document the state of the Earth's resources and environment on a long-term basis. Small satellite missions can be accomplished in a variety of ways. One option here is to focus on a single task and create a small satellite system (bus and payload) for the specified remote-sensing purpose using commercially available technologies. Another possibility is to leverage technological advancements to achieve the further shrinking of engineering components and the development of microtechnologies for use in sensors and equipment that enable the creation of dedicated, well-targeted, and high-performance Earth observation missions (Sandau, 2010).

The IAA study mentioned above summarized the state-of-the-art situation in terms of small satellite missions and explored the additional elements that contribute to the cost-effectiveness of Earth observation missions involving small satellites (Sandau, 2006a). Having access to the necessary skills represents a critical step toward the creation of a cost-effective task. As the number of nations to have successfully launched spacecraft increases, the pool of experience available to address the issues associated with tiny satellite missions expands (Sandau, 2006b). Current technology enables the use of next-generation cameras capable of producing high-resolution images. Such cameras serve as the payloads of nanosatellites. This is one of the most prevalent applications of small satellite constellations. Indeed, a number of firms are currently attempting to acquire high-resolution photos of the Earth, including Planet Labs, which has launched over 330 satellites into space since 2013 (Alén Space, 2019a).

2) Telecommunications

Throughout recent history, satellite communications have been considered one of the most reliable indicators of both technological and societal progress. In this respect, over the last few decades, astounding and unexpected advances and changes have occurred across a wide range of fields, including broadcasting, mobile communications, Earth observation and remote sensing, interplanetary exploration and transportation, and remote monitoring, meaning that such developments have encompassed commercial, military, and scientific applications (Burleigh, 2019). In addition, many advancements have occurred in telecommunications, allowing small satellites to relay higher volumes of data, communicate from distant points of the solar system, and collect radiometric data for navigational purposes (Babuscia, 2020). While small satellites are not yet capable of fully replacing geostationary orbit (GEO) telecommunications satellites, they can be used for communications purposes (Choi, 2022).

One such application is the automatic identification system (AIS) technology mandated by the International Maritime Organization for all vessels with a displacement of over 300 tons. Small satellites equipped with this technology can receive and transmit data concerning the locations of ships at sea. This enables ships' operators to precisely locate vessels anywhere on Earth, thereby enhancing maritime safety (Alén Space, 2022). Spire Global is considered one of the most promising start-ups currently pursuing the commercialization of related technologies. The company intends to launch a constellation of small satellites in order to monitor maritime traffic.[1] Another important example is Sky and Space Global, a limited liability company based in the United Kingdom that aims to connect remote areas of the world that are currently unconnected (Cocking, 2017). Similarly, companies such as SpaceX, OneWeb, Telesat, and Amazon are all developing small satellite constellations, which are popularly dubbed mega-constellations, in an effort to ensure global internet connectivity (Pachler et al., 2021).

3) Technology demonstrations

The singularity of a satellite can be used to evaluate experimental components or technologies designed to be employed in both small and traditional satellites. The cost-related benefit associated with this process is apparent when comparing the costs of testing sophisticated technologies on a small satellite versus testing them on a more complex satellite. If the tested system fails, the manufacturer will suffer financial and time losses; however, such losses will be insignificant when compared with the possibility of losing an entire primary satellite mission due to a single component failure (Alén Space, 2019b). In such a scenario, a small satellite will be constructed to incorporate the most recent technology and con-

[1] *Spire Global to provide satellite-AIS services for EMSA*, SAFETY4SEA, https://safety4sea.com/spire-global-to-provide-satellite-ais-services-for-emsa/ (last visited Feb. 25, 2022).

firm its successful application, which will also serve as the primary purpose of the satellite mission. Moreover, there has been a reduction in the dangers associated with technology deployment in areas with no prior flying experience. A good example of this concerns the European Space Agency (ESA) launching the world's first nanosatellite, OPS-SAT, which is dedicated to demonstrating the significantly enhanced mission control capabilities that will be made possible when satellites are equipped with more powerful onboard computers. Although OPS-SAT is barely 30 cm tall, it is equipped with an experimental computer that is ten times more powerful than the computer of any ESA spacecraft currently in operation (*OPS-SAT*, 2022).

4) Astronomy and atmospheric science

The international scientific community has used a number of small satellites to conduct astronomical studies. The first attempt at such a research approach is the BRITE constellation, which has been orbiting the Earth since 2013 and consists of five nanosatellites from Austria, Canada, and Poland. The mission of the constellation is to "observe the brightness differences of massive luminous stars" so as to advance scientific understanding of stellar structure and evolution (Weiss et al., 2014). The QB50 constellation, which is funded by the European Union (EU) and contains approximately 50 CubeSats from various countries worldwide, represents the second attempt. Its mission is to conduct atmospheric research in the lower thermosphere, the least studied layer of the atmosphere, which is located between altitudes of 90 km and 320 km. The CubeSats' sensors also provide essential details about their re-entry operation (Mayence, 2016). This project is significant due its research goals and the fact that it is the result of a large-scale international partnership.

5) National security

For many years, space was considered the domain of a small number of countries. Formerly, only the spacefaring nations could fund space programs and satellite networks; however, the rise of the small satellite has permanently overturned this paradigm. As a consequence, small satellites with high capabilities are likely to play an essential role in the future of national security space architecture (Major RJ Bonometti & Lieutenant Colonel ED Nicastri, 1989). More specifically, the military intelligence and communications satellites of the past typically had comprehensive measurements (Jakhu & Pelton, 2014). Rather than competing with conventional satellites, small satellites could be used to assist in achieving the strategic targets of different types of missions. One related concept is "responsive space", which uses the particular qualities of small satellites to boost military capabilities and enable rapid responses to specific threats. In the case of a military danger or other emergency, the military could gain an advantage by rapidly deploying small satellites in order to increase its intelligence concerning the relevant situation (Jakhu & Pelton, 2014).

6) Education and capacity building

Small satellites, especially CubeSats, have proven to be highly effective in relation to educating and capacity building. For example, in 2009, volunteers from AMSAT-UK and AMSAT-NL, both non-profit organizations, began the design of a new model of CubeSat known as the FUNcube Project. FUNcube-1 is a 1U CubeSat with a mass of less than 1 kg, and it is the first satellite to have the primary mission objective of providing educational outreach to schoolchildren (Korzan, 2014). As part of the associated project, each school is provided with a customized dongle that attaches to a personal computer and communicates with FUNcube-1 through the dongle's interface. Additional resources have been made available online by AMSAT-UK, including classroom guidelines that instruct teachers regarding the teaching of scientific ideas to students using the dongle and recommended classroom activities (Korzan, 2014). In addition, the research opportunities offered by the Education Office of the ESA include instruments and platforms for small satellites in terrestrial and lunar orbits intended to validate the learning methods applied to engineering and knowledge/skill transfer models for students (Rodríguez et al., 2021). Moreover, the Basic Space Technology Initiative (BSTI) was developed to promote improved access to and use of space applications in support of policy and decision-making for sustainable development by enhancing fundamental space technology development capabilities (Basic Space Technology Initiative, BSTI, 2022). In addition, small satellite technology can be used to enhance education and capacity building in developing countries because the number of science students is rapidly increasing. Additionally, selected candidates enroll in PhD programs at universities or science institutions to continue their studies and research. Many of these researchers are aware that the modern era is referred to as the "space-age" and have developed an interest in space science and technology (Mathai & Haubold, 2018).

Since the beginning of the space age, space activities have been conducted by spacefaring nations because these activities require advanced technology and enormous capital for construction and operation (Degrange, 2019). However, with the emergence of small satellite technology, this idea has changed. It is significantly cheaper to build small satellites, and the technology is more readily available (Dornik & Smith, 2016).[2] As a result, small satellites are being used in various space activities as discussed earlier (Aglietti, 2020).

4. Small Satellites According to the UN Space Treaties

Although small satellites fundamentally differ from traditional satellites, it is evident that the current space law regime applies to small satellites as "space objects" in the same way as it does to traditional satellites. Indeed, none of the current legal instruments distinguish between space objects based on their dimensions, meaning that small satellite operations are not regulated differently from other space activities. This section will examine the relevant provisions of the

[2]Michael Dornik & Milton Smith (2016), *Small Satellite Industry and Legal Perspectives in the United States*, *in* SMALL SATELLITES 8-9.

UN space treaties regarding small satellites activities.

Outer space is the province of mankind, which is why a legal regime governing outer space has been developed by the UN Committee on the Peaceful Uses of Outer Space (UNCOPUOS) (Hameed, 2018). This body of law consists of five treaties,[3] three of which are highly relevant to small satellites, namely the Outer Space Treaty (OST), the Liability Convention, and the Registration Convention. The OST is considered the Magna Carta of international space law (He, 1997), providing as it does the basis for states parties' rights and obligations in relation to their space activities. It is primarily based on the Declaration of Legal Principles Governing States' Activities in the Exploration and Use of Outer Space, which was enacted the UN General Assembly in 1963 through resolution 1962 (XVIII), although it includes a few new provisions. The OST entered into force on 10 October 1967, and it contains the most fundamental and all-encompassing principles that were later elaborated by the other UN space treaties (VON DER DUNK, 2015) with the following fundamental principles relating to small satellite activities.

1) The exploration and use of outer space shall be carried out for the benefit and in the interests of all countries and shall be the province of all mankind, and outer Space shall be free for exploration and use by all States[4]

According to this principle, small satellite activities typically serve the interests outlined in Article I of the OST, as different states parties carry out activities that are more diverse than traditional satellite activities, including Earth observation, telecommunications, technology demonstrations, astronomy and atmospheric science, national security, and education and capacity building, as discussed earlier in this paper. This rationale behind this principle is the fact that small satellite technology is less expensive and more accessible than traditional satellite and human spaceflight activities (CubeSats, 2022). The increasing deployment of small satellite technology in LEO has the potential to reshape the landscape of various space activities. This new space paradigm will not mean the end of more traditional satellite technology, as small satellites will be unable to satisfy the insatiable desire for all that space activities involve. However, it does open up

[3]The treaties commonly referred to as the "five United Nations treaties on outer space" are as follows: 1) Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty): Adopted by the General Assembly in its resolution 2222 (XXI), opened for signature on 27 January 1967, entered into force on 10 October 1967. 2) Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space (Rescue Agreement): Adopted by the General Assembly in its resolution 2345 (XXII), opened for signature on 22 April 1968, entered into force on 3 December 1968. 3) Convention on International Liability for Damage Caused by Space Objects (Liability Convention): Adopted by the General Assembly in its resolution 2777 (XXVI), opened for signature on 29 March 1972, entered into force on 1 September 1972. 4) Convention on Registration of Objects Launched into Outer Space (Registration Convention): Adopted by the General Assembly in its resolution 3235 (XXIX), opened for signature on 14 January 1975, entered into force on 15 September 1976. 5) Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (Moon Agreement): Adopted by the General Assembly in its resolution 34/68, opened for signature on 18 December 1979, entered into force on 11 July 1984.

[4]Article I of the OST.

plenty of possibilities, most of which expand the range of business options even further (Freelan, 2014).

Moreover, small satellites encourage independent scientific inquiry concerning outer space, with universities and research institutes regularly using them in scientific experiments (Millan et al., 2019). For instance, the UN Office for Outer Space Affairs (UNOOSA) recognizes small satellites as an effective capacity-building tool and encourages both information exchange and the development of small satellite activities (Basic Space Technology Initiative, BSTI, 2022). In addition, the Asia-Pacific Space Cooperation Organization (APSCO) promotes satellite development by training students and academics, assisting member states with the development of radiometric calibration capabilities, and developing small satellites through the Joint Small Multi-Mission Satellite Constellation program. Furthermore, Strathclyde University intends to provide capacity-building training to students at the Cape Peninsula University of Technology as part of a global partnership funded by the United Kingdom in an effort to improve fire detection rates in South Africa (Economic and Social Council, 2020).

2) States shall not place nuclear weapons or other weapons of mass destruction in orbit or on celestial bodies or station them in outer space in any other manner[5]

The first paragraph of Article IV of the OST aims to prohibit the presence of nuclear and other weapons of mass destruction (WMD) in outer space and on celestial bodies (Zedalis & Wade, 1978). While the term "weapons of mass destruction" is undefined in the treaty, it is widely recognized to encompass nuclear, chemical, and biological weapons (Kimball, 2020). Article IV would be violated if small satellites carrying nuclear weapons or other WMD orbited the Earth. Yet, due to their small size and low weight, as well as their relatively limited power budget, small satellites are unlikely to be chosen to carry lethal weapons into orbit. As a result, the chances of a small satellite mission violating Article IV are considered quite remote (PALKOVITZ, 2019).

3) States shall be responsible for national space activities whether carried out by governmental or non-governmental entities[6]

According to Article VI of the OST, the regime governing space activities is based on the principle that states parties bear international responsibility for national governmental and non-governmental entities' activities in outer space. They must also ensure that all national space activities are conducted in accordance with the obligations set out within the OST. All national space activities must be authorized and continuously supervised by the appropriate state. More specifically, states parties fulfill this obligation by authorizing space activities, imposing conditions on those activities, and supervising the conducting of the activities. The responsibility of States parties for their national space activities represents a critical incentive for states to regulate those national space activities.

[5]Article IV paragraph 1 of the OST.

[6]Article VI of the OST.

When it comes to small satellite activities, the obligation to authorize and supervise national space activities is not dependent on the size of the space objects in question; therefore, states parties must also authorize and supervise the activities of small satellites—each launching state is held internationally liable for any damages caused to other states (Asta Tūbaitė-Stalauskienė, 2019).

Although there is no precise definition provided in the OST as to what constitutes a "national activity", the terms of the domestic space law of a particular state party will clarify the scope of the activities to which it refers. In essence, such domestic space law represents an interpretation by the drafters of the legislation of what they consider to be "national activities in outer space", at least for the purposes of the specific national law (Freelan, 2014).

4) States shall be liable for damage caused by their space objects[7]

Article VII of the OST establishes broad international liability on the part of states parties for damage caused by the launch of space objects (de Rozavel & Smith, 2009). The appropriate state party is not only responsible for its national activities, but also potentially for any damage to another state or its natural or juridical persons by such an object or its parts on the Earth, in the airspace, or in outer space, including the Moon and other celestial bodies, caused by national space activities. Here, the term "liability" refers to the circumstance in which a state party incurs an obligation to pay damages to another state after causing damage to its citizens or property (International Committee of the Red Cross, 2017). Notably, states parties are potentially liable for all compensable damage, regardless of whether the activity in question was illegal or not (Johnson, 2013).

Another UN space treaty that sets out the principle of international state liability for damage caused by space objects is the Liability Convention, which establishes a dual liability regime based on the question of whether the damage occurred on the Earth's surface (including to aircraft in flight) or in outer space (Lampertius, 1991).

- Article II[8] refers to harm experienced on the surface of the Earth or to aircraft in flight. It provides for absolute liability.
- Article III[9] deals with damage caused in outer space and provides for fault-based liability.

The Liability Convention elaborates on Article VII of the OST.[10] Yet, while the broad provisions of Article VII are typically read and implemented in conjunction with the Liability Convention, it is worth noting that the Liability Convention, as the *lex specialis* of international liability for space activities, established an international regime that is distinct from the OST's regime (Hobe et al.,

[7]Article VII of the OST.

[8]Article II of the Liability Convention.

[9]Article III of the Liability Convention.

[10]*Convention on International Liability for Damage Caused by Space Objects*, United Nations Office for Outer Space Affairs, https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introliability-convention.html (last visited Mar. 11, 2022).

2017).

5) The obligation to register space objects[11]

Article VIII of the OST constitutes an obligation and explicitly grants "jurisdiction and control" over registered space objects. Although the OST expressly prohibits national appropriation through any claim of sovereignty, a state party retains the right to exercise sovereignty over its registered space objects. It is also important to note that Article VIII does not specify a time limit for retaining a state party's jurisdiction and control over space objects within its registry (Chung, 2019). The "jurisdiction" here refers to enacting and enforcing laws and rules concerning a person and objects. The applicable law is determined by jurisdiction. Moreover, the "control" refers to the factual situation whereby the state of registry has the authority to enact technical rules in order to achieve the mission of the relevant space object, and if necessary, to direct, halt, modify, and correct the elements of that space object and its mission. While the OST requires the registration of space objects, it includes no provision governing their actual registration. The Registration Convention was explicitly established to address this omission (Marchisio, 2010).

The Registration Convention elaborates on Article VIII of the OST, which establishes the principle of space object registration and its primary consequence, namely the ability to exercise jurisdiction over registered space objects (von der Dunk, 2003). In addition, it broadens the scope of the UN Register of Objects Launched into Outer Space, as established by resolution 1721B (XVI) in December 1961, and addresses issues concerning states parties' responsibilities for their space objects.[12] Articles I, II, and III of the Registration Convention requires all space objects, including small satellites, to be registered as such.

Small satellites that are not registered or are registered late tend to defeat the purpose of the Registration Convention (Larsen, 2017). Satellites that are not registered represent a particular issue. At present only 7% of space objects are unregistered (Larsen, 2015). Historically, universities and amateur or small launch operators frequently failed to register their launches because they believed them to be too small and insignificant to qualify as space objects. However, they remain subject to international law despite the failure to register, as small satellite registration might be considered customary international law (Palkovitz & Masson-Zwaan, 2012).

6) States shall avoid harmful contamination of space and celestial bodies[13]

Outer space arguably requires special protection because it is an exceedingly vulnerable environment that cannot afford to experience any damage (Larsen, 2006). More importantly, the unrestrained degradation of this pristine environment would undoubtedly impede future exploration and uses of outer space, in

[11]Article VIII of the OST.

[12]*Convention on Registration of Objects Launched into Outer Space*, United Nations Office for Outer Space Affairs, https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introregistration-convention.html (last visited Mar. 11, 2022).

[13]Article IX of the OST.

addition to jeopardizing free access to outer space. This would prove detrimental to all space actors, especially non-spacefaring nations (Viikari, 2008). Article IX of the OST is the essential space law provision governing the protection of the outer space environment and its preservation for peaceful purposes. It requires states parties to exercise "due regard" for the interests of other countries when conducting any space activity, which is referred to as the "due regard principle".

More precisely, Article IX seeks to address environmental concerns regarding space by establishing a proscriptive positive legal obligation on all states parties (Chung, 2018) to avoid harmful contamination of outer space, to avoid causing adverse changes to the Earth's environment due to introducing extraterrestrial matter, and to conduct appropriate international consultations if there is reason to believe that space activities will cause potentially harmful interference to the space activities of other states (Goehring, 2020).

5. Conclusion

The growing number of small satellite systems and launches is considered to play an essential role in conducting new space activities. As a consequence, private space companies have been established in countries worldwide. Moreover, the development of these space activities has opened up new opportunities for novel and creative uses of space systems, especially among new entrants and users from emerging economies. To date, small satellites have generally been launched into LEO, with the associated missions expanding access to space while requiring less time and money than traditional satellite missions. As a result, small satellites are being used in various space activities such as Earth Observation, telecommunication, technology demonstrations, astronomy and atmospheric science, national security, and education and capacity building. When compared with traditional satellites, small satellites are characterized by small masses, low development costs, and short development times. Yet, even though small satellites fundamentally differ from traditional satellites, it is evident that the current space law regime applies to small satellites as "space objects" in the same way as it does to traditional satellites. Thus, as the current legal regime does not distinguish between space objects based on their dimensions, small satellite operations are not regulated differently from other space activities. Conducting space activities by using small satellites must comply with the five UN space treaties. This body of law consists of five treaties, three of which are highly relevant to small satellites, namely the Outer Space Treaty, the Liability Convention, and the Registration Convention.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Aglietti, G. S. (2020). Current Challenges and Opportunities for Space Technologies.

Frontiers in Space Technologies, 1, 1. https://doi.org/10.3389/frspt.2020.00001

Alén Space (2019a, July 4). *Small Satellite Applications: 26 Businesses in Space to Start Now.* https://info.alen.space/small-satellite-applications-businesses-in-space-to-start-now

Alén Space (2019b, September 12). *10 Advantages of CubeSats vs. Conventional Satellites.* https://info.alen.space/advantages-of-cubesats-vs-conventional-satellites

Alén Space (2022). *Satellite Constellations for Vessels Safety.* https://alen.space/small-satellites-for-ais-services/

Babuscia, A. (2020). *Telecommunication Systems for Small Satellites Operating at High Frequencies: A Review.*

Bille, M., & Lishock, E. (2002). *EXPLORER I—A New Look at America's First Satellite.*

Bonometti, M. R. J., & Nicastri, L. C. (1989). The Role of Small Satellites in Our National Defense. In *Small Satellite Conference* (p. 1). USU's Institutional Repository.

Burleigh, S. C. et al. (2019). From Connectivity to Advanced Internet Services: A Comprehensive Review of Small Satellites Communications and Networks. *Wireless Communications and Mobile Computing, 2019,* Article ID: 6243505. https://doi.org/10.1155/2019/6243505

Choi, T. (2022). *The Case for Small GEOs in the Coming LEO Space War.* http://interactive.satellitetoday.com/the-case-for-small-geos-in-the-coming-leo-space-war/

Chung, G. (2018). Emergence of Environmental Protection Clauses in Outer Space Treaty: A Lesson from the Rio Principles. In A. Froehlich (Ed.), *A Fresh View on the Outer Space Treaty* (pp. 1-13). Springer. https://doi.org/10.1007/978-3-319-70434-0_1

Chung, G. (2019). Jurisdiction and Control Aspects of Space Debris Removal. In A. Froehlich (Ed.), *Space Security and Legal Aspects of Active Debris Removal* (pp. 31-47). Springer. https://doi.org/10.1007/978-3-319-90338-5_3

Cocking, S. (2017, February 7). Business Showcase: Sky and Space Global. *Irish Tech News.* https://irishtechnews.ie/business-showcase-sky-and-space-global

CubeSats, European Space Agency (2022). https://www.esa.int/Enabling_Support/Preparing_for_the_Future/Discovery_and_Preparation/CubeSats

de Rozavel, A. K., & Smith, L. J. (2009). Article VII. *Cologne Commentary on Space Law, 1,* 128.

Degrange, V. (2019). Active Debris Removal: A Joint Task and Obligation to Cooperate for the Benefit of Mankind. In A. Froehlich (Ed.), *Space Security and Legal Aspects of Active Debris Removal* (pp. 1-15). Springer. https://doi.org/10.1007/978-3-319-90338-5_1

Dornik, M., & Smith, M. (2016). Small Satellite Industry and Legal Perspectives in the United States. In *Small Satellites* (pp. 8-9). Brill Nijhoff.

Economic and Social Council (2020). *Exploring Space Technologies for Sustainable Development and the Benefits of International Research Collaboration in This Context.* U.N. Doc. E/CN.16/2020/3. https://unctad.org/system/files/official-document/ecn162020d3_en.pdf

Freelan, S. (2014). A Delicate Balance: Regulating Micro Satellite Technology in a Big Satellite World. *University of Western Sydney Law Review, 18,* 3.

Goehring, J. S. (2020). Can We Address Orbital Debris with the International Law We Already Have? An Examination of Treaty Interpretation and the Due Regard Principle.

Journal of Air Law and Commerce, 85, 313.

Hameed, H. (2018). Small Satellites-Entrepreneurial Paradise and Legal Nightmare. *Journal of Space Technology, 8,* 72.

He, Q. Z. (1997). The Outer Space Treaty in Perspective. *Journal of Space Law, 25,* 1.

Heidt, H. et al. (2000). CubeSat: A New Generation of Picosatellite for Education and Industry Low-Cost Space Experimentation. In *14th Annual/USU Conference on Small Satellites* (p. 1). Utah State University's (USU) Institutional Repository (IR).

Hobe, S. et al. (2017). *Cologne Commentary on Space Law: Outer Space Treaty.* 142 § 1 (BWV Verlag. 2017).

International Committee of the Red Cross (2017, April 27). *Space Law Revisited: The Regime of International Liability in Space.* Medium. https://medium.com/law-and-policy/space-law-revisited-the-regime-of-international-liability-in-space-66a864fa5157

ITU UNOOSA (2015). *Guidance on Space Object Registration and Frequency Management for Small and Very Small Satellites.*

Jakhu, R. S., & Pelton, J. N. (2014). *Small Satellites and Their Regulation.* Springer. https://doi.org/10.1007/978-1-4614-9423-2

Johnson, C. D. (2013). *Legal and Regulatory Considerations of Small Satellite Projects.*

Kimball, D. (2020). *The Outer Space Treaty at a Glance.* Arms Control Association. https://www.armscontrol.org/factsheets/outerspace

Kopacz, J. R. et al. (2020). Small Satellites an Overview and Assessment. *Acta Astronautica, 170,* 93-105. https://doi.org/10.1016/j.actaastro.2020.01.034

Korzan, D. (2014). FUNcube-Cosmic Teaching Aid. *Rocznik Towarzystwa Naukowego Płockiego, 6,* 265-266.

Lampertius, J. P. (1991). The Need for an Effective Liability Regime for Damage Caused by Debris in Outer Space. *The Michigan Journal of International Law, 13,* 452-453.

Lappas, V., & Kostopoulos, V. (2020). A Survey on Small Satellite Technologies and Space Missions for Geodetic Applications. In V. Demyanov, & J. Becedas (Eds.), *Satellites Missions and Technologies for Geosciences* (p. 6). IntechOpen. https://doi.org/10.5772/intechopen.92625

Larsen, P. B. (2006). Application of the Precautionary Principle to the Moon. *Journal of Air Law and Commerce, 71,* 295-306.

Larsen, P. B. (2015). Berlin Space Protocol: Update. *ZLW, 64,* 385.

Larsen, P. B. (2017). Small Satellite Legal Issues. *Journal of Air Law and Commerce, 82,* 289.

Marchisio, S. (2010). National Jurisdiction for Regulating Space Activities of Governmental and Non-Governmental Entities. In *United Nations/Thailand Workshop on Space Law* (pp. 1-7). UNOOSA.

Mathai, A., & Haubold, H. (2018). United Nations Basic Space Science Initiative (UNBSSI) 1991-2012 and Beyond. *Creative Education, 9,* 192-248. https://doi.org/10.4236/ce.2018.92015

Mayence, J.-F. (2016). QB 50: Legal Aspects of a Multinational Small Satellite Initiative. In I. Marboe (Ed.), *Small Satellites: Regulatory Challenges and Chances* (pp. 195-210). Brill Nijhoff.

Millan, R. M. et al. (2019). Small Satellites for Space Science: A COSPAR Scientific Roadmap. *Advances in Space Research, 64,* 1466-1517. https://doi.org/10.1016/j.asr.2019.07.035

Murugan, P., & Agrawal, Y. (1682). Small Satellites Applications, Classification and Technologies. *International Journal of Science and Research (IJSR), 9,* 1682-1687.

O'Connell, K. (2022). *Remarks on the Trillion Dollar Space Economy*. Office of Space Commerce. https://www.space.commerce.gov/remarks-on-the-trillion-dollar-space-economy

Pachler, N. et al. (2021). An Updated Comparison of Four Low Earth Orbit Satellite Constellation Systems to Provide Global Broadband. In *2021 IEEE International Conference on Communications Workshops (ICC Workshops)* (pp. 1-7). https://doi.org/10.1109/ICCWorkshops50388.2021.9473799

Palkovitz, N. (2019). *Regulating a Revolution: Small Satellites and the Law of Outer Space*. Kluwer Law International BV.

Palkovitz, N., & Masson-Zwaan, T. (2012). Orbiting under the Radar: Nano-Satellites, International Obligations and National Space Laws. In C. M. Jorgenson (Ed.), *Proceedings of the International Institute of Space Law* (p. 566). Eleven International Publishing.

Pelton, J. N., & Madry, S. (2020a). *Handbook of Small Satellites: Technology, Design, Manufacture, Applications, Economics and Regulation* (Vol. 8). Springer. https://doi.org/10.1007/978-3-030-36308-6

Pelton, J. N., & Madry, S. (2020b). Introduction to the Small Satellite Revolution and Its Many Implications. In J. N. Pelton, & S. Madry (Eds.), *Handbook of Small Satellites: Technology, Design, Manufacture, Applications, Economics and Regulation* (pp. 3-31). Springer. https://doi.org/10.1007/978-3-030-36308-6

Ritchie, G., & Seal, T. (2020, July 10). Why Low-Earth Orbit Satellites Are the New Space Race. *Washington Post*. https://www.washingtonpost.com/business/why-low-earth-orbit-satellites-are-the-new-space-race/2020/07/10/51ef1ff8-c2bb-11ea-8908-68a2b9eae9e0_story.html

Rodríguez, J. S. et al. (2021). Experimental Approach for the Evaluation of the Performance of a Satellite Module in the CanSat Form Factor for *in Situ* Monitoring and Remote Sensing Applications. *International Journal of Aerospace Engineering, 2021,* Article ID: 8868797. https://doi.org/10.1155/2021/8868797

Sandau, R. (2006a). *International Study on Cost-Effective Earth Observation Missions* (p. 113). CRC Press.

Sandau, R. (2010). Status and Trends of Small Satellite Missions for Earth Observation. *Acta Astronautica, 66,* 112. https://doi.org/10.1016/j.actaastro.2009.06.008

Sandau, R. et al. (2006b). Cost-Effective Earth Observation Missions Outcomes and Visions from the International IAA Study. In *57th International Astronautical Congress* (p. 1). Utah State University's (USU) Institutional Repository (IR). https://doi.org/10.2514/6.IAC-06-B5.4.04

Satellite. (2022). Merriam-Webster Dictionary. https://www.merriam-webster.com/dictionary/satellite

Sinelnikov, V. et al. (2014). Sputnik 1 and the First Satellite Ionospheric Experiment. In *40th COSPAR Scientific Assembly* (p. 1). COSPAR.

The European Space Agency (2022). *OPS-SAT*. https://www.esa.int/Enabling_Support/Operations/OPS-SAT

Tūbaitė-Stalauskienė, A. (2019). Small Satellites: National Regulatory Challenges. *Teisė, 111,* 190-204. https://doi.org/10.15388/Teise.2019.111.11

United Nations Office for Outer Space Affairs (2022). *Basic Space Technology Initiative (BSTI)*. https://www.unoosa.org/oosa/en/ourwork/psa/bsti/index.html

UNOOSA, Basic Space Technology Initiative (BSTI). (2022). https://www.unoosa.org/oosa/en/ourwork/psa/bsti/index.html

Viikari, L. (2008). *The Environmental Element in Space Law: Assessing the Present and Charting the Future* (p. 147). Brill Nijhoff. https://doi.org/10.1163/ej.9789004167445.i-396

Virgili, B. B., & Krag, H. (2015). *Small Satellites and the Future Space Debris Environment*.

Volynskaya, O. A., & Kasyanov, R. A. (2016). Launching Numerous Small Satellites—A Flourishing Business? The Case of the Russian Federation. In I. Marboe (Ed.), *Small Satellites: Regulatory Challenges and Chances* (pp. 83-104). Brill Nijhoff. https://doi.org/10.1163/9789004312234_007

Von Der Dunk, F. (2015). *Handbook of Space Law* (p. 29). Edward Elgar Publishing. https://doi.org/10.4337/9781781000366

von der Dunk, F. G. (2003). *The Registration Convention: Background and Historical Context* (p. 451).

Weiss, W. W. et al. (2014). BRITE-Constellation: Nanosatellites for Precision Photometry of Bright Stars. *Publications of the Astronomical Society of the Pacific, 126,* 573-585. https://doi.org/10.1086/677236

Whalen, D. J. (2022). *Communications Satellites: Making the Global Village Possible*. Communications Satellites Short History, National Aeronautics and Space Administration. https://history.nasa.gov/satcomhistory.html

Young, O. R., & Onoda, M. (2017). Satellite Earth Observations in Environmental Problem-Solving. In M. Onoda, & O. R. Young (Eds.), *Satellite Earth Observations and Their Impact on Society and Policy* (pp. 3-27). Springer. https://doi.org/10.1007/978-981-10-3713-9_1

Zedalis, R. J., & Wade, C. L. (1978). Anti-Satellite Weapons and the Outer Space Treaty of 1967. *California Western International Law Journal, 8,* 454-466.