Legal Challenges and Responses on Construction and Operation of Small Satellite Constellation

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Abstract

The rise of small satellite constellations in Low Earth orbit (LEO) to transmit high-speed Internet to all parts of the world is a relatively new development in the use of outer space. However, it also brings legal issues at the same time. Because, presently, there is a lack of legal binding with regards to the proliferation of space debris, the increased risks of orbital collision, the satellite network service, and the rational, efficient, and economical use of radio-frequency spectrum and the various orbital slots used by those small satellite constellations in LEO. The primary purpose of the research is to analyze the legal challenges posed by the proliferation of small satellite constellations in LEO and propose the legal regimes dealing with those challenges. It is based on documentary research relating to those issues. The research comes up with the appropriate international legal framework, which is the current international space law regime is facing challenges, i.e., Space Traffic Management (STM), Active Debris Removal (ADR). As well as legal regimes to regulate the satellite network service and to manage orbital slot and radio frequency in LEO.

Keywords: Small Satellite Constellation; Legal Challenges; Long-Term Sustainability; Low Earth Orbit

Introduction

The proliferation of small satellite constellations in Low Earth Orbit (LEO) to provide high-speed Internet to all areas of the world is unprecedented. States, international intergovernmental organizations, and private companies worldwide plan to deploy small satellites into Earth orbit (Morssink, 2019). Due to the fact that it is inexpensive and expandable, especially in the area of commercial activities (Nair, 2019). For instance, recently, in March 2018, the US Federal Communication Commission (FCC) just approved SpaceX's application to launch 4,425 LEO satellites, and these satellites are the first phase of nearly 42,000 satellites envisaged. Besides the SpaceX company's application, many private companies are also planning to launch small satellites' mega-constellations shortly. For example, OneWeb with 2,720 satellites, Amazon with 3,236 satellites and Samsung with 4,600 satellites. Furthermore, Norway has recently registered 4,257 satellites for its steamed network with the International Telecommunication Union (ITU), with Canada and France also registering 794 and 4,000 satellites, respectively (Nair, 2019).

Considering this advanced space technology, the difference between large and small satellite has become harder to identify. At present, this issue is still controversial and debatable. Therefore, there are many ways to define a small satellite's meaning to differentiate them from the larger, less modern satellites. The most accepted definition, given by The International Academy of Astronautics (IAA) through the IAA study of Earth observation satellites, categorizes small satellites into four groups, relying on their mass to define their classification. These four groups are Mini satellites, Microsatellites, Nanosatellites, and Pico satellites. Mini satellites are limited between the weight of less than 1000 kg to 100 kg, Microsatellites being less than 100 kg to 10 kg, Nanosatellites being less than 10 kg to 1 kg, and Pico satellites being less than 1 kg (Ram Sarup Jakhu & Pelton, 2014). Furthermore, in terms of the radio frequency assignment, ITU Radiocommunication Sector (ITU-R) has considered any satellite that weighs less than 500 kg a 'minisatellite' (Koudelka, 2016). Notably, all definitions that IAA and ITU-R give are based on their mass alone, regardless of their maneuverability, shape, or other features.

Technically, a satellite refers to any object that orbits another larger object in space, like the Earth orbiting the sun. However, when we are talking about satellites, we usually think about artificial satellites. The first artificial satellite, launched into Space in October 1957, was called Sputnik (Tronchetti, 2013), and it was about the size of a beach ball. Sputnik signaled the beginning of the space race. And since then, we have been launching more and more objects into orbit. Companies such as SpaceX, Amazon, Telesat and OneWeb want to launch thousands of satellites to make what they call mega-constellations which is a network with hundreds or even thousands of small satellites all orbiting and working together in a complete system (Ravishankar et al., 2021). The states' motivations, international organizations, and private companies have small satellite constellations come down to two main reasons. Firstly, these satellites' hardware costs have decreased dramatically, and secondly, the demand for internet connectivity all over the world has been increasing exponentially (Dornik & Smith, 2016). Therefore, it has become more valuable for these entities mentioned before, providing high-speed internet at the low price that currently exists. Most internet satellites nowadays operate in Geostationary Earth orbit (GEO), around 35,786 kilometers above the Earth's surface (Wittig, 2009). They remain fixed on top of one area, but the small satellite constellation that SpaceX, OneWeb, Amazon, and Samsung, are proposing that will operate what is called "Low Earth orbit" (LEO) or between 180 to 2,000 kilometers above Earth's surface (Nair, 2019). In theory, this should cut down on the latency issues, with speeds up 20 times faster than current GEO satellites (Handley, 2019). A small satellite constellation's construction and operation can carry the excellent opportunity to connect the world altogether. However, it could also cause legal issues such as potential orbital collision, space debris, satellite network service, radio spectrum and orbital slot allocation

Objectives

1. To Develop an international rule on space traffic management (STM) to deal with the potential collision in orbit
2. To develop an international legal framework for Active Debris Removal (ADR) to deal with the overcrowded space debris
3. To establish a legal regime regulating satellite network service to deal with the supervision on internet access and cybersecurity of the local government

4. To establish the specific legal regime for orbital slots and radio frequencies management in the Low Earth Orbit to deal with the scarcity of radio frequencies and orbital slots soon

Concept theory framework

1. Orbital collisions

The potential collision to the other satellites which already existed in the outer space will be much higher because of the large number of small satellite constellation in LEO, and they will possibly be endangering the safety of other space missions and sustainability of space activities in general. In scientific literature, the risk of collision in an overcrowded LEO. This summarized by a theory called the Kessler Syndrome, which means when two objects collide in space, they generate more debris, and those debris will be colliding with other objects, creating even more shrapnel and litter until the entirety of Earth's orbit (Degrange, 2019). This hypothetical scenario came to life in February of 2009 when an inactive Russian communications satellite Cosmos 2251 collided with an active commercial communication satellite operated by the U.S. based Iridium Satellite. The incident produced around 2,000 pieces of debris (Larsen, 2017) etc.

2. Space debris

Space debris issues would be concerned because of the proliferation of space debris produced by increasing the use of outer space by the community of nations. This population, comprising non- operational spacecraft, derelict launch vehicle upper stages, mission-related objects, and fragments from satellites and orbital stages, without any means of control, this debris could pose a risk of colliding the operational satellites. The expected launching of small satellite constellation into low earth orbit will further the amount of space debris because those small satellites generally have a short lifetime.

3. The satellite network service

When the small satellite constellations are settled and functioned, the traditional firewall system could not work anymore. Furthermore, the satellite network could cover anywhere in the world, and foreign network providers are able to provide transnational network services freely. So, it is difficult for local governments to regulate the internet access and cybersecurity of their citizen. Moreover, It is also considered that the transmission of Internet signals to a foreign country without its permission constitutes a harmful interference with the telecommunications of the receiving country and is therefore prohibited by the ITU laws and regulations (Joel R Paul, 1985).

4. Radiofrequency and Orbital slot allocation

All satellites in outer space need to use the radio frequency to communicate with the earth station, but the orbital slot and spectrum are limited (Morssink, 2019). The rising numbers of launching small satellite constellations could lead congestion in the useful orbit and increased potential for conflict over frequency bands because the radiofrequency is perceived as a scarce resource, there is a risk of a shortage of spectrum when more and more satellites are launched, the scarcity of frequencies will increase as well. Moreover, many satellite operators are currently planning to deploy small satellite constellations for broadband communication service in the Ku-, Ka-, and V-band, where some of them have already started launching. Consequently, new challenges are expected for increased potential harmful interference with the existing satellites in Earth's orbit (Braun, Voicu, Simić, & Mähönen, 2019).

Materials and Methods

This research is based on documentary research, e.g., international laws, national laws, and regulations, research papers, books, articles, treaties, etc. which are relating to the construction and operation of the small satellite constellation.

Results

This research come up with the appropriate international legal framework to deal with the construction and operation of small satellite constellation, which is the current international space law regime is facing challenges to deal with this new space activity. There are four legal proposals as following:

1. Developing international rules on space traffic management (STM) to deal with the potential collision in orbit

There are multiple constellations, each with thousands of satellites being proposed to provide global broadband internet services (Tonkin & De Vries, 2018), both the constellation owners and other LEO operators will have to deal with increasing numbers of the potential collisions. Space Traffic Management (STM) system will have to take this new space activity into consideration. It is necessary for the international community to establish the data information sharing and code of conduct, which are consisting of rules on launching safety, rules on human spaceflight safety, rules on orbital prevention area, and rules on operation on orbit.

2. Developing an international legal framework for Active Debris Removal (ADR) to deal with the overcrowded space debris

Increasingly more space debris would be produced by the numerous launching of the small satellite constellation. Therefore, the current space law regime and guidelines of space debris mitigation might not be enough to deal with this problem, and it is time to establish international legal regimes on active debris removal (ADR). The ADR should establish a certain committee and fund for debris removal, and the committee has the authority to identify space debris, decide whether to remove certain space debris, and responsible for the damage caused by removal, etc.

3. Establishing a legal regime regulating satellite network service to deal with the regulation on internet access and cybersecurity of the local government

This form of small satellite constellation raises questions of national sovereignty, cultural independence, and free flow of information. It should be regulated by the new legal regime on satellites network, and this legal regime should establish the rights and obligations among users, states, and providers of service. This kind of problem is similar to the problem of direct television broadcasting from artificial satellites. Therefore, it might be possible to use the Principles Governing the Use by States of Artificial Earth Satellites for International Direct Television Broadcasting, adopted in 1982 (Resolution 37/92) as a model to establish the legal regime of the satellite network.

In case of cybersecurity, it should use the Paris Call for Trust and Security in Cyberspace, Digital Geneva Convention, Cybersecurity Tech Accord, and Charter of Trust for a Secure Digital, as a model to establish the legal regime to deal with the problems.

4. Establishing the specific legal regime for orbital slot and spectrum management in the LEO to deal with the scarcity of radio frequencies and orbital slots soon

There exists a need for declaring LEO as Limited Natural Resource and standardization of regulations all over the world to avoid the chaos, keep all players on board, and simplify procedures specifically in the context of small satellite constellation because the purpose of the mega-constellations is also to use frequency bands and the orbit slots for the same general purpose of communications (Ram S Jakhu, 2017). In keeping with the need of the present times as also the principle of rational, efficient, and economical use, the existing provision could be extended to include LEO.

Conclusions and Discussion

1. The legal challenge of the potential satellite collision

When the small satellite constellations are launched, the potential collision to the other satellites existing in outer space will be much higher. Theoretically, there is the possibility of a massive collision in low Earth orbit, namely the "Kessler Syndrome." In 1978, the NASA scientist, Donald J. Kessler, envisaged that low Earth orbit in the future would be overcrowded and possibly cause a collision. Each collision will generate more space debris that will cascade into the Earth (Kessler, Johnson, Liou, & Matney, 2010). Recently, there was a reported accidental collision in low Earth orbit between the Iridium 33 and defunct Russian satellite Cosmos 2251, which alerted the world to the sustainability of peaceful operations in Outer Space (Ram S Jakhu, 2010). In collision avoidance, the Outer Space Treaty (OST) article IX laid down that States parties to the treaty shall be guided by the principle of cooperation and mutual assistance. Moreover, conducting all their activities in outer space, regarding all other State parties' corresponding interests to the treaty. However, the language of the OST is quite general and ambiguous. There is a lack of specific details to cope with orbital collision avoidance. It only deals with the result of damage caused by the space object.

Notably, all rights and obligations for large satellites are practically applicable to small satellites as well because there is no distinction between small and large satellites in the current space law regime (Mosteshar, MARBOE, & chances, 2016). It is evident that, when the Outer Space Treaty was signed, no legal challenges were ever anticipated in this construction and operation of small satellite constellations in LEO. Therefore, all types of satellites are recognized as space objects regulated by the two major international space law treaties, relevant to the damage caused by space activities, such as the 1967 Outer Space Treaty and the 1972 Liability Convention. A State party has the option to bring a claim for compensation under any of these treaties if any other State party causes damage. It is necessary to take into consideration that all damage liability is recoverable. To this point, Article VII of the Outer Space Treaty laid down that the launching State shall be held internationally liable for damage caused by their space objects, either on the Earth, in the airspace, or outer space. Along with Article II of the 1972 Liability Convention reiterates that a launching State shall be held responsible for all reparations and compensation associated with the damage caused. This includes space object on the surface of the Earth or aircraft in flight and clarifies "launching State" in Article I to "a State which launches or procures the launching of a space object or a State from whose territory or facility a space object is launched."

Besides, Article VI of the OST stipulates that States parties to the treaty shall have international responsibility for national outer space operations, whether government agencies or non-governmental bodies carry out those activities. The operations of non-governmental entities in outer space, shall entail the authorization and continued supervision of the relevant State Party. Therefore, the State Parties to the treaty shall be responsible for all actions carried out by an international organization in which the State participates. Notably, the treaty neither sets limits on the amount of liability nor specifies the term damage. However, the definition of the word 'Damage' is laid down in the 1972 Liability Convention Article I (a), “which means loss of life, personal injury or other damage to health; or loss of or damage to property of States or persons, whether a natural or legal person or property of international intergovernmental organizations.”

2. Small Satellite Constellations and Orbital Space Debris

The advent of the space-age, more than 10,596 satellites have been launched into Earth's orbit (UNOOSA, 2021), of which about 3,372 are still operational (Grimwood, 2021). However, in a few years, that amount could rise dramatically, according to SpaceX's proposal to launch 42,000 satellites as part of its Starlink Internet initiative (Massey, Lucatello, & Benvenuti, 2020). If this continues, SpaceX alone will be responsible for a fivefold rise in the number of spacecrafts deployed by all humans. However, the primary concern is debris. This is summarized by a theory called the Kessler Syndrome, which posits that when two objects collide in space, they generate more debris that collides with other space objects, creating even more shrapnel and litter until the entirety of Earth's lower orbit is impassible.

Space debris' proliferation is a significant concern due to increasing outer space use by spacefaring nations and their non-organization entities. According to the NASA database, more than 500,000 pieces of debris are being tracked when they orbit the Earth (Force & Law., 2016). NASA also warns that many millions of debris cannot be tracked because they are not large enough to be tracked by conventional methods (Garcia, 2013). Consequently, this debris could pose a collision risk to other operational satellites.

The increase of space debris in low Earth orbit by the launch of small satellite constellations has been envisaged due to those satellites having a short average lifespan of 3 to 5 years. They will become debris in space. Presently, there is no international formal definition of "space debris". Nonetheless, this term has exponentially increased in use in discussion with UNCOPUOS, especially a Technical Report on Space Debris (1999) by the Scientific and Technical Subcommittee of the UNCOPUOS, which uses the definition as follows (Wright, 2019):

> *"All man-made objects, including their fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional."*

The main issue that stems from small satellite constellations is that they will cause a dramatic increase in space debris in the future if the law remains unchanged. Currently, there is no hard law neither in the form of an international treaty nor any other global framework that aims to deal with this anticipated problem. The existing international law regimes, specifically the 1967 Outer Space Treaty and the 1972 Liability Convention, only deal with the consequences when debris causes any damage. They, however, do not consider the generation of defunct space debris.

3. The satellite network service

When the small satellite constellations are settled and functional, the traditional firewall systems will be ineffectual due to most internet connections nowadays existing in a submarine fiber-optic cable network. This network connects the servers and internet providers of different countries and regions across stretches of oceans and seas. Unlike cable network, small satellite constellations operate in LEO, facilitating almost lightspeed data transfer in a space vacuum. Therefore, technically, small satellite constellations will become the direct internet service provider and bypass the firewall. Furthermore, the satellite network could cover anywhere globally, and foreign network providers can provide international network services freely. So, it is difficult for local governments to regulate the internet access of their citizen. Countries have typically regulated the flow of information across borders by restricting Internet access, censoring publications, restricting access to airwaves and controlling domestic printing and broadcasting (Paul & Rev., 1985). This legal issue is similar to direct television via satellite. Before 1982, there was the emergence of direct television via satellite, the so-called Direct Broadcast Satellite (DBS), which can reach home television audiences without the cooperation of ground stations under the receiving country's control. At that time, there was a fear that DBS would be abused to export western culture, ideology, and commercialism to less developed countries.

The issue of the free flow of information was raised in the General Assembly and discussed frequently. The Group of 77, composed mostly of less developed countries of the General Assembly, called for a New World Information Order (NWIO) to redirect the flow of news and information between rich and developing countries. The NWIO is generally linked to three principles as follows (Paul & Rev., 1985):

(1) Developed countries should provide resources to improve their national news media infrastructure so that less developed countries can compete with news media from developed countries.

(2) An international code of professional responsibility should apply to the activities of foreign journalists.

(3) International news and information should be subject to some form of censorship in order to protect countries from defamatory statements that interfere with domestic or foreign policy and from reporting that is culturally or ideologically biased.

The DBS discussion came to an end in 1982 when the United Nations General Assembly adopted a resolution on direct television broadcasting, namely 'Principles for the Use of States of Artificial Earth Satellites for International Direct Television Broadcasting' (hereinafter 'The 1982 Resolution'). The 1982 Resolution contains ten principles which are entitled Purposes and Objectives, Applicability of International Law, Rights and Benefits, International Co-operation, Peaceful Settlement of Disputes, State Responsibility, Duty and Right to Consult, Copyright and Neighboring Rights, Notification to the United Nations and Consultations and Agreements between States (Lesko & L., 1976).

Nevertheless, there is still a lack of an international regime that governs small satellite constellations for providing internet access to all areas of the world, when the traditional firewall could not filter the free flow of content from the Internet anymore. It could raise concerns about sensitive information and national security contents of the receiving countries, for example, pornography, racism and incitement to war. It is also considered that the transmission of Internet signals to a foreign country without its permission constitutes a harmful interference with the telecommunications of the receiving country and is therefore prohibited by the ITU laws and regulations.

4. Radiofrequency and Orbital Slot Allocation

All satellites in outer space need to use radio frequencies to communicate with the earth station, but the orbital slots and spectrum are limited. It calculated that about 30,000 small satellites could operate in the low earth orbit (Shouping, 2019). Apart from the environmental considerations that need to be considered, these increasing numbers could lead to congestion in useful orbits and an increased potential for conflict over frequency bands. Because radio frequency is perceived as a limited resource, there is a risk of frequency shortages when more and more satellites are launched, and the frequency scarcity will increase as well (Morssink, 2019). The challenges are increasingly evident with each mega-constellation launch, and the existing resources of the ITU are under-equipped to address these issues.

Under Article I of the Constitution of the ITU, the objectives of the ITU are, among other things, as follows:

(a) Maintaining and extending international collaboration between all states parties in maintaining and ensuring reasonable use of telecommunications,

(b) To promote the advancement of technological infrastructure and their most useful application to improve the efficiency of telecommunications networks by increasing their utility, and

(c) To promote a broader approach to telecommunications problems in the global information economy and culture through collaboration with other international and regional intergovernmental and non-governmental organizations dealing with telecommunications.

ITU is responsible for allocating radio frequency bands and monitoring radio frequency allocations with these objectives in mind. In this case, its purpose is to prevent dangerous interference between radio stations in different countries. One of the ITU resolutions notes that the ITU Radiocommunication sector must ensure the rational, equitable, efficient and economical use of radio frequency spectrum by all radiocommunication services, including those using satellite orbits. This research will separately analyze three topics as the following:

4.1 The Principle of Equitable Access

The ITU also adopted the concept of equitable access, and this is the presumption that each country should have the right to have access to space at all times (Copiz, 2001). This concept is part of Article 44 (2) of the ITU Convention. It refers explicitly to the GEO. Since the ITU started to allocate orbital slots and spectrum, problems emerged with the first-come, first-served approach. By the time those developing countries were able to build the advanced technologies needed to construct and launch satellites, the GEO would have been overcrowded at the ITU and overcrowded in space (Cappella, 2019). The special status of the GEO was embedded in Article 44 (2) of the ITU Constitution. All member states must understand that the spectrum of radio frequencies and satellite orbits, including GEO, are limited natural resources that must be used nationally, efficiently, and economically according to the ITU Constitution. Additionally, the Preamble to the Radio Regulations identifies the same principles. Curiously, Article 44 (2) has been interpreted saying that "the efficient and economical use of orbits is a prerequisite for achieving the ultimate aim of equitable access."

However, non-geostationary Earth orbit (NGSO) satellites, particularly LEO satellites, are not governed by the idea of an equitable access principle, but rather, these orbits and related radio frequencies and orbital slots are being allocated on a first-come, first-served basis. The emergence of a small satellite constellation in the LEO would also give rise to similar concerns.

4.2 The current allocation mechanism

The rights and obligations of the ITU Member States in the field of international spectrum/orbit resource management are incorporated in the Constitution (CS) and the ITU Convention (CV), and the Radio Regulations (RR), which complement them. These international instruments consist of the basic principles and lay down the fundamental regulating as the following essential elements (I. UNOOSA, 2015):

(1) Allocation of the radio frequencies to various types of radiocommunication services;

(2) The rights and obligations of the member states to have access to the spectrum/orbit resource;

(3) International recognition of these rights by recording frequency assignments and any related obits, including geostationary satellite orbits used or planned for use in the Master International Frequency Register (MIFR).

The ultimate purpose of the ITU RR Regulations is to maintain a non-interference environment for the service of the satellite network while at the same time ensuring rational, equitable, efficient and economical use of radio frequency spectrum and satellite orbit resources. The procedure for organizing the use of frequencies is laid down in the ITU Radio Regulation ('RR') and consists, in short, of the following step (I. UNOOSA, 2015):

a) Advance public information (API);
b) Coordination with other States;
c) Notification and recording of the specific frequencies in the Master International Frequency Register (MIFR)

This requires that all radio frequency usages obtain international recognition. If a government or non-government entity plans to launch a satellite, they should consult the MIFR prior to choosing a frequency. The administration will typically give the API to the ITU for geostationary and non-geostationary satellites no earlier than seven years. No later than two years before the scheduled date of entry into the network's operation or system. The ITU shall cancel any frequency assignment that is not placed into service during the time needed after it has been reported to the administration at least three months before the expiration of that period. This is according to the ITU goals to ensure optimal use and equitable access. However, the number of satellites in non-geostationary orbits (NGSOs) is forecast to grow dramatically (Tonkin & De Vries, 2018). Because there is an ongoing demand for broadband services, many satellite operators are currently planning to deploy small satellite constellations for broadband communication service in the Ku-, Ka-, and V-band, where some of them have already started launching. Consequently, new challenges are expected for increased potential harmful interference with the existing satellites in Earth's orbit (Braun et al., 2019).

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