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Satellite Mega Constellations: Conflict between Freedom of Exploration and Unsustainable Outer Space Activities

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Abstract: *In the era of space commercialization, the State is no longer the sole actor in international space activities; private companies such as SpaceX and OneWeb are now playing huge roles in these endeavors. The Mega constellation of satellites is devised by these private companies to provide low-cost and low-latency internet services to remote areas. This large-scale deployment is a network of a large number of satellites. Even though this connectivity venture is guaranteed under the freedom of exploration principle of the law of outer space, it is potentially hazardous in terms of problems connected with the accumulation of space debris and interference with astronomy research. Additionally, the legal vacuum concerning these issues is an area of great concern. This research has employed normative juridical research methods along with statutory and conceptual approaches. This study will examine the limits and scope of the principle of freedom of exploration and assess the urgency of ensuring the sustainability of mega constellation satellite projects. Through these examinations, the research aims to present the case for a robust space governance as a part of sustainable development practices.*

Keywords: *freedom of exploration; sustainability; mega constellations satellite, outer space, internet connectivity*

I. Introduction

Nicolas Peter has classified the evolution of space activity into four stages. Before World War II, the period was referred as the "Proto-space age" occurred. This era was characterized by the development of rocket and astronautics technology, which was spearheaded by Robert H. Goddard, Herman Julius Oberth, and Konstantin Tsiolkovsky, among others.[1] A decade after the end of World War II, outer space was no longer a

[1] Nicolas Peter, "Towards a New Inspiring Era of Collaborative Space Exploration," in *Humans in Outer Space - Interdisciplinary Odysseys*, ed. Luca Codignola and Kau-Uwe Schrogly (Wien: Springer, 2009), 107–18.

difficult-to-reach area for humans. In the 1950s, countries have competed to send their representatives into space.

This post-world war phase of space exploration is referred as "Space Exploration 1.0." At this stage, the competition between the United States and the Soviet Union in space exploration activities were the primary focus of international media (Peter, 2009).[2] During this era of "space race," numerous monumental space exploration events occurred, including the launch of the Sputnik satellite in 1957,[3] Yuri Gagarin's flight into space in 1961, [4] and Apollo 11's historic landing on the Moon in 1969.[5] During this time, the previous lack of international cooperation has disappeared, bringing significant development to all participating countries.[6] During this stage, the deployment of satellites into the earth's orbit was a major advancement in space technology. Since the first satellite launch, over 1,500 satellites have been placed on earth's orbits for commercial, military, weather, and research purposes. About 40% of the satellites are owned by the United States, 13% by China, 10% by Russia, 3% by the United Kingdom as well as India, and 29% by other nations.[7]

During the Cold War between the United States and the Soviet Union, each nation tried to prove its technological superiority in space exploration. In 1991, at the end of the Cold War, the competing nations agreed to cooperate and built the International Space Station along with other countries. This collaboration paved the way for advanced economies to engage in space business enterprises. In the second stage of space exploration, also known as "Space Exploration 2.0," space is filled not only by the two dominant powers but also by many new actors, such as the European Space Agency (ESA) and other national space agencies.[8] This period commenced in 1991 and concluded in 2015. This stage of space exploration is marked by the increasing number of bilateral and multilateral agreements between space agencies, which laid the groundwork for the internationalization of space activities.[9] The establishment of the International Space Station (ISS) as a joint project between the United States (NASA), Russia (Roskosmos), Japan (JAXA), Canada (CSA), and Europe (ESA) was important markers of the globalization of space explorations. With an expanding space economy, private investments and companies came into the picture, and thus, the government is no longer the only regulatory body involved in space exploration.

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2 *Ibid.*

3 Peter Jankowitsch, "The Background and History of Space Law," in *Handbook of Space Law*, ed. Frans von der Dunk and Fabio Tronchetti (Cheltenham: Edward Elgar Publishing Ltd., 2015), 1–28, https://doi.org/10.4337/9781781000366.

4 Elya Taichman, "The Artemis Accords: Employing Space Diplomacy to De-Escalate a National Security Threat and Promote Space Commercialization," *American University Security Law Brief* 11, no. 2 (2021): 111–46, https://www.cfr.org/backgrounder/space-exploration-and-us-competitiveness.

5 Frans Von der Dunk, "Legal Aspects of Private Manned Spaceflights," in *Handbook of Space Law*, ed. Frans von der Dunk and Fabio Tronchetti (Cheltenham: Edward Elgar Publishing Ltd., 2015), 662–716, https://doi.org/10.4337/9781781000366.

6 Nicolas Peter, "The Changing Geopolitics of Space Activities," *Space Policy* 22, no. 2 (May 2006): 100–109, https://doi.org/10.1016/j.spacepol.2006.02.007.

7 George Barakos and Helmut Mischo, "Space Mining Is the Industry of the Future ... or Maybe the Present?," *Moon Mining*, February 2020, https://www.researchgate.net/publication/339627406.

8 Peter, "The Changing Geopolitics of Space Activities."

9 Peter, "Towards a New Inspiring Era of Collaborative Space Exploration."

With the advancement of technology, a substantial part of the world's population is now the consumer of satellite-based communications, weather forecasting, remote sensing, global positioning, and broadcasting.[10] So, space exploration is no longer solely motivated by the establishment of political supremacy; it has now become an important part of the world's economy. This is the defining feature of "Space Exploration 3.0" in which the economic potential of space exploration activities will increasingly become the impetus for its long-term plans.[11]

This enormous economic potential has prompted numerous private companies, comprising SpaceX, Blue Origin, Virgin Galactic, Amazon, OneWeb, andSamsung, among others, to invest in space activities. SpaceX, a company founded by Elon Musk, has a wide range of business goals through harnessing space technologies. SpaceX has talked about its plan to "colonize" Mars and launch thousands of satellites in low earth orbit (LEO) via Starlink satellite technology.

Starlink is a mega *constellation* of satellite network operated by SpaceX. The Starlink mega *constellation* is comprised of small satellites (227 kg/500 lb) designed to provide low-latency and low-cost internet services to remote and unreachable areas.[12] The Starlink satellite mega constellation is meant to provide internet access to remote and hard-to-reach areas at a lower cost. Due to the low earth orbit deployment of the satellites, they can rapidly carry large amounts of data at any point on the earth, and thus, saving us the hard and cumbersome task of laying fiber-optic cables. Starlink is, thus, viewed as a profitable as well as a humanistic endeavor.

The Starlink constellation started with a network of 60 satellites orbiting at 335 to 354 miles from the earth's surface. In recent months, the Starlink network of satellites counts around 4,487, according to the data submitted by SpaceX to the United States government. 1600 satellites at 1,110 kilometers, 400 satellites at 1,130 kilometers, 375 satellites at 1275 kilometers, and 450 satellites at 1325 kilometers were deployed in this mega constellation. According to an agreement with the Federal Communication Commission (FCC)[13], SpaceX has planned to launch a total of 12,000 satellites in two batches. In the first batch, Starlink intends to place 4,409 satellites, and in the second one, 7,518 satellites. SpaceX has launched around 4,400 satellites as of March 2023, and this number will continue to increase as SpaceX intends to launch 42,000 satellites in the future and conducts studies to comply with FCC licensing requirements.[14]

OneWeb and Amazon are two other private companies involved in the satellite mega constellation project. Amazon's Kuiper system will launch 3236 satellites and OneWeb's 2000 satellites; both will be LEO satellites.

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[10] Ricky Lee, *Law and Regulation of Commercial Mining of Minerals in Outer Space* (Heidelberg: Springer, 2012), http://www.springer.com/series/6573.

[11] Peter, "Towards a New Inspiring Era of Collaborative Space Exploration."

[12] Christopher D. Johnson, "The Legal Status of MegaLEO Constellations and Concerns About Appropriation of Large Swaths of Earth Orbit," in *Handbook of Small Satellites*, ed. Joseph N.Pelton and Scott Madry (Springer International Publishing, 2020), 1–22, https://doi.org/10.1007/978-3-030-20707-6_95-1.

[13] *Ibid.*

[14] Przemek Mróz et al., "Impact of the SpaceX Starlink Satellites on the Zwicky Transient Facility Survey Observations," *The Astrophysical Journal Letters* 924, no. 2 (January 1, 2022): L30, https://doi.org/10.3847/2041-8213/ac470a.

These activities do not violate the applicable international space law and regulations.[15]

According to the Space Treaty of 1967, nations are free to conduct space exploration. Members of the Space Treaty are permitted in Article 1 to access, explore, and utilize outer space, including the Moon and other celestial bodies. The Article 1 states, "Outer space, including the Moon and other celestial bodies, shall be free for exploration and use by all states, on the basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies."

The article makes it clear that states are free to access and conduct space exploration[16] but they must comply with all rights, obligations, and prohibitions outlined in applicable international law.

However, since the launch of Starlink's mega constellation of satellites, criticism has been rife, especially about its environmental impact. Since May 2019, when SpaceX launched its first batch of satellites, astronomy researchers and scientists have been concerned about the interference of these satellites with their observations.[17]. Indonesia has four observatories located in Bandung, Jakarta, Tenggarong, and Timau.[18] In addition to the perceived astronomical impact, it is feared that increased crowding in space and the consequent space debris can cause pressure on the orbits and cause collisions and other hazards.

Space debris is a general term referring to all tangible human-made materials in space other than functional space objects.[19] The ESA estimated that in January 2021, around 34,000 debris greater than 10 cm, around 900,000 debris between 1 cm and 10 cm, and around 128 million debris within 1 mm to 1 cm of dimension are floating in the earth's orbit.[20] Along with the presence of debris, so many satellites are crowding at the same altitude that the chances of collisions have increased in spite of the presence of risk mitigation systems. Also, new technologies are being developed to remove space debris. Electro Optic Systems (EOS) is an Australian company that uses an observatory-based laser-emitting devices to track and "move" debris away from the pathways of satellites and other space assets. The EOS laser system is one of the "active debris removal" (ADR) technologies where net, robotic arm, spear, magnet, and foam are utilized to de-orbit space debris. Debris removal through nets, similar to the operation of fishnets. A net gets thrown at a piece of debris to get it wrapped and dragged away from its orbit. Tethers are also used to pull away space debris.[21]

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15 Jonathan C. McDowell, "The Low Earth Orbit Satellite Population and Impacts of the SpaceX Starlink Constellation," *The Astrophysical Journal* 892, no. 2 (April 6, 2020): 1–10, https://doi.org/10.3847/2041-8213/ab8016.

16 Stephan Hobe, Bernhard Schmidt-Tedd, and Kai-Uwe Schrogl, eds. *Cologne Commentary on Space Law: Outer Space Treaty*. Vol. 1. BWV Verlag, 2017.

17 *Ibid.*

18 A. G. Admiranto et al., "Preliminary Report of Light Pollution in Indonesia Based on Sky Quality Observation," in *Journal of Physics: Conference Series*, vol. 1231 (Institute of Physics Publishing, 2019), https://doi.org/10.1088/1742-6596/1231/1/012017.

19 Zhong-Ping Zhang, Fu-Min Yang, Hai-Feng Zhang, Zhi-Bo Wu, Ju-Ping Chen, Pu Li, and Wen-Dong Meng. "The use of laser ranging to measure space debris." *Research in Astronomy and Astrophysics* 12, no. 2 (2012): 212.

20 Hugh Lewis, Jonas Radtke, Alessandro Rossi, James Beck, Michael Oswald, Pamela Anderson, Benjamin Bastida Virgili, and Holger Krag. "Sensitivity of the space debris environment to large constellations and small satellites." *Journal of the British Interplanetary Society* 70, no. 2-4 (2017): 105-117.

21 Jason L. Forshaw, Guglielmo S. Aglietti, Thierry Salmon, Ingo Retat, Mark Roe, Christopher Burgess, Thomas Chabot et al. "Final payload test results for the RemoveDebris active debris

Though, from time to time, debris get pulled away from orbits of satellites and other space assets, collisions between these debris are a greater concern. This scenario is known as the Cascade Effect (Kessler Syndrome), where the amount of space debris become so high that they will be constantly colliding with each other, and through breaking up, more small debris are produced. Eventually a "debris belt" would form around the earth and become a permanent danger and hindrance for space accessibility.[22] In the 1980s, the U.S. National Space Policy prescribed minimizing the creation of orbital space debris. Where also in future plans the parties involved can prioritize debris removal by removing the larger debris first because larger space debris contributes more to the occurrence of the Kessler Syndrome.

The greater the number of satellites at the same altitude, more is the likelihood of collisions between satellites, other space assets, and debris. LEO, which is at a height of approximately 2000 kilometers above the earth's surface, is more prone to collisions.

Considering the loophole in the freedom of exploration principle and the laws that regulate space explorations, global space governance is essential for environmental protection and sustainable development practices. This study aims to examine this gap by looking into the scope and limitation of the freedom of exploration principle and finding appropriate measures that can be adopted by the international community in order to minimize the negative impacts from the launches of mega constellations satellite in low earth orbit.

II. Legal Materials and Methods

This study employs normative juridical methodology, in which legal analyses are based on applicable laws and regulations (law in books), or law is conceptualized as rules or norms, which are standards for acceptable human behavior. This study will analyze the principle of freedom of exploration in the context of the satellite mega constellation. Through research of national and international laws in books, journals and news articles, and other documents, the greatest extent possible knowledge and information were gathered for this study.

III. Result and Discussion

The Scope and Limitation of Freedom of Exploration

The principle of freedom of exploration is one of the basic principles in the Outer Space Treaty. In addition to the non-appropriation principle, the freedom of exploration principle is also a basic norm (*grundnorm)* in the 1967 Outer Space Treaty, which was unanimously accepted by UN member countries. Article 1 paragraph 2 of the Outer Space Treaty of 1967 regulates the principle of freedom of exploration by stating, "Outer space, including the Moon and other celestial bodies, shall be free for exploration and use by all states without discrimination of any kind, on the basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies." It has been clearly stated that outer space, the Moon, and other space objects are

removal mission." *Acta Astronautica* 138 (2017): 326-342.

[22] Bohumil Doboš, and Jakub Pražák. "Master spoiler: a strategic value of Kessler Syndrome." *Defence Studies* 22, no. 1 (2022): 123-137.

free to be explored and used by all countries, abiding by the rules of international law and the values of equality. Now, a question arises about how the scope of the freedom of exploration is regulated. Does "freedom of exploration" mean any space activities are allowed, or does a limit to the freedom of exploration exist?

Another question relating to scope is whether or not "activities" are required for all explorations and uses. When it comes to "exploration and use," Article III of the Treaty refers to "activities in the exploration and use." This addition of a term creates confusion about the difference in meanings, if any, and if so, how they should be differentiated. For example, what could be the variations in the import of "exploration and use," must be done "for the benefit and in the interests of all countries," "without any discrimination of any kind," "on the basis of equality," and "activities in the exploration and use" must be done "in the interest of maintaining international peace and security and promoting global cooperation."

Are positive and negative connotations attached to the word "activities"? If you do something inappropriate, does it count as a negative "act"? Could an "omission" be considered a negative "act" if it falls under the definition of a negative "act?" It's impossible to argue that the word "activity" has a negative connotation if Article III is read as requiring all parties to engage in exploration and use activities. However, since such an interpretation could logically not find much support, the issue of viewing activities negatively would still be present.[23] It appears that exploration and use are not activities that should be viewed as negative. Without positive activity, how can we explore and use the term "activity" in a meaningful way? Exploration and use, by their very definitions, seem to imply some sort of activity or a set of activities. This would imply that the drafters of the treaty lacked precision or made a distinction that was almost meaningless. Although "activities" may have been intended to cover the various individual sequences of actions that go into producing the total results, exploration and use may have been intended to cover the total human effort or result involved. From these interpretations, it may be concluded that the drafters may not have meant to refer to the entire treaty but to the individual articles.[24]

Turning to the question, how does this article regulate the scope of freedom of exploration? Gorove and Radhey have a similar understanding of the limitations on the freedom of exploration. Gorove argues that the freedom of exploration is a general principle outlined in Article 1 of the 1967 OST. This principle has two limitations in its implementation, namely, general and specific limitations. General restrictions imply that freedom of space exploration must bring benefits and serve human interests., the prohibition of discrimination, the equality principle, and international law. The specific limitation on freedom of exploration is that military and potentially hazardous contamination-causing space exploration activities are prohibited.[25]

Moreover, Radhey [26] contends that the principle of freedom of exploration contained in Article 1 of the 1967 OST is constrained

[23] Stephen Gorove, "Freedom of Exploration and Use in the Outer Space Treaty: A Textual Analysis and Interpretation." *Denver Journal of International Law & Policy* 1, no. 1 (2020): 15.

[24] *Ibid.*

[25] *Ibid.*

[26] Radhey Soundarya Gnanesh, "A Tale of Two Planets in International Space Law: Limitations to

by three factors: common benefits and interests, freedom of access for all states, and the principle of non-appropriation. According to Radhey, "restrictions based on common benefit and interest" means that whether the countries are taking part in the activities or not, the benefits of space operations must be evenly distributed to all for the sake of human development. This clause is included to ensure that the benefits are fairly distributed among all countries of the world.[27] However, Hobe and Kai believe that Article 1 Paragraph 1 relating to common benefits and interests is intended only for countries and not for other parties (private, individuals, and NGOs).[28]

Apart from this exclusion of private entities and NGOs, space resource benefits are said to be equally shared by all State parties. This equitable sharing speaks of the non-discrimination principle, which emphasizes the prohibition of any kind of unfair distribution of space's natural resources.[29]

The final limitation on the freedom of exploration is the non-appropriation principle. To prevent nations from colonizing space, the freedom of space exploration is constrained by the principle of non-appropriation. Space colonization is closely related to claims of sovereignty over land or territories. [30] The prohibition of territorial claims and sovereignty in outer space can be found in the *travaux préparatoires* OST 1967, in a letter written by Arthur Goldberg[31], the permanent representative of the United States to the Chairman of the Committee on Peaceful Uses of Outer Space as well as in the statements made by the Belgian, Brazilian, and Australian delegations emphasizing the prohibition. [32] This principle is also employed to prevent military activities in the outer space.

According to Prof. Prayitna Abdurrasyid, the principle of freedom exploration entails that every nation is free to set up stations and install space assets to conduct experiments and to use celestial bodies in part or in whole.[33] If one looks further into Article 1 of the OST, they can find that the principle of freedom meant that every nation is equally free to conduct exploration activities in space, regardless of their level of economic and scientific development. From the statement that space is considered "the common heritage of mankind," it can be deduced that sovereignty cannot be claimed in space.

Mega Constellations of Satellites

Modern technological advancements provide fresh prospects for commercial success. With the advent of LEO satellites, fiber-optic-transoceanic cables, which provided intercontinental radio communications and continent-wide television broadcasts, were

the Freedom of Exploration and Use." In *Assessing a Mars Agreement Including Human Settlements*, pp. 167-180. Cham: Springer International Publishing, 2021.

27 *Ibid.*

28 Hobe, Stephan, Bernhard Schmidt-Tedd, and Kai-Uwe Schrogl, eds. *Cologne Commentary on Space Law: Outer Space Treaty*

29 Radhey Soundarya Gnanesh, "A Tale of Two Planets in International Space Law: Limitations to the Freedom of Exploration and Use."

30 *Ibid.*

31 Letter from Arthur Goldberg, Permanent Representative of the U.S., to the Chairman of the Comm. on the Peaceful Uses of Outer Space (June 16, 1966), http://www.unoosa.org/pdf/limited/c2/AC105_C2_L012E.pdf. Accessed 3rd February, 2023.

32 UNCOPOUS Legal Sub Committee (5th Session) 'Summary Record of Seventy First Meeting' (1966) U.N. Doc A/AC.105/C.2/SR.71 and Add 1.

33 Agus Pramono, "THE DIRECTION OF SPACE REGULATION IN GLOBAL DYNAMICS." *Diponegoro Law Review* 2, no. 2 (2017): 359-371.

rendered as a much lesser alternative. A satellite mega constellation is a network of human-made satellites operating to provide a vast span of global communications coverage., Despite the huge cost involved in these mega constellations of LEO satellites, their surprisingly beneficial functions are undeniable. The Iridium constellation was the first major effort to put a satellite-based telephone system for world-wide coverage. Technical problems coupled with unsuitable business ideas led to the failure of the Iridium constellation. The satellites were overpriced in comparison to the value they delivered, and the technology was still too nascent to make them accessible at an affordable price.[34]We are on the threshold of a new age. Over the past two decades, commercial providers have made great progress in reducing the costs of satellite launch, and developments in satellite and wireless communications have made it possible to construct a powerful and complex satellite at a low-cost. Similar advancements in computers and networks have facilitated control of an arbitrarily large constellation of satellites in LEO that behave like a static network of "cell towers in the sky." At present, it is a cutting-edge technology and with time, it will get more sophisticated and less expensive.[35]

Motorola built and operated the Iridium satellite constellation, the first of its kind, between 1997 and 2002. The launchers used vehicles imported from the United States, Russia, and China. Satellites were positioned in the constellation orbit at an altitude of 780 kilometers and at an inclination of 86.4°, for a global coverage. As cell phones became more affordable, Iridium was forced to file for bankruptcy. After emerging from the ruins of bankruptcy, the company now concentrates on niche markets and military customers who have a greater need for high-quality communications than the average consumer. Iridium-NEXT, a second-generation constellation, commenced construction in 2017 after a 15-year wait with no new launches.[36]

With 48 satellites, Globalstar is a constellation identical to Iridium has entered the market in 1999. In 2002, it filed for bankruptcy but recovered the losses and is still in business. Its satellites orbit at a 1400-kilometer altitude with a 52°- inclination. The 31 satellite constellation from Orbcomm is intended to provide industrial equipment with global low-bandwidth data connectivity. Orbcomm went bankrupt in 2000, but has since been restructured and is still providing service. In 2014, it has launched a second generation of OG2 satellites. Its satellites orbit at a height of 750 kilometers above the earth's surface with an inclination of 52°.[37]

Till date, more than 4000 satellites have been launched as part of the Starlink constellation operated by SpaceX. A final constellation size of up to 42,000 satellites has been approved by regulatory authorities. Currently, the highest altitude and inclination of the Starlink satellites are 550 km and 53°. However, the final configuration is likely to incorporate additional shells at various altitudes and inclinations. Recently, SpaceX has abandoned plans to fly its whole constellations at heights below 600 kilometers. The Starlink satellites' initial

[34] G. Long, "The Impacts of Large Constellations of Satellites." (2020).

[35] A. Venkatesan, Lowenthal, J., Prem, P., & Vidaurri, M, "The impact of satellite constellations on space as an ancestral global commons" *Nature Astronomy* Vol. 4, Issue 11, (2020): 1043–1048) https://doi.org/10.1038/s41550-020-01238-3

[36] G. Long, "The Impacts of Large Constellations of Satellites."

[37] *Ibid.*

satellite deployment at the specified latitude enraged the astronomy community.[38]

Subsequently, the first 74 satellites of OneWeb's 650-satellite network have been launched in 2020. Unlike SpaceX, OneWeb has chosen a height of 1200 km and an inclination of 88° for its satellites. Since atmospheric resistance is minimal at this height, satellites are far less likely to get destructed. Following the recent bankruptcy of its "phase 2" constellation, OneWeb has issued regulatory files indicating that it aims to eventually have up to 48,000 satellites.[39]

The Rwandan government submitted a proposal of two satellite constellations with a total of 337,322 LEO satellites to the International Telecommunication Union (ITU) in 2021. [40] The Canadian private company Kepler has also proposed to the ITU, the creation of a large satellite constellation consisting of nearly 115,000 satellites. In February 2023, the Chinese government submitted a plan of 13,000 satellites to the ITU in Geneva and is known to be aiming to achieve "a strategic position in the context of Starlink's capabilities". Known as the Guowang project, it is intended to serve as an internet satellite and "a new national infrastructure" for the Chinese government.[41]

The increasing number of companies and nations participating in the satellite constellation need to be accompanied by future-readiness of procedures, mechanisms, and legal instruments, so that their operations are performed with regularity and legal certainty. However, no internationally binding procedures and mechanisms related to the regulation of the launch and operation of mega constellation satellites are currently in place and no authority is particularly responsible to assess the environmental impact of these satellite constellation activities. ITU is only authorized to regulate the procedures and mechanisms for managing orbital slots in GEO (Geostationary orbit), so LEO remains unoccupied. Additionally, the ITU lacks the authority to conduct future studies on the environmental effects of such a large number of satellite constellations.

The Conundrum of Freedom of Exploration and the Viability of Sustainability of Outer Space Activities

Where does the principle of freedom of exploration in space activities appear in the phrase to cover the greatest possible area of the globe? Article 1 of the OST contains the phrases "freedom of exploration" and "freedom of access," which, according to Prof. Prayitna Abdurrasyid, mean that every state is free to set up stations and installations to conduct experiments and also use celestial bodies in part or in whole. From this interpretation, the activities of satellite mega constellations and their primary purpose do not violate the freedom of exploration principle.

The satellite mega constellations, however, have been criticized by astronomers and space scientists because the satellites are believed to have hindered their pursuits in different ways. They have interfered with the

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38 *Ibid.*

39 *Ibid.*

40 Bruce W. MacDonald, Carla P. Freeman and Alison McFarland, *China and Strategic Instability in Space: Pathways to Peace in an Era of US-China Strategic Competition*, United States Institute of Peace, February 2023. https://www.usip.org/sites/default/files/2023-02/20230209-sr-515-china-strategic-instability-space.pdf

41 *Ibid.*

observations of space researchers as the light reflected from the numerous satellites obscures their view. The impact of large satellite constellations is influenced by the brightness of the satellites' reflected light, which can be measured. Because satellites in 650 km orbit are illuminated by the Sun for only a few hours at twilight, they have a lesser impact than those in 1000 km orbit, which may be illuminated for the entire night, depending on latitude and time of the year. This is a result of how long the Sun is shining on the satellites.

Observatories of Indonesia, such as the Timau, Bandung, Jakarta, and Tenggarong will become a major plateau in Southeast Asia. These observatories play a great role for astronomical activities, and provide support in astronomy research. Observatories can be categorized as ground-based observatory, space-based observatory, and airborne observatory. Ground-based observatories are situated on land and the architecture of these buildings has some similarities. Space-based observatories are telescopes around the earth's orbit or in outer space. An airborne observatory is an airplane, airship, or balloon with an astronomical telescope.

To prevent the interference in space observation, Indonesian scientists and researchers, as an important voice in the astronomers' community of the world, need to convey their ideas and opinions on the regulation of the mega constellation satellites in international space forums.

With the launch of innumerable satellites into the outer space, the likelihood of Kessler syndrome increases. Among many space assets, the International Space Station in LEO is in an impact path of such debris. Countries, such as Indonesia, along with U.S., China, Canada, Australia, India, and Saudi Arabia have witnessed falling of space debris into their territories. An increase in space debris would resist space exploration activities, and lives on earth would become endangered.

These threats and threat perceptions, however, would not be a legal basis to state a case against satellite mega constellations, as they do not violate the principle of freedom of exploration. A strong legal basis for free exploration and free access exists in the Outer Space Treaty and international responsibility in the 1972 Liability Convention. Space exploration is also legally valid and accepted by all nations, irrespective of their part in it.

However, the freedom of exploration still contains loopholes and a legal vacuum. The limitations of freedom of exploration do not account for the impact of launching the mega constellation satellite on astronomy, the occurrence of Kessler syndrome, and the increasing amount of space debris. According to Article 1 of the Outer Space Treaty of 1967 and the opinions of experts, the freedom of exploration is not restricted in any way by the effects of the mega constellations. Therefore, it is necessary to revisit the principle to make it accountable for the consequences. The impact of losses from each exploration activity must be considered. This needs to be done to provide legal protections for those who have been harmed by this activity.

The legal vacuum of space governance, esp. related to the launches of massive numbers of satellites needs to be corrected. With these measures, further damages to humanity can be resisted.

The Need to Establish Legal Instruments Related to the Launches of Satellite Mega Constellation

Undeniably, the creation of mega constellations of satellites does bring advantages to humankind. Whether in the context of economic development or as advancement in human capabilities, in many ways, we all are beneficiaries of space technologies. However, the problem that it brings must also be a concern for the international community, and the absence of a robust international legal instrument needs to be addressed. In the forthcoming international regulation forum, at least three issues related to the launches of satellite mega constellations need to be covered. First and foremost, the most fundamental issue is the responsibility and liability of states concerning damages caused by satellites. Second are the aspects of licensing and registration, and third is the space debris.

Unfortunately, the existing *Corpus Juris Spasialis* has not yet specifically addressed the concerns expressed about the launch of mega constellations. Particularly, the OST does not explicitly provide any opening for rectifying harmful effects of space exploration activities. Nevertheless, Article 1 of the OST provides a general legal basis that restricts activities with the bounds of international law. Such a provision is regarded as an essential principle of Outer Space Law.[42]

In the context of the undesirable consequences of satellite mega constellations, the OST's alternative applicability could be found under Article IX through the principle of due regard, accounting for the interests of other State parties to the OST. Although the provision does not explicitly address the issues deriving from satellite mega constellations, the principle would urge states to undertake measures accounting for the interests of other State parties and the international community.

According to international space law, states have a responsibility and liability for mega constellations of satellites that cause harm anywhere outside the earth's surface. Under the principle of "fault" liability, the damage will be borne by the state or people responsible. In case of such damage identified, it is important to determine the responsible parties.

The Registration Convention provides a basis for aiding the identification of space objects. State's accountability is naturally applicable to these large-scale satellite constellations. Article 2 of the Registration Convention fundamentally obliges the registration of space objects launched into the earth's orbit by entry in an appropriate registry that the launching state shall maintain. The launching states are obliged to notify the Secretary-General of the United Nations about the registry. In this context, the placement of satellites within LEO must comply with the Registration Convention. When satellites are launched jointly, the launching states shall jointly decide who will register the object in accordance with paragraph 1 of the Registration Convention.[43]

The crucial problem, besides the fact that not all states register their space object, is the question that whether multiple satellites or constellations should be registered

[42] Christopher D Johnson, 'The Legal Status of MegaLEO Constellations and Concerns About Appropriation of Large Swaths of Earth Orbit' in J. Pelton (ed.) Handbook of Small Satellites (1st Edition, Springer, 2020)

[43] Registration Convention Article 2

separately, or as a single complex space object, or as groups. Bielicki states that the current practice is inconsistent [44] with the convention because satellites belonging to a constellation get registered separately. The Navstar satellites, which jointly create the GPS system, and the Kosmos satellites which are a part of the Russian GLONASS system, are cases in point.

Considering the advancements of satellite mega constellations, the current approach followed under the Registration Convention is questionable, as highlighted by the Chair of the Working Group regarding the status and application of the five United Nations Treaties on Outer Space (WG TRE).[45] Here, challenges would be about integrating the fundamental principles of registration under Outer Space Law with regard to the purposes of registration.[46]

The last issue concerns space debris. The definition of space debris has not been properly given by the Space Treaties under the UN, but an adequate definition was provided by the European Space Authority. The coordination of space debris is mostly done by the Inter-Agency Space Debris Coordination Committee (IADC) but the cooperation is still based on voluntary compliance because of non-binding guidelines.[47]

From the build-up of concerns through non-mitigation of issues surrounding satellite mega constellations, it could be concluded that necessary legal instruments are absent. Scattered provisions and principles, along with voluntary and non-legally binding guidelines, are insufficient to address the problems that satellite mega constellations will bring. For sustainable development, a legal instrument to address the problems in this aspect must be sought.

Ensuring Long-Term Sustainability of Space

a. Preventing Kessler syndrome

With a large number of satellites launched for mega constellations, the potential for collision is increasing, and so is the creation of space debris. This theory is named the Kessler syndrome, coined after the NASA scientist Donald J. Kessler. According to Kessler, the accumulation of debris in lower earth orbit can trigger a dangerous chain reaction of collisions. In 2010, Kessler with his team also predicted that a slow yet continuous growth in collision fragments will not stop until their numbers are reduced to a certain extent. Here, the collision between Iridium 33 and Cosmos 2251 is significant.[48]

The privately owned satellites of enterprises like Starlink, OneWeb, and Kuiper, among others, are substantially adding to the creation of space debris. Anti-Satellites (ASAT) are a major creator of space debris. One such ASAT caused an alarm when China, in 2007, conducted tests that caused two satellites to accidentally collide. From whomever the dangers come from, the management of space activities needs to be governed by stringent rules of law.

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[44] Damian M. Bielicki, "Legal Aspects of Satellite Constellations", *Air & Space Law*, 45, no.3 (2020): 245-264

[45] Chair of the Working Group on Status and application of the five United Nations treaties on Outer Space (WG TRE) 'Registration of Large Constellations and Megaconstellations' (29 March 2022).

[46] *Ibid.*

[47] Anél Ferreira-Snyman, "Environmental Responsibility for Space Debris and the Implications for Developing Countries in Africa", *The Comparative and International Law Journal of Southern Africa* 46, no.1 (2013):19-51

[48] P. Larsen, "Small satellite legal issues", *Journal of air law & commerce*, 82 (2017):300.

With the shared interest of states and private entities in outer space activities, the cooperation and mutual assistance principle is detrimental to minimizing careless and dangerous satellite launches. Unfortunately, article IX of the OST does not explicitly define, nor does it provide examples of cooperation and mutual assistance. Thus, mitigation attempts of the issues also suffer from a lack of details. Furthermore, the circumstances when the OST was formulated are not the same with the current situation where mega satellite constellations are quite frequent.[49]

If a binding legal instrument is to be proposed, it must be formulated in alignment with the UN Committee on the Peaceful Uses of Outer Space (COPUOS) guidelines for sustainable outer space activities. Also, all state and non-state activities covering space mission, the launching of space objects, services, and disposal must uphold the principles set in the OST.[50]

Nikita Bhakare proposed the concepts of Space Sustainability Ratings (SSR) and Space-Traffic Management (STM) to be included in future legislative framework.[51] She has also added that public-private partnerships should be brought in to facilitate ease of legal access besides financial and business relationships. According to the concept of SSR, which was an initiative by Bryce Space and MIT, companies need to apply sustainability principles while tracking satellite activities and other space operations. ADR is another part of the goal of sustainable space activities, which is about controlling the space debris from growing further.

b. Minimizing space debris

The issue of space debris has been a growing concern since the last decade, due to the rising number of instances of outer space use by states and private entities. According to NASA, more than 500,000 pieces of debris orbit the earth.[52] From April 2020 to April 2021, the number of satellites launched into LOE has increased by 28%.[53] Those are just the types of debris that can be tracked. Much smaller debris are left untracked, which have every potential for collision.

Regional efforts are one of the ways states have tried to establish guidelines to eliminate space debris and to prevent further growth. One such guideline is the European Debris Safety and Mitigation Standard issued by ESA. The guideline sets out protocols for implementing specific compliance measures with general safety standards that apply to all programs and industries that are involved in the management, research, planning, manufacturing, launch, and advancement of space missions in Europe or any other external European agency.

The UNCOPUOS Space Debris Guidelines, which are the most comprehensive set of directives, were approved by the UN General

[49] Suwijak Chandaphan, & Li, Shouping "Legal Challenges to the Construction and Operation of Small Satellite Constellations", *Journal of East Asia and International Law*, 14, (2021): 131-146. 10.14330/jeail.2021.14.1.07.

[50] *Ibid.*

[51] Nikita Bhakare, The Need for Evolving Legal Framework for Regulation of Space Debris Caused by Satellite Constellations, Proceeding of 8th European Conference on Space Debris, the ESA Space Debris Office Ed. T. Flohrer, S. Lemmens & F. Schmitz, 2021

[52] M. Garcia, Space Debris and Human Spacecraft, National Aeronautics and Space Administration Website (Aug. 7, 2017), https://www.nasa.gov/mission_pages/station/news/orbital_debris.html.

[53] Nibidita Mohanta, How Many Satellites Are Orbiting the Earth in 2021?, GEOSPATIAL WORLD (May 28, 2021), https://www.geospatialworld.net/blogs/how-many-satellites-are-orbiting-the-earth-in-2021/.

Assembly in 2007.: The UNCOPUOS Space Debris Guidelines[54] The guideline prescribes states to limit debris during normal operations, minimize the potential for break-ups during operational phases, limit the probability of accidental collisions in orbit, avoid international destruction and other harmful activities, minimize the potential for post-mission break-ups resulting from stored energy, limit the long-term presence of spacecraft and launched orbital stages in LEO after the end of a mission, and the interference of spacecraft and launched vehicle orbital stages with the GEO region after the end of their mission.[55]

Unfortunately, such guidelines do not bind states and no sanction for enforcement is available when states do not comply. Additionally, the remediation of current space debris, which has an enormous capacity in producing additional debris due to fragmentation is not addressed in the guideline.

More satellite mega constellations launched into low earth orbit will gradually contribute to creating a large graveyard of junk in outer space. The imminent danger of millions of pieces of space debris floating in outer space calls for the attention of the international community and all stakeholders to cooperate and come up with effective solutions.

The principle of freedom of exploration has its limitations and there is no policy or regulation that prohibits the launches of satellite mega constellations. However, in order to have binding laws on outer space operations aligned with sustainable development practices, establishment of global space governance is necessary.

IV. Conclusion and Suggestions

From this research, it can be concluded that the principle of freedom exploration as proposed in OST, contains general and specific limitations. These loopholes make way for unchecked satellite constellations by states and private entities. However, as these mega constellations do not violate the principle of freedom of exploration, the treaty needs revisiting based on current situation.

The legal vacuum in regulating the launch of a large number of satellites encourages operators such as SpaceX, OneWeb, Amazon, the Rwanda Government, and Kepler to continue to launch a large number of satellites. Interference with astronomical work and Kessler syndrome, along with environmental hazards are the biggest concerns from unrestricted outer space operations.

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[54] Space Debris Mitigation Guidelines of the United Nations Committee on the Peaceful Uses of Outer Space, G.A. Res. 62/217, U.N. Doc. A/62/217 (Dec. 22, 2007), https://www.unoosa.org/documents/pdf/spacelaw/sd/COPUOS_space_debris_mitigation_guidelines.pdf.

[55] A. de Waal Alberts, The Degree of the Lack of Regulation of Space Debris Within the Current Space Law Regime and Suggestions for a Prospective Legal Framework and Technological Interventions, *Space Security and legal aspects of active debris removal* (2019):93-106.

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