Space debris as environmental threat and the requirement of Indonesia’s prevention regulation

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Abstract. Non-operational satellites and other space junk, including jettisoned spent rocket stages, old satellites and other space objects, are creating a huge stock of garbage in outer space. Space debris environment poses a damage risk to spacecraft in Earth orbit and also poses the risk of damage on the ground if debris survives Earth's atmospheric re-entry. From the early 1960s, Indonesia has promptly begun to perform space activities. From rocket research and development in 1970, programs related to space science and technology in 1980, and currently Indonesia operates its own 6 satellites (5 in GSO and 1 in LEO). Indonesia has ratified Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, 1967 (Outer Space Treaty) with the Law Number 16/2002 and also enacted Law Number 21/2013 on Space Activities. However, the lack of regulation regarding on environmental protection aspect on outer space should highlight Indonesian law system as the development of space technology threaten the territory also. This writing aims to study the space debris and environmental protection on the national level and utilized that as a means on space environmental sustainability in Indonesia.

1. Introduction
Since first Sputnik’s launch in 1957 as initial space activities, there have been more than 4000 rocket launches, as well as many other related debris-generating occurrences like more than 1500 in orbit fragmentation events [1]. Of these satellites, about 3,600 remain in space, and most only 1,000 are still in operation; the rest are just roaming in outer space [2].

The Inter-Agency Space Debris Coordination Committee's Space Debris Mitigation Guidelines and the subsequent UN Space Debris Mitigation Guidelines has set the first internationally accepted definition of space debris, i.e. "all man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are nonfunctional [3]. The adopted definition of space debris also includes re-entry objects, which are captured by the Earth atmosphere. Around 66% of all cataloged objects in space history have decayed, with most of these burning up due to aero thermal heating [4]. Thus, cataloged objects in space orbital are, essentially, space garbage.

The sources of this debris are normal launch operations certain operations in space, fragmentations as a result of explosions and collisions in space, firings of satellite solid rocket motors, material ageing effects, and leaking thermal-control systems [1].

While the threat of space debris is clearly alarming in the international community, Indonesia yet established any regulations concerning this problem. However, in regards to the increasing number of
Indonesian space activities, Indonesia also poses a threat from space debris, and furthermore, could additionally serve as the source of the debris itself.

The harmful nature of space debris to other objects in space is primarily due to their extraordinary speeds of travel capability. For example, in Low Earth Orbit ("LEO"), properties as small as one centimeter in diameter generates massive energy that it can knock a satellite out of its orbit [5].

On their way back to the Earth, the unused space objects could also cause massive collision. Collisions between debris and functioning satellites comprise not only economic damage but also environmental damage. In case of a collision, a satellite can inevitably lose its ability to correct its orbit and become another hazard in space, without any way to steer onto a steadier orbital path. This significantly increases the chance of a damaged satellite careening into some other orbiting object, be it another satellite or a piece of debris, and repeating the cycle of debris generation [6]. Elise Epperson Crow on her writing recorded at least 4 massive collisions regarding the space debris [5] such as:

- In 1991, the Russian navigation satellite Cosmos 1934 collided with debris from a Russian rocket body. The collision resulted in thousands of new debris pieces in space.
- In 1996, the French Satellite Cerise collided with a debris fragment, further increasing the total amount of debris in space.
- On February 10, 2009, a privately owned U.S. Iridium communications satellite, Iridium-33, collided with a defunct Russian military satellite, Cosmos 2251.16 The collision resulted in hundreds of pieces of larger, traceable debris.
- On 2011, Chinese deliberately destroyed their Fengyun-JC spacecraft in an anti-satellite weapon test. That collision resulted in over 2,000 pieces of traceable debris, and an estimated 35,000 pieces of smaller debris.

The more debris accumulates in space, the more likely it is that another collision will occur and contribute to the problem. Major collisions are currently predicted to occur every five years [5]. The purpose of this study is seeking the harmful effect of space debris on the space environment. This study will also highlight the practice on International Law to prevent such damage and Indonesia practices as part of the international community. Lastly, those references will be cited as a suggestion on how Indonesia can contribute to the sustainability of the outer-space environment.

2. Methods
This study will utilize literature research as the primary methodology. The research will underline on Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, 1967 (Outer Space Treaty) with the Law Number 16/2002 and Law Number 21/2013 on Space Activities as the underlying source, along with customary international law, general principles of law, international treaties, conventions, declarations and decisions of international organizations. The authors will beforehand determine present environmental law on the space debris and highlight the connection to the current situation. After the connection has been established, the suggestion to the gap between the current situation and the present law will be drawn. Experts writing then will be used to resolve the lack of regulation and suggestion to Indonesia Law.

3. Results and Discussion
3.1. Outer Space Activities
The recent classification of the jurisdiction on space could be seen on article IV of the Moon Treaty 1979. This treaty interprets stated territories as ‘the common heritage of mankind’ and is excluded from national appropriation (territorium commune humanitatis). The concept of the common heritage of mankind conveys the idea that the management, exploitation, and distribution of the natural resources of the area in question are matters to be decided upon by the international community and are not to be left to the initiative and discretion of individual States or their nationals [7]. However, while the national ownership of outer space completely eliminated by this principle, this regulation also reveals
opportunities for space exploitation in another area, such as commercially exploit the outer space with commercial exploration and commercial satellite launch.

For example, aside from the national owned satellite launch, The United States Communications Satellite Act of 1962 allows Communications Satellite Corporation (COMSAT), or private communication corporation, to own and operate, either by itself or in conjunction with foreign governments or business entities, a commercial communications satellite system; to furnish, for hire, channels of communications; and to own and operate satellite terminal stations. This also followed by European Conference on Satellite Communications (CETS) and establishment of Interim Arrangements for a Global Commercial Communications Satellite System [7].

Aside from the massive launch of commercial private communication satellite, space explorations also become second-highest activities in outer space. Involvement of commercial actors in exploration programmers is at present a dominant consideration of governments and increasingly eager agencies to explore alternative mechanisms to take advantage of private contributions to engage in future programmers and achieve challenging space exploration goals [8]. The commercially funded space exploration aims towards New Space ecosystem, a business-driven dynamic of the space sector characterized by the following interrelated trends [8]:

- New entrants in the space sector including large information and communications technology (ICT) firms, start-ups and new business ventures,
- Innovative industrial approaches with announcements and initial developments of ambitious projects based on new processes,
- Disruptive market solutions providing, for example, integrated services, lower prices, reduced lead time, lower complexity or higher performance among other value proposition features,
- Substantial private investments from multiple sources and involving different funding mechanisms,
- New industry verticals and space markets targeting the provision of New Space applications.

In this new ecosystem, space exploration and human spaceflight have grown into domains of interest for private companies, entrepreneurs and investors, eager to engage in commercial endeavors and conduct business in these fields. Together with new target markets pursued by commercial actors, space mining, orbital tourism or even planetary colonization were currently put under the spotlight by ambitious private project announcements [8].

3.2. Space Debris Environmental Threat
Space debris includes any manufactured object in space that serves no practical purpose, includes non-functional spacecraft, unused fuel and dead batteries from satellite break-ups, paint flakes, rocket bodies and mission-related debris (including human refuse). As stated earlier, the harmful characteristic of space debris comes from its self-generating nature or the cascade effect, or Kessler syndrome [9]. When orbital debris collides with other space objects, the result is more debris. Eventually, some chain reactions of collisions could potentially harm some of the most valuable orbits. According to the cascade effect hypothesis, even if humans add no additional debris to the Earth's orbit, the amount of orbital debris could still grow exponentially, based on the amount that previously exists [10].

On outer space, even a significantly microscopic object can cause significant harm to anything it collides with. For example, a half-millimeter chip can puncture a spacesuit, and a marble-size object can knock a satellite off. Aside from the economic loss, the secondary impacts for many on-ground operational systems that rely on satellites remain, nonetheless. A collided-with satellite means that the ground systems that depend on it must immediately provide backup or suffer a stoppage until the satellite is repaired or replaced. Services outages due to the collision could plunge anywhere between mere broadcast outages to full out global crises. Virtually all modern communications, commercial and scientific interests are similarly threatened by collisions [10].

Aside from the remaining man-made fragments and elements from satellite launch, space debris also possesses another environmental harm to the earth. This is due to the nuclear materials that often used
in satellite activities. In 1978, when a Soviet satellite malfunctioned and fell to Earth, radioactive debris scattered over northern Canada [6].

3.3. Space Debris Regulation and State Responsibilities

Existing international bodies and guidelines for handling space debris are currently limited compared to other environmental issues. Currently, space regulation is based on five core space law conventions:

- The Outer Space Treaty 1967 (OST),
- Rescue Agreement 1969,
- Liability Convention 1972,
- Registration Convention 1975, and
- Moon Treaty 1979.

Out of treaties mentioned above, The Outer Space Treaty and the Liability Convention are the most important with respect to the protection of the near-Earth space environment. Those two treaties have generalized several points on prevention and minimization of risks posed by space debris [11] such as:

- Prevention and minimization of risks posed by space debris can be seen on article I, paragraph 2 of the Outer Space Treaty. This particular article clearly stated the freedom of outer space is, not granted unlimitedly, but is subject to various limitations. It is in particular tied to the "benefit and interests of all countries", and international law according to Article I, paragraphs 1 and 2, and Article III, OST.
- Furthermore, article IX, sentence 1 OST set an obligation to prevent or at least to minimize the risks related to space debris by providing that:
  
  "In the exploration and use of outer space, including the Moon and other celestial bodies, States Parties to the Treaty shall be guided by the principle of cooperation and mutual assistance and shall conduct all their activities in outer space, including the Moon and other celestial bodies, with regard to the corresponding interests of all other States Parties to the Treaty.
  
  This article could be defined as the definitional decision to outline "space debris" respect to the qualification of "harmful. "This article could be defined as the definitional decision to outline "space debris" respect to the qualification of "harmful.""

- The responsibility to minimize the risks related to space debris also come with the obligation to avoiding space collision on Article IX, sentences 3 and 4,
  
  "If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space, including the Moon and other celestial bodies, would cause potentially harmful interference with activities of other States Parties in the peaceful exploration and use of outer space, including the Moon and other celestial bodies, it shall undertake appropriate international consultations before proceeding with any such activity or experiment. A State Party to the Treaty which has reason to believe that an activity or experiment planned by another State Party in outer space, including the Moon and other celestial bodies, would cause potentially harmful interference with activities in the peaceful exploration and use of outer space, including the Moon and other celestial bodies, may request consultation concerning the activity or experiment."

- Furthermore, removal and recycling also necessary to prevent future collision, as stated on Article VIII OST
  
  "A State Party to the Treaty on whose registry an object launched into outer space is carried shall retain jurisdiction and control over such object, and over any personnel thereof, while in outer space or on a celestial body. Ownership of objects launched into outer space, including objects landed or constructed on a celestial body, and of their component parts, is not affected by their presence in outer space or on a celestial body or by their return to the Earth. Such objects or component parts found beyond the limits of the State Party to the Treaty on whose registry they are carried shall be returned to that State Party, which shall, upon request, furnish identifying data prior to their return."
Article VI, OST confirms that States bear international responsibility for "national activities in outer space." This responsibility required allocation of financial burden and technology transfer. However, the stated responsibilities blurred, as, on space activities, more than one country usually bound in to. For example, a satellite could be owned by State A, while the owner of the satellite still lacks on launching facilities, or simply collaborate with State B. Eventually, the launch will carry on State B, not on State A as the legitimate owner of the satellite.

Furthermore, the rising of COMSAT also opens the possibility of inter-boundaries satellite transactions between countries. The owner of the satellite could possibly different from the launch state, or the manufacture state. This case could confuse the responsibility on space debris management. The owner of the satellite perhaps different from the launch state, or the manufacture and assembly state. This case could obscure the responsibility for space debris management.

To avoid such debate, Under Article VI of the Outer Space Treaty, states parties have assumed direct responsibility for all actions qualifying as national activities in outer space'. It provides a direct responsibility for national activities of non-governmental entities in the outer space. Thus, a State is directly responsible for national space activities of governmental and non-governmental entities. 'National activities' signify a national endeavor, whether to be performed by a governmental agency or private entity [12].

In this manner a national activity for which a State is to be held responsible encompasses activities undertaken by its nationals, in the outer space as well as activities undertaken from its territory. The state is responsible for all activities as national activities, on which the State possesses the possibility to exercise jurisdiction and control [12].

The text of the OST and the travaux preparatoires, indicate no intention to deviate from concepts of general international law, according to which a State has jurisdiction over an activity carried on by its nationals. Further, nationality should determine the appropriate state since responsibility is for "national activities [12].

3.4. Indonesian Space Debris Regulation

Indonesia is one of the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) participated country, which applies a guidelines policy for mitigating space junk to prevent the risk caused by space junk for all space activities carried out or against state assets in countries space [13].

This participation is based on the fact that Indonesia exhibits an interest in space, it is necessary to promote the protection of the space environment. Indonesian satellites have contributed to space junk as well. Since the first Indonesian satellite orbited in 1976, three satellites failed to operate completely. The Palapa B2 Satellite failed to orbit at the launch, the Palapa C1 Satellite which was barely able to operate for two years due to battery charging problems, and Telkom-3 Satellite lost before arriving at its orbit. Although the percentage of Indonesia's satellite waste in space tends to be small compared to the overall amount of satellite waste contributed by other countries, the Indonesian satellite that is currently still functioning and will be launched. This shows the potential to increase the amount of space junk in space [14].

Indonesia’s commitment to prevent space junk can be seen in Article 8 (e) of Law Number 21/2013 on Space Activities. This article stated

“Space Activities are prohibited to: ...... conduct activities that may cause contamination and/or damages to the Earth and Space environment as well as harmful to the Space Activities including the destruction of Space Objects.”

However, even though Indonesia has set the first national initiative to prevent space junk, the current space policy is yet enough to anticipate a growth in the garbage number or to mitigate waste in space. This is since most of Indonesia's regulation lack of deep and elaborated research. In fact, space debris demonstrates the possibilities to disrupt national security. This law incorporates zero policies to prevent the harmful potentials of the space debris. For this purpose, a necessity for inter-state institutions and mechanisms for the responsibility of countries own space debris arises.
As a suggestion to Indonesia Regulation, based on the findings of the International Congress on Space Debris Remediation, the regulation should include following practical conditions as necessary [15]:

- a “cost effective” technique;
- a proper legal and policy framework to protect the parties involved and to deal with “alternative use” concerns;
- available and willing targets for removal or customer for servicing;
- funding: for the time being, for establishing, testing and developing technologies and Space Debris Remediation (SDR) techniques; in the future—for carrying out such operations;
- accurate tracking and necessary assistance during operations;
- capability to locate, approach, connect deorbit/servicing device, control orientation and to move the target object to desired destination;
- safety of the public on the ground, at sea, travelling by air and in space.

4. Conclusion

As a satellite launch state, Indonesia exhibits an interest in space, and furthermore has contributed to space junk as well. Under Article VI of the Outer Space Treaty, states parties have assumed direct responsibility for all actions qualifying as national activities in outer space'. It provides a direct responsibility for national activities of non-governmental entities in the outer space. Thus, a State is directly responsible for national space activities of governmental and non-governmental entities. 'National activities' signify a national endeavor, whether to be performed by a governmental agency or private entity. However, Indonesian Space Regulation is still lack of practical conditions necessary to prevent such pollution. Indonesia is recommended to look further into practical condition on satellite launch and create a regulation based on environmental-friendly approach system.

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