Environmental protection in the exploitation and use of space resources

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Abstract. Space resources activities are per se ultra-hazardous activities, which may be harmful to both outer space and the Earth environment. At the dawn of space mining, however, predominant in space mining missions is wealth and technology perspective. Environmental protection, has not been an important consideration. The principle of sustainable development and the new ecocentric approach could help to make a correct balance between protecting environment and promoting industrial development. But many obstacles of environmental protection do exist, such as inadequacies of the current space law, difficulties in practice, ethical dilemma in planetary protection. Thus, for promoting sustainable exploitation and use of space resources, this article suggests some solutions, including: 1) strengthening the legal regime; 2) promoting international cooperation; and 3) developing the appropriate ethic.

1. Introduction
The conduct of mining activities, on Earth or asteroids, is inherently detrimental to the physical environment. Environmental protection has thus become an increasingly relevant consideration for negotiating mining-related agreements, such as the Agreement relating to the implementation of Part XI of the United Nations Convention on the Law of the Sea (10 December 1982) (UNCLOS) and the Model Mine Development Agreement 1.0 (MMDA 1.0). These mining-related agreements, however, protects the environment indirectly. With regard to environmental protection in space mining, the mainstream debates thus far have taken place from the traditional perspective of industrial development. In contrast, the environmental dimension has attracted only limited attention. This article recommends a greater focus on the latter approach and explores the environmental dimension of space mining.

The next section discusses the role of environmental protection at the dawn of space mining. It starts from discussing environmental problems causing by space mining activities. After analyzing major impetus in these activities, it attempts to identify the correct balance between protecting environment and promoting industrial development. Section 3 discusses the principle of sustainable development and the new ecocentric approach in international environment law. It argues that an integrated and inclusive approach by balancing the development needs and environment needs should be adopted. Meanwhile, space environment itself should be given greater consideration. Section 4 points out current obstacles in the environmental protection in space mining. Section 5 proposes some legally, politically and ethically viable ways to address the issue of environmental protection in space mining for the sustainable use of the outer space.
2. The role of environmental protection at the dawn of space mining

2.1. Environmental problems related to space mining
Space resources activities are *per se* ultra-hazardous activities, which may be harmful to both outer space and the Earth environment. For instance, to support space mining, a large number of satellites and launch vehicles sent to near-Earth Space would result in a dramatic increase of space debris. And the Heatpipe-Operated Mars Exploration Reactor (HOMER), a robust and low technical risk fission system, is being used to enhance lunar and Martian mining in life support, operations, in-situ propellant production. However, as a nuclear power sources (NPS), there is also a risk of waste production and neutron leakage, thus adversely affecting the environment. Additionally, biological contamination by material from Earth to a target body with space probes or human space missions, could make it difficult to explain the origins of microbial life in mineral environments. At the same time, returning spacecraft with samples may also spread pollution or bring back waste. As a result, we should carry out these activities with a high standard of care and due diligence.

2.2. Major impetus for space mining
In reality, it is the wealth and profits that carry more weight in States’ contemplation of space mining. According to National Aeronautics and Space Administration (NASA), the minerals that lies in an asteroid belt between Mars and Jupiter hold wealth equivalent to a staggering $100 billion for every person on Earth. And the business case of the commercial return of highly valuable Martian regolith and samples has been proposed as one of the most straightforward candidates for a source of income for private Mars settlements. Consequently, not only governments but also ambitious private actors are engaged in space mining activities for the space-based economic opportunities. For example, NASA has launched OSIRIS-REx spacecraft in 2016 to explore the asteroid Bennu before collecting a sample to return to Earth. The United Arab Emirates is also making a multipronged effort to establish a space mining industry, including an investment of more than $5 billion, and continuous launch of satellites. Besides, several commercial initiatives have started for asteroids and the moon, by Planetary Resources, Deep Space Industries, Google Lunar X-Prize, Lunar Missions Ltd, Moon Express and so on.

Table 1. Benefits of space-sourced propellants *a*.

| Cislunar Activity                                      | Space-Sourced Propellant Benefit          |
|-------------------------------------------------------|------------------------------------------|
| Transportation from Earth to Geosynchronous orbit      | 10-20% lower cost                        |
| Transportation from Earth to Lunar surface             | 70% lower cost                           |
| Cost of a human mission to Mars                        | 2-3 times reduction                      |
| In-space transportation                                | Essentially the cost of space-sourced propellant |

*a* The data are collected from the Lunar Polar Prospecting Workshop: Findings and Recommendations.

Technological innovation is another impetus for space mining. Through space resources activities, a series of technologies and hardware are being developed to build the space structures and generate rocket fuel. And a substantial breakthrough has been made to achieve the benefits of In Situ Resource Utilization (ISRU) for a reasonable cost, mass, and risk, which will change the way we explore the outer space. For example, Moon Direct would be the most effective transportation system to access to the lunar surface. By making using of LOx/H2 propellant produced at a lunar polar base, it could support the operation of a lightweight Lunar Excursion Vehicle (LEV) flight system. These
space-sourced propellants can dramatically reduce the cost of every other activity in cislunar space. Table 1 provides some examples.

At the dawn of space mining, predominant in the above ambitious missions is wealth and technology perspective. Environmental protection has not been an important consideration. As space mining is becoming a reality, more attention should be paid to the non-traditional element of environmental protection. However, protecting the environment at the cost of surrendering space mining would be extremely difficult for States to accept, especially considering their quest for the wealth and technology. What is the correct balance between protecting environment and promoting industrial development? International environmental law may give a good answer to enhance space sustainability.

3. The legal basis of environmental protection in space mining

International law, since its creation, has adhered to no intrinsic geographical limits [1]. According to Article III of the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies (19 December 1966) (the Outer Space Treaty), general international environmental law is applicable to environmental protection of the outer space as well as the Earth.

3.1. The principle of sustainable development

The term ‘sustainable development’ was explicitly introduced in 1987 by Brundtland Report of the World Commission on Environment and Development (WCED), “Our Common Future”. It is defined as “development that meets the needs of present without compromising the ability of future generations to meet their own needs.”. The Rio Declaration on Environment and Declaration (Rio Declaration), 1992 and the International Law Association set out this concept in more detail. Today, the principle of sustainable development has been incorporated into various international or national instruments and gained widespread endorsement. It suggests a holistic approach to environmental problems, and is recognized by many as the best paradigm to reconcile environmental protection and development. It is anthropocentric with the aim of ensuring both sustainable human progress and human survival. Accordingly, it never purports to promote a policy of no economic growth for the needs of the environment, but believes the possibility of a new era of economic growth based on policies that sustain and expand the environmental resource base. Meanwhile, an integrated and inclusive approach to sustainable development also means environmental protection is taken into account in decision-making. It is evidenced by Principle 4 of Rio Declaration, which provides that “in order to achieve sustainable development, environmental protection shall constitute an integral part of the development process and cannot be considered in isolation from it.”.

When the Outer Space Treaty was concluded, it emphasized on the peaceful use of the outer space, while environmental protection was not a priority or concern. But this issue is becoming particularly important at the dawn of space mining, as the interaction between mankind and the environment increases. The principle of sustainable development, as the best paradigm to reconcile environmental protection and development, could provide a basis for all concerns regarding the environmental repercussions of space mining. Under this principle, environmental protection should be taken into account when States and private actors conduct space mining activities in pursuit for profits and technology. And they are also required to conduct environmental impact assessment and monitoring process in the overall mission phases.

3.2. New ecocentrism

Given that narrow focus on humans alone seems rather imprudent, international environment law are starting to turn their attention to the inherent value of environment. Protocol on Environmental Protection to the Antarctic Treaty designates Antarctica as a Special Conservation Area and acknowledges the intrinsic value of Antarctic, including its wilderness and aesthetic values. Similarly, the 1992 Convention on Biological Diversity recognizes the intrinsic value of biological diversity and
its importance for evolution and for maintaining life sustaining systems of the biosphere. Opposed to the early anthropocentric and utilitarian approach, there is a growing trend of ecocentrism.

The space environment is much more fragile and sensitive than that of Earth. Over 21,000 orbiting debris larger than 10 cm in diameter are now being tracked and their degradation is extremely slow [2]. Besides, asteroids are not necessarily lifeless rocks, but may instead contain vital and possibly irreplaceable scientific evidence about the formation of the Solar System. New ecocentric approach requires human to respect the inherent value of both the space environment and the Earth environment, which may be largely beneficial to reducing risks of environmental degradation in space mining activities.

4. Obstacles of protecting the environment in space mining

4.1. Inadequacies of the current space law
As the exploitation and use of space resources is to take place and relevant national legislation is adopted, the existing international law might be challenged in several ways. And the applicable environmental protection provisions are no exception. Article IX of the Outer Space Treaty has laid the basis for environmental protection of outer space. It requires that States pursue studies and conduct exploration of outer space so as to avoid their harmful contamination and also adverse changes in the environment of the Earth. Besides, according to Article VI, States are obliged to consider the environmental aspects for the authorization and supervision of national activities in outer space and adopt appropriate measures when necessary. However, some terms are rather vague and broad and are subject to interpretation, such as ‘harmful contamination’, ‘adverse changes’.

4.2. Difficulties in practice
Similar to other global commons, outer space faces a collective action problem. Environmental protection, like mitigating orbital debris, is not only faced with a number of complex technical challenges but also a costly undertaking. Accordingly, every player may delay its actions and wait for others to respond. Besides, the US has preferred withholding its most accurate Space Situational Awareness (SSA) data and information essential for detection and tracking of debris. Some important technologies are chosen, used and developed based on the political alliances. Accordingly, other countries with limited SSA capabilities are difficult to obtain uniform information about space debris. Moreover, the shortsightedness shown in our past endeavors is likely to recur, such as irresponsible exploitation. For example, commercial investments although essential to develop space mining ventures because of its high cost and risk could also create longer term environmental problems. Private corporations focusing on shareholder profits may not place great value on general scientific significance and the long-term consequences of their actions.

4.3. Ethical dilemma in planetary protection
The Committee on Space Research (COSPAR) promulgated Planetary Protection Policy (PPP) as an international standard on procedures to avoid organic constituent and biological contamination in space exploration. However, current COSPAR Policy is criticized for its reliance on our present state of knowledge to make crucial determinations whether a particular celestial body is of biological interest. Many target bodies that life may exist thereof but not detected by the scientific investigations conducted to date, are at risk of contamination [3]. For example, the Russian Phobos Grunt was not required to be decontaminated, as the target body Phobos is identified to be of little or no biological or chemical interest in regard to the search for the origins of life. But the risks to its environment may be substantial.

5. Solutions for sustainable space mining
As warned by Hobe, space mining almost certainly has an impact on the celestial and earthly environment. But this is not meant to prohibit space mining activities. We should not overlook that
space exploration and use in the long run is necessary for our survival, making a continuous technological development a necessity. Some resources like water, could be extracted for life support in the outer space. And it is permitted to capture an asteroid for the purpose of planetary defense. Based on the principle of sustainable development and new ecocentrism, a legally, politically and ethically viable approach for environmental protection is the only choice we can make now.

5.1. Strengthening the legal regime
It is becoming clear that the regulatory structure around resource extraction, retrieval, and processing needs to be formulated to avoid environmental contamination. Otherwise, it would appear that space and Earth environments could easily become at risk. A general consensus should be reached in the United Nations and scientific organizations, as the exploration and use of outer space shall be the province of all mankind. But the conclusion of a new treaty seems challenging and time-consuming, given various interests of States active in the asteroids mining. Actually, international space law failed in any progressive development for nearly three decades. Consequently, it is never practical to change international space law radically now, which remains essential in the international rule of law of outer space. Maybe we could follow the example of the Antarctic Treaty System and formulate an environmental code of conduct (ECC) first. The ECC is not legally binding, and contains more detailed operational rules or technical standards to supplement the space law. Mostly, the ECC would be more flexible and easier to be amended in keeping with continuous technological or scientific development. Such a fluid regime is much essential due to the significant uncertainties related to space activities.

5.2. Promoting international cooperation
International cooperation is rewarding to counter a common environmental concern in space mining. According to the principle of sustainable development, all countries in the world have common and collective responsibility to keep space free of environmental hazards and debris. On one hand, these countries, individually and in concert, must establish relevant regulations to share information about space debris and develop transparency and confidence building measures, which is particularly essential in the protection of space environment. On the other hand, an international tax or license on launch operations should be established to implement the polluter pays principle. And then the taxing authority is able to purchase active debris removal service. By covering the developmental costs, the operators would make a prudent and economical decision before conducting space mining activities.

5.3. Developing the appropriate ethic
The ‘Environmentalist’s Paradox’ does exist in the exploration and use of space. To protect the space environment, we need to understand it firstly and clearly define what we seek to protect, which requires robotic or human operation. But during the process, this inevitably involves the introduction of waste and the spoiling of the very environment we seek to protect [4]. Actually, the appropriate ethic in space exploration and use should make a balance between development and environment. Planetary parks system is suggested in some representative regions of Mars to maintain them in a reasonable state of cleanliness for their various values, such as intrinsic worth, responsibility to future generations, protection of sites of natural beauty, utilitarian and historical value. Meanwhile, non-park areas are still allowed to be developed for scientific or commercial purpose. Another way out of the Environmentalist’s Paradox is to apply strict standards and procedures from the earliest stages of mission design. It is argued that a sample-receiving laboratory should be built prior to the launch date of sample return mission to give scientists and technicians adequate time to train on its capabilities and use.

6. Conclusions
As space mining is to take place, the related hazards will be of magnitude far greater than those seen today. The simple pursuit for wealth and technology is neither practical nor desirable. The principle of
sustainable development suggests an integrated and inclusive approach by balancing the development needs and environment needs, which would help humanity fully realize the potential of the space resources. And the new ecocentric approach requires protecting both space and Earth environment. But given various obstacles of environmental protection in space mining, a legally, politically, ethically viable approach for environmental protection is essential. Thus, this article suggests some solutions, including: 1) strengthening the legal regime; 2) promoting international cooperation; and 3) developing the appropriate ethic.

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