

Space Mining and Environmental Hazards: Assessing India's Legal and Institutional Preparedness

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Abstract:

Humanity has developed space mining into both a technological advancement frontier and an economic opportunity because it provides critical mineral resources beyond Earth together with water reserves and energy supplies. The pursuit of space resources creates multiple environmental risks which involve both orbital debris accumulation and the damage caused to celestial bodies and permanent destruction of outer space life systems. This paper examines environmental difficulties through India's institutional and legal system while using an environmental lens. Despite the rising space exploration capability of the Indian Space Research Organisation (ISRO) India lacks detailed regulatory measures to handle ecological threats stemming from space mining operations. Indian space mining enterprises operate under broad guidelines from the Draft Space Activities Bill (2017) and the regulatory oversight of IN-SPACe due to minimal specific regulations. The Outer Space Treaty (1967) has India as a member though the country has not yet adopted the Moon Agreement (1979) which sets regulations for lunar resource extraction and environmental protection. Indifference in legal interpretation and void environmental standards about space protection exposes India to lack of preparedness for fulfilling its space environmental obligations. India's strategic goals remain distant from its regulatory structures because they require urgent institutional changes. The research supports developing an active structured legal structure which combines space governance and environmental protection for India's program. The researchers draw policy suggestions from US and Luxembourgian international legal models to advance India's compliance with international environmental and ethical norms. The research delves into how India can contribute to developing sustainable space mining methods that benefit the Global South. The research demonstrates that India must implement regulations for environmental protection during space mining operations to preserve its ecological equilibrium and prove its responsibility as a nation engaging in space exploration.

Keywords: *Space Mining, Environmental Hazards, India's Space Law, Outer Space Treaty, Sustainable Space Governance*

Introduction

The current twenty-first century witnesses an important change in space exploration because governments and private entities choose to move beyond discovery into prioritizing extraterrestrial resource extraction. Space mining stands as a central global interest because it involves extracting minerals along with water and important materials from Moon and asteroids together with Mars. Supporters propose that space mining operations would solve Earth's decreasing natural resource problem while assisting extended human settlement initiatives in space.

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The advancing industrial sector poses essential difficulties because it deals with environmental protection alongside legal authority management and equitable distribution systems. The space mining efforts create more implications than economic advancement and technological achievements because they require thorough evaluation of environmental ethics and international legal frameworks.²

Environmental risks stand as the most urgent matter in connection with space mining operations. The environmental hazards from space mining activities produce three major effects: launch of space debris into orbit and the unintended pollution of celestial objects while permanently damaging extraterrestrial ecosystems. A fundamental principle exists in the 1967 Outer Space Treaty but both non-appropriation guidelines and responsibility to avoid harmful contamination remain vague in their application to commercial mining activities and environmental protection standards.

Few space-faring nations have endorsed the Moon Agreement of 1979 although it strives to solve resource management alongside space environmental concerns. The absence of regulatory standards produces confusion particularly for nations like India since they advance space operations without established laws for space resource management.³

India holds a critical strategic role that is vital to global future space mining activities. Indian Space Research Organisation (ISRO) has proven its technological expertise thus positioning India to be a main actor in upcoming space mining operations. The current legal framework together with institutional capability in India do not provide sufficient coverage of environmental aspects that pertain to space mining operations. Currently enforced policies including the Draft Space Activities Bill (2017) mainly address commercial oversight together with regulatory frameworks yet they do not contain environmental safeguards and sustainability protocols.

The Indian National Space Promotion and Authorization Centre (IN-SPACe) alongside other regulatory bodies continue to develop and have not yet determined standard practices to protect space environment. The existing institutional gaps carry major risks for India because it enters a domain which will be both competitive and legally unclear.⁴

Historical Background

The development of space exploration has moved through three phases including military confrontation followed by scientific teamwork which has now expanded to commercial ventures. The space mission started when the Soviet Union launched Sputnik-1 in 1957 which officially triggered the competition between the United States and the USSR. The historical epoch was mainly defined by international power competition between nations before reaching its peak with the Apollo 11 Moon landing in 1969.

The scientific investigation of space alongside national recognition served as the primary space activities during that time when extractable resources remained beyond consideration.⁵ The scope of space strategic planning grew to cover practical

² Steven Freeland, *Balancing the Future of Human Activities in Outer Space: Sustainable Development and the Law of Outer Space*, 11 Melb. J. Int'l L. 249 (2010).

³ Sandeep Joshi, *India's Space Law: The Need for a Comprehensive National Framework*, 59 Indian J. Int'l L. 63 (2021).

⁴ Indian National Space Promotion and Authorization Center (IN-SPACe), *Policy Framework and Structure*, Gov't of India (2023), <https://www.inspace.gov.in/>.

⁵ John M. Logsdon, *John F. Kennedy and the Race to the Moon* (Palgrave Macmillan 2011).

implementations of space technology applications such as satellite communication together with weather prediction and navigation capabilities.

Outer space became accessible for economic exploration including space mining after the Cold War period began in the late 1990s. This transition occurred because space launch costs decreased while technology improved and private companies like SpaceX Blue Origin and Planetary Resources displayed increasing interest. This shift facilitated a changing perspective on treating space science as an extension of surface markets and resource extraction domains.⁶

Mining operations on asteroids along with lunar mining had evolved from academic theory into a practical goal. The increasing interest in space resource extraction has encouraged both U.S. and Luxembourg legislative bodies to create new laws that support private exploitation.⁷ Future policy development for India's space program requires historical event awareness to create sustainable initiatives as shown by ISRO's mission expansion innovations.⁸

The Concept and Scope of Space Mining

Space mining which can be denoted as extraterrestrial resource extraction includes the collection of materials from celestial bodies that consist of asteroids and Moon surfaces as well as other planetary surfaces. Space mining has caught momentum since the beginning of the 21st century based on the combination of geopolitical tensions and space commercial activities with planetary resource limitations on Earth's surface.

Human survival in space relies on the extraction of water ice alongside helium-3 alongside platinum group metals and rare earth elements because these substances provide both space mission support and Earth resource management. The same water imported from the Moon or asteroids serves both as drinking water for human consumption and provides valuable rocket fuel components through its oxygen-hydrogen split for extended space missions.⁹

Space mining seeks its first targets from near-Earth asteroids (NEAs) because these asteroids hold significant amounts of nickel, cobalt and platinum which serve as core components for modern electronic devices and clean technology features. The Moon stands as an excellent prospective target because its helium-3 resource at the surface offers prospects for nuclear fusion energy technology. In-situ resource utilization (ISRU) applications seek to utilize space materials for building space structures and supporting life functions and creating rocket thrust to avoid Earth-based distribution networks.

The ability to use space resources is essential for sustaining enduring economic activity during space exploration and settlement operations.¹⁰ Space mining regulations are not fully developed because of technological advancements and growing corporate commitment. According to the Outer Space Treaty from 1967 the entire realm of outer space belongs to humanity yet it lacks clarity about possessing rights to mining assets.

⁶ Joseph N. Pelton, *New Solutions for the Space Debris Problem* (Springer 2019).

⁷ Fabio Tronchetti, *The Regulation of Commercial Space Mining: The U.S. and Luxembourg Legal Approaches*, 41(4–5) Air & Space L. 307 (2016).

⁸ Indian Space Research Organisation (ISRO), *Annual Report 2022–23*, Dep't of Space, Gov't of India (2023), https://www.isro.gov.in/media_isro/pdf/AnnualReports/2023/AR_English_2022_2023.pdf.

⁹ Ram S. Jakhu & Joseph N. Pelton, *Global Space Governance: An International Study* (Springer 2017).

¹⁰ G. Genta & M.J. Rycroft, *Space: The Final Frontier?* (Springer 2011).

The treaty specifically bans national acquisition of space but fails to clarify the ownership rights of extracted resources. Since the Outer Space Treaty maintains unclear rules about space mining ownership various countries including the United States and Luxembourg established domestic laws which provide private entities rights to claim ownership of extracted space resources. The implementation of these national laws creates problems because they may not comply with international space law requirements and equal outer space usage principles.¹¹

As a rising force in space activities India does not have established legal rules for space mining operations. The Draft Space Activities Bill (2017) includes provisions for commercial space participation yet does not address space resource environmental impact or ethics or ownership claims. The essential requirement for India's upcoming Moon and asteroid missions involves a complete strategy which must include technological development alongside legal infrastructure establishment and environmental protection measures.¹²

Environmental Hazards of Space Mining

Many economic prospects and technological breakthroughs from space mining operations come with major environmental risks against celestial bodies and surrounding space. The environmental concerns stemming from space mining pose threats to both mined celestial bodies and create further risks to the entire space environment which includes Earth-based orbit and forthcoming space exploration missions.

Primary environmental consequences of space mining include corks of space debris in addition to planetary contamination and the upset of extracrestrial ecosystems. Urgent solutions must be deployed because these challenges threaten to cause permanent ecological destruction.¹³ Mining operations on asteroids and the Moon have the potential to generate space debris when such activities cause machines to break along with loss of tools and waste materials.

These areas contain dangerous space debris that threatens vehicles both with crew and without crew aboard. Space mining operations will create a growing space debris problem because tracking and management systems are not fully established yet. Space activities face additional challenges since resource expedition missions increase spur uncontrolled debris proliferation in low Earth orbit (LEO) and beyond regions thereby creating major operational difficulties along with higher expenses.¹⁴

The contamination of space objects represents a significant environmental issue alongside others. Introducing Earth-based microbes together with pollutants into pristine environments remains a crucial concern for space exploration activities. The pollution of space areas such as the Moon and Mars and asteroids would simultaneously interfere with scientific evaluations while permanently damaging these interplanetary habitat systems.

¹¹ Philip T. Metzger, *Space Resources and the Challenge of In Situ Resource Utilization (ISRU)*, 126 Acta Astronautica 686 (2016), <https://doi.org/10.1016/j.actaastro.2016.02.005>.

¹² Gov't of India, *Draft Space Activities Bill*, Ministry of Law & Just. (2017), <https://www.prsindia.org/billtrack/draft-space-activities-bill-2017>.

¹³ Philip T. Metzger, *Space Resources and the Challenge of In Situ Resource Utilization (ISRU)*, 126 Acta Astronautica 686 (2016), <https://doi.org/10.1016/j.actaastro.2016.02.005>.

¹⁴ Lotta Viikari, *The Environmental Element in Space Law* (Martinus Nijhoff 2008).

Legal Framework for Space Mining: International and Domestic Perspectives

The contamination of space objects represents a significant environmental issue alongside others. Introducing Earth-based microbes together with pollutants into pristine environments remains a crucial concern for space exploration activities. The pollution of space areas such as the Moon and Mars and asteroids would simultaneously interfere with scientific evaluations while permanently damaging these interplanetary habitat systems.

The introduced contamination represents both scientific and ethical problems because it would obstruct future studies about Earth's origins and extrasolar living systems. Under the Outer Space Treaty (1967) states must prevent damaging pollution of space and celestial bodies but insufficient enforcement actions have been taken against them.¹⁵

Space mining creates unknown ecological effects that scientists have yet to determine properly. The scientific community has yet to thoroughly study the long-lasting effects that space mining has on celestial bodies caused by structural modifications and orbital changes that might impair their ability to support future investigations. Space mining lacks an extensive environmental protection framework thus industry managers address potential risks through individual efforts because international agreements are sparse.

The world needs immediate worldwide cooperation to establish responsible methods that reduce environmental damage from space mining operations.¹⁶ The infantile development phase of space mining in India has strengthened its visibility since the Indian Space Research Organisation (ISRO) continues to establish its ongoing space program. The Government of India now takes steps to create systematic laws regarding space activities through the Draft Space Activities Bill of 2017.

The Draft Space Activities Bill of 2017 contains regulations for licensing and environmental protection but disregards specific policies regarding space mining activity. The absence of clear regulations for space mining operations and environmental protection makes India unprepared to handle both the environmental threats and complex legal frameworks that would accompany space mining operations.¹⁷

The policy framework at IN-SPACe supports India's space policy by establishing a government organization to promote space ventures where private operators interact with the industry. The policy framework of India reveals an important legal inadequacy because it fails to specify rules for space mining combined with environmental protection measures. India needs to join international standards regarding space mining governance because sustainability and ethical practices of space mining necessitate this alignment.

India must actively join international conversations about space law change because this will help establish a complete responsible system for space resource management.¹⁸ Practical space mining operations demand an established legal framework which is vital for future development of the industry. India needs to create legal instruments which will address

¹⁵ Lotta Viikari, *Supra Note 14*

¹⁶ Fabio Tronchetti, *Supra Note 7*

¹⁷ Gov't of India, *Draft Space Activities Bill*, Ministry of Law & Just. (2017), <https://www.isro.gov.in>.

¹⁸ Indian National Space Promotion and Authorization Center (IN-SPACe), *Policy Framework and Structure*, Gov't of India (2023), <https://www.inspace.gov.in>.

ethical and environmental issues linked to space mining initiatives since it aims to become a prominent power in this field.

India needs to advance its domestic space laws and sign international space agreements together with participating in new regulatory developments in order to establish itself as a leading force in ethical space resources management.¹⁹

Environmental Implications of Space Mining

Technological progress in space mining needs deeper study since it produces significant effects in both outer space and our planet. Space mining operations take place in delicate untouched space settings that scientists have not fully studied yet. When Earth's neighbours are mined for materials their surface becomes damaged while small object orbits shift and many new pieces of space debris appear.

These actions cannot be undone because they destroy untouched areas where scientists can research the beginnings of our solar system and life. Technology transfer from Earth to space bodies breaks space protection rules under international space ethics and law standards.²⁰

The growing amount of space debris has become a major concern for everyone. When robots or crews mine space they create machine parts and wasted fuel alongside other outputs so space debris problems will increase further. The pollution poses both current operational risks and future mission threats. Returning extracted materials back to Earth creates possible damage to our planet through re-entry pollutants and crash dangers.

The Outer Space Treaty from 1967 requires states to steer clear of harmful space contaminations yet offers no tools to ensure compliance. Due to insufficient international support for the Moon Agreement of 1979, it influences very little about space mining activities. The present system lacks effective rules to protect our environment from mining in outer space.²¹

Given its current space power status India should include environmental regulation when making new space mining rules. The Indian Space Research Organisation (ISRO) and IN-SPACe should take a leading role in space environmental management by adopting worldwide space industry standards of practice.

India needs to support international efforts that create treaties with effective environment protection rules and systems to handle space mining issues. The nation needs to take these actions because they both secure space resources and help India lead the space community globally.²²

Comparative Legal Frameworks on Space Mining and Environmental Protection

Each nation state has separate regulations on space mining as they each create individual legal systems that control human activity in space. On September 25, 2015, the United States

¹⁹ Lotta Viikari, *Supra Note 14*

²⁰ *Ibid*

²¹ Joseph N. Pelton, *Supra Note 6*

²² Indian Space Research Organisation (ISRO), *Annual Report 2022–23*, Dep't of Space, Gov't of India (2023), https://www.isro.gov.in/media_isro/pdf/AnnualReports/2023/AR_English_2022_2023.pdf.

became the first country to allow companies to extract space resources, when the U.S. Commercial Space Launch Competitiveness Act of 2015 was passed.

According to American law U.S. citizens are permitted to exercise their ownership rights on space resources, however, Article II of the Outer Space Treaty prohibits owners from claiming the resources. Corporate protections identical to the provisions in its adopted legislation were included in the Space Resources Law in 2017 when Luxembourg enacted the legislation. New legal standards are adopted which arouse widespread notice because they do not harmonize with current space governance agreements and, therefore, jeopardize the stability of global governance institution.²³

As Russia and China did not specify any national legislation regarding the extraction of resources, their outer space rules comply with the world practice standards. However, extraction of resources can take place only within the frameworks given international approval, said Roscosmos together with its Russian space counterpart.

The Chinese government supports multilateral outer space governance participation through its membership in the United Nations Committee on the Peaceful Uses of Outer Space (COPUOS). Worldwide disagreement of the national and international regulations on space resources gives absent of alignment, which boosts the potentiality of political power confrontations.²⁴

Academic studies show that India requires additional complete legal structures to govern space mining operation. Though the Draft Space Activities Bill (2017) presents licensing and private participation regulations, it has no distinct resources retrieval regulation and environmental conservation regulation. There is no developed space mining governance in India due to the fact that it does not initiate regulatory creation in the sector.

For India to set up ethical regulations in place it needs to take decisions using both unipolar governance systems and collective advocacy frameworks for their business goals and to follow the environmental standards.²⁵

Comparative Legal Approaches to Space Mining Regulation

As the potential for profitable business in the area of commercial exploration of space is increased, governments of various countries create laws to oversee space mining operations. The Commercial Space Launch Competitiveness Act (2015) provided American citizens with the right to possession of space derived material while the United States maintained Outer Space Treaty commitments.

Starting from 2017, the government transforms the laws through its Space Resources Law of Luxembourg, which allows businesses to possess the spacecraft mine materials through the acquiring of the licenses. The national policies do not embrace the principle that all humans possess joint ownership of the resources of outer space.²⁶

In this regard India does not support the Moon agreement of 1979 as they vehemently reject claims of state and private property and they want an international body to govern space

²³ Fabio Tronchetti, *Supra Note 7*

²⁴ Ram S. Jakhu & Joseph N. Pelton, *Supra Note 9*

²⁵ Sandeep Joshi, *Supra Note 3*

²⁶ Fabio Tronchetti, *Supra Note 7*

resources. Having ignored its development process by the leading spacefaring nations, the Moon Agreement does not operate.

Being forced to create their own set of independent rules, countries have done so independently, without any multinational regulations on this matter. There are a variety of legal frameworks from which to operate in outer space, which poses challenges to ensuring fair participation access, and obtaining the durability of operation necessary to achieve environmental sustainability and peaceful operations.

As mentioned in present day space law, while the lack of international regulatory coherence results in technological developments that exist in state capabilities of unequal states, it creates an obstacle to global benefit thereof.²⁷ Such modern space nation approaches are critical knowledge for India as they directly affect the policy direction. At present India has no space mining policy, but knowledge gathering from other countries will help it create a suitable legal structure and strategic policy framework.

For India's future space legislation, the goal should be the establishment of a strategic balance between market success and responsible conduct satisfying international standards while preserving the interests of the long term space environmental and geopolitical space interests.²⁸

Conclusion

There is rapid progress in India's space exploration mission owing to technological development and wide scale participation in the global space program. The stage of space mining operations is important when national authorities struggle to pass space mining regulations along with environmental regulations.

Immediately the problems related to the resource extraction generated as a consequence of space mining activities should be managed through proper environmental legislations. The rules that make up the international agreements together with Outer Space Treaty principles are not enough in regulating the space mining procedures when there are critical environmental events. The system of safeguards in IN SPaCe policy documentations as well as the Draft Space Activities Bill does not protect India's space legislation system against these security threats enough.²⁹

However, the current establishment is in need of more advanced practices of governance that can link space debris environmental mitigation efforts and planetary defence with space ecological conservation. Since India has its own space activities with international implications, the country is required to apply its own legal frameworks for them that adhere to global standards without undermining ongoing space exploration efforts. Due to the absence of basic outer space environmental laws, the lack of strategic needs in India because of the absence of the system of an enforceable law, the entry into space mining is difficult.³⁰

²⁷ Ram S. Jakhu & Joseph N. Pelton, *Supra Note 9*

²⁸ Fabio Tronchetti, *Supra Note 7*

²⁹ Gov't of India, *Draft Space Activities Bill*, Ministry of Law & Just. (2017), <https://www.prsindia.org/billtrack/draft-space-activities-bill-2017>.

³⁰ Joseph N. Pelton, *Supra Note 6*

Recommendation

A series of strategic procedures, therefore, need to be established by India to adequately deal with space mining developments. The Indian government should also establish an entirely new act of Space Mining which will modify the procedures of environmental reviews as standards for sustainability, and manoeuvring the doctrines of ownership of authority alongside policy of profit sharing.

Space Mining is conceived as a legal institution which requires combination of necessary technical details with global sustainability measures in order to protect the environment.³¹ After the first requirement, the second one is a necessity for the creation of institutional competency. IN-SPACe should transform into a fully operational space mining regulatory organization fit with a global network of space mining partnerships and purposed with meeting such environmental oversight standards.

The onus is thus on Indian institutions to act as a conduit to negotiate with the international community on drawing up new rules that would force space resource extraction activities to sustain their business. To develop space mining methods with moral values and with respect of the environment, they work together academic institutions, industrial entities and civil organizations. Organizational methods are an organization of methods used by the India to reach its economic goals and to green ecological aspects of space research.³²

³¹ Steven Freeland, *Supra Note 2*

³² Indian National Space Promotion and Authorization Center (IN-SPACe), *Policy Framework and Structure*, Gov't of India (2023), <https://www.inspace.gov.in>.