

REGULATION OF IN- SITU RESOURCES UTILIZATION (ISRU) ON LUNAR AND MARTIN SURFACES

*Aaradhya Nagyan*¹

VOLUME 2, ISSUE 1 (JANUARY-JUNE 2026)

ABSTRACT

The anatomy and potential colonization of extraterrestrial bodies such as the Lunar and Martin surfaces have necessitated the development of In– Situ Resources Utilization (ISRU) technologies. The resources involve harnessing and processing regional resources like martin ice and lunar regolith to produce essential commodities such as water, oxygen and construction materials. The advancement of In-Situ resource utilization technologies had increased interest in lunar and martin exploration, which has brought significant legal, ethical and regulatory challenges. Existing international space treaties, such as the outer space treaty, 1967 and the moon agreement, 1979 provide broad provisions but fail to state clear legal guidelines on the extraction, ownership and commercialization of extra-terrestrial resources. The absence of comprehensive regulatory framework creates ambiguity regarding the rights of nations, international organizations and private entities involved in ISRU. Further there is lack of consensus on equitable resource distribution and environmental sustainability in outer space activities. The paper is attempted to analyze these gaps by examining existing legal provisions, identifying challenges and proposing a structure, regulatory framework for smooth functioning of ISRU on lunar and Martin surfaces.

Keyword: Space, Extraterrestrial, In- Situ Resource Utilization, Space Mining, Geopolitical.

¹ Aaradhya Nagyan, Research Assistant, National Law University, Jodhpur

INTRODUCTION

In- Situ Resource Utilization (ISRU), is a process of generating on products with local material on other planets is a process of generating own products with local material on other planets with aim to make human space, exploration, more sustainable, and permanent.ⁱ ISRU create sustainable commodities on other planets. The processes of ISRU includes water, evolution, solid oxide, electrolysis and hydrogen reduction, also technologies such as advanced, propulsion, advanced power systems and cryogenic fluid management. The evolution of ISRU method for the extensive exploration of extra-terrestrial and in particular for the exploration of lunar and martin will become increasingly important in the upcoming decades. It is impossible to transport required resources from earth such as commodities, hence, raw products need to be collected and modified. Some of the most important resources that need to be produced include water, oxygen, and methane along with construction and radiation shielding materials. The new space technologies that are being considered additive, manufacturing of lunar and martin is a probability. The moon and Mars regolith is the layer of loose, heterogeneous region that covers the solid rock, including soil, dust, broken rocks and other required material presented on the surfaces. With the exploration of new technologies, the processing of critical resources, such as water, metals, salt and useful volatiles may be concentrated on the extraterrestrial surface. The resource utilization scientists will require processing such as collection, storage, drilling, sorting and chemical processing of lunar and martin regulate for development. Mining tendering are focused on robotics. Extraterrestrial mining on lunar will likely start with extraction of water from the moon as it is estimated that moon accommodates the amount of water contained in ice sheets found in permanently shaded craters, i.e. 40 of these craters' states 600 million metric tons of water ice.ⁱⁱ This amount of water ice would be enough to launch one space shuttle quotidian for 2,200 years. Water can further be processed for extraction of hydrogen, which can be used as jet fuel or be used to drink and produce food further more provide radiation protection. However, In-Situ Resources Utilities is not limited to water, metals, mind from these terrestrial bodies can be used to 3D print spaceship integrate.

ISRU practice of resource exploration could provide materials for life, support, construction, material, propellant and energy to Spacecraft payloads. Several field tests in late 2000s were done to understand the environmental technique in outer space though production has not yet

been implemented. ISRU technique aims to discover water, rocket propellant solar cell production, and building materials on locations such as moon, mars, asteroids, martian, moons and planetary atmosphere.

Water: it is an essential element which is use for life support such as for drinking, producing oxygen, growing food and numerous other industrial processes the extra territorial water has been stumble in many forms throughout the solar system and numerous water extraction technology have been discovered the investigation includes chemically bound regolith, some manner of permafrost or solid ice on heating can discover the water. Though it is not as easy as it appears because permafrost could be harder than plan rock. Therefore, necessitating tough mining operations on Mars water can be extracted, simply through the process of WAVAR. Rocket propellant: the production of rocket propellant has been tendering from the moon's surface by processing water ice. The difficulties in this process are faced during extraction of water from the regolith and at extreme extremely low temperatures.ⁱⁱⁱ Many discoveries electrolyze the water to produce oxygen, hydrogen and cryogenically as liquids. This scheme requires large amount of equipment's and power. The monopropellant hydrogen peroxide (H₂O₂) can be produced from water on moon and Mars. Solar cell production: it can be produced from material present in lunar soil.^{iv} Aluminum, glass, and silicon: these three primary materials are required for solar cell production. They are found in high concentration, a lunar soil and could be used to produce solar cells. Solar arrays manufactured on lunar surface can be used to support operations and satellites. Building materials: the colonization on extra-terrestrial will require obtaining local resources available such as. The study explores artificial mars soil mix with Tetraethoxysilane (TEOS) and epoxy resin; it produces high values of resistance, strength, strength and flexibility parameters. Space mining involves extraction of metals from space which may be cost effective than bringing such material from earth or any other large body like mars or moon.^v

With the development of space technology, the thought of human settlement on the moon and mars is changing from science fiction to reality. One of the critical concerns in deep space mission is resource depend on earth which is not logistically and economically viable for long-term missions. ISRU recommends a solution by utilizing the available material on lunar and Martian to support human and robotic consideration. As technological advancements have made

In-Situ resources, utilization feasible, it's legal and regulatory implication remain largely undetermined. The unclear legal framework creates uncertainties regarding environmental sustainability, resource ownership, and the rights of different space actors.

LEGISLATIVE FRAMEWORK AND CHALLENGES

Key Challenges

1. Lack of clear ownership rights: outer space treaty, 1967 provisions prohibit national appropriation of outer space stating it and clear whether private nations or companies can claim ownership of extracted resources.
2. Conflicts between international and national laws: nations like United States and Luxembourg have their own legislature permitting private entities to extract extra-terrestrial resources potentially conflicting with international laws.
3. Absence of comprehensive ISRU framework: the existing provisions of international treaties do not specifically address In- Situ Resources Utilization, due to not clear regulation it leads to ambiguity.
4. Environmental and Ethical Considerations: existing space treaties focuses on minimizing harmful contamination but there is no comprehensive guideline on sustainable ISRU activities.
5. Dispute Resolution Mechanism: There are no legal provisions to arbitrary disputes related to outer space operations, leading to potential conflicts over extraction rights and resource claims.

Legislative Framework

International regulations and treaties applicable to extraterritorial activities lack behind rapid technological development. Currently, there are no legal provisions on outer space activities. Hence, there is significant legal uncertainty on how to proceed in mining and exploration on the lunar and martian under existing international and national laws. The international agreement asserts that no government can claim celestial body or outer space as their own, due to such assertion private companies interested in investing in outer space faces uncertainties as a measure impediment to upcoming commercial development of moon and mars. The private companies argue that the absence of rights is in impudent to obtaining external financing, be a

hindrance to the protection of their expenditure in space and adequate guarantee of their expenditure.

- Outer Space Treaty is the official available international space law which came into existence in 1967 and has been signed and rectified by above hundred nations. Article 1 of the treaty states: the exploration and use of outer space shall be carrying out for benefit and in interest of all nations.^{vi} Outer space includes the moon and other celestial bodies, it further states that the outer surface shall be free for exploration and use by all nations without discrimination of any kind, i.e. on a basis of equality and there shall be free access to all areas. The article does not clearly state whether the extraction of extraterrestrial is lawful.
- The international Institute of space law addresses that: as the outer space treaty provisions do not express right to extract space resources, hence it does not prohibit such action. Article 1 provides the countries for free exploration and use of celestial bodies in space without discrimination. The treaty does not clarify on the free use of non-renewable natural space resources. It can be addressed that outer space treaty is the constitution of international space law.
- Moon treaty: Addresses resource extraction from the lunar. It states that lunar and other celestial bodies in space, including their natural resources are the province of all mankind (Marboe 2016) and common heritage of all mankind (Roth 2015). The moon treaty has not been signed by many countries, including United States and other space faring nations because it was believed that the moon treaty is obsolete and could create a significant barrier to private space mining.^{vii}
- The liability convention: addresses damage caused by space objects that includes the agreement on rescue and return of astronauts and objects instigated into extra-terrestrial. It creates a liability regulation for damage affected by spacecraft and creates strict liability standards for negligence and accidents on earth surface or elsewhere. The provision of liability convention resolves disputes through the claims commissions which are decided with the consent of the parties.
- The Hague international Space resources, governance working group: the goal of the group is to prepare regulatory framework. It supports international laws for the benefits and interest of all nations and humanity for peaceful scientific development.

- United Nation Office for Outer Space Affairs: Outer space affair was established in year 1958, it was to ensure peaceful exchange of affairs among different countries relating to space. Many developing countries believe that space material and space exploration can be an economic help to them. In 2005 international committee on global navigation satellite system (ICG) was established with aim to advance, similarity, straightforwardness and interoperability between all the satellites navigation system. In 2006 UN-SPIDER strategy was made to provide open stage to utilize the space innovations for fiasco.^{viii} The body also regulates international treaties and international agreements related to outpace laws.
- US legal framework: United States was the first country to start working on space legislative structure and has been successfully leading the world in space matters. US has definite public space law, most powerful regulation and admin administrator system exercising on space activities.
- India is one of the biggest hubs in developing extraterrestrial exploration, but still lacks with strict legal structure. Though India has policies and regulations for functioning:
 1. Remote Sensing Data Policy of 2011: it allows obtaining, disposal and executive of far of detecting information.
 2. The Satellite Communication Act 1997: the act regulates and develops satellite communications.
 3. The Draft Space Activities Bill: it was drafted in 2017; the bill is still yet to become a working act.

CONCLUSION

The ordinance of In-Situ Resource Utilization activities on lunar and Martian surfaces is a concern that requires immediate attentiveness as space exploration make headway. Presently international treaty stipulates general principles, but lack specific regulation for resource utilization. The research concludes that a multilateral framework is essential to preside over ISRO activities, ensuring equitable access to space resources. Alliance among nations, legal clarity on ownership, rights and environmental shield must be embodying into succeeding space policies to facilitate sustainable extraterrestrial investigation.

The current international regulatory framework and guidelines governing extra-terrestrial resource utilization is in adequate to address the challenges of ISRU on the lunar and martin

surfaces. A well-structured, multilateral and legal framework, incorporating principles of equity, sustainability and International Corporation will facilitate fair and responsible In- Situ resources utilization activities.

RECOMMENDATIONS AND SUGGESTIONS

1. Environmental and ethical considerations: strict guidelines on minimum ecological damage to auto space and maintain planetary protection.
2. International Corporation and Treaty Amendment: amending existing space treaties, such as including mechanisms for fair resource allocation and dispute resolution
3. Development of Unified Legal Framework: an international legislative framework needs to be established under the governance body to regulate the ISRU functioning and ensuring equitable, excess and sustainability principles. The lawmakers must periodically review ISRU activities and amend legal provision according to the development.

i NASA, 'Overview: In-Situ Resource Utilization' (NASA, no date) <https://www.nasa.gov/overview-in-situ-resource-utilization/>

ii Shreya Mane, 'Overview on In-Situ Resource Utilization on Mars' (2024)

https://www.researchgate.net/publication/380066511_Overview_on_In-Situ_Resource_Utilization_on_Mars

iii Stanley O Starr and Anthony C Muscatello, 'A comprehensive review of in-situ resource utilization for lunar and Martian exploration' (2019) *Planetary and Space Science*

<https://www.sciencedirect.com/science/article/abs/pii/S0032063319301618>

iv International Space Exploration Coordination Group, In-Situ Resource Utilization Gap Assessment Report (April 2021) <https://www.globalspaceexploration.org/wordpress/wp-content/uploads/2021/04/ISECG-ISRU-Technology-Gap-Assessment-Report-Apr-2021.pdf>

v Peng Zhang, Wei Dai, Ran Niu, Guang Zhang, Guanghui Liu, Xin Liu, Zheng Bo, Zhi Wang, Haibo Zheng, Chengbao Liu, Hanzhe Yang, Yifan Bai, Yang Zhang, Dong Yan, Kefa Zhou and Ming Gao, 'Overview of the Lunar In Situ Resource Utilization Techniques for Future Lunar Missions' (2023) *Space: Science & Technology* <https://www.sciopen.com/article/10.34133/space.0037>

vi Christopher Daniel Johnson, 'The Outer Space Treatylocked' (2018) *Oxford Research Encyclopedia of Planetary Science* <https://doi.org/10.1093/acrefore/9780190647926.013.43>

vii Janani A, 'The Moon Agreement & India' (ILE Legal Blog, 2 January 2023) <https://blog.iledu.in/the-moon-agreement-india/>

viii United Nations Office for Outer Space Affairs, 'United Nations Office for Outer Space Affairs (UNOOSA)' (Sustainable Development Goals Knowledge Platform, 2024) <https://sdgs.un.org/un-system-sdg-implementation/united-nations-office-outer-space-affairs-unoosa-49126>