

INTERNATIONAL JOURNAL OF LAW MANAGEMENT & HUMANITIES

[ISSN 2581-5369]

Volume 7 | Issue 2

2024

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Legal Challenges and the Concept of the Commons in Commercial Space Mining: A Need for Uniformity in International Space Law

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ABSTRACT

The Outer Space Treaty of 1967, ratified by more than 100 nations, stipulates in Article II that space is not a national resource and should only be utilised for peaceful purposes. As a result, the legal environment for commercial space mining activities becomes complicated, necessitating coordination and collaboration among several nations and international organisations. The consideration of space as a commons is a crucial component of regulating commercial space mining. This consideration has given rise to the notion that space should be viewed as a common heritage of mankind, raising concerns about ownership and exploitation of space resources. The consequences of considering space as a commons for commercial space mining are examined in this paper, along with any possible conflicts that could develop between companies and states. Defining commercial space mining is an essential component of this research paper. Commercial space mining involves the extraction and processing of resources from celestial bodies for profit. This paper examines the many resources that could be extracted, such as water, metals, and rare earth elements, as well as the benefits and hazards of doing so commercially. The Outer Space Treaty does not explicitly address the issue of commercial mining of space resources, such as asteroids or lunar regolith. This has led to legal uncertainty and controversy over the rights and obligations of states and private actors in this domain. Some states, such as the United States and Luxembourg, have enacted national laws granting property rights to citizens or companies that extract or appropriate space resources. Other states, such as Russia and China, have opposed this approach and argued that it violates the Treaty and the principle of the common heritage of mankind. The Artemis Accords, too, while not binding, establish that when nations engage in mining activities on the moon, they do not obtain property rights over the extracted materials. The paper examines the application of international conventions vis-a-vis regional laws related to commercial space mining. The paper adopts a doctrinal method of research based on

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secondary sources along with regional case studies involving leading companies worldwide in the field of Space Mining. In conclusion, this paper underscores the need for uniformity in international law relating to commercial space mining for legal clarity and certainty, a concrete dispute resolution mechanism, fair competition, environment protection and equitable distribution of profits. The paper also recommends that international organisations, such as the United Nations or a specialised agency, should develop and oversee such laws in consultation and cooperation with states and private actors.

Keywords: *Commercial space mining, Space as a commons, Space law, Space resources, International treaties, Regional laws.*

I. INTRODUCTION

Commercial space mining has become a reality with the increasing commercialisation of space activities and the advent of new technologies. However, this new frontier presents various legal challenges and raises questions about the concept of the commons in outer space. This paper examines the legal challenges and opportunities presented by commercial space mining and argues for the need for uniformity in international space law to provide a clear legal framework for commercial space mining.

One of the key challenges facing commercial space mining is the question of ownership and property rights in outer space. Under current international law, it is unclear whether private entities have the right to extract and utilise resources from celestial bodies such as asteroids or the Moon. This paper examines this issue in detail and argues for the need for clear legal guidelines on property rights in outer space.

Another essential aspect to consider is the potential economic impact of commercial space mining. The extraction and utilisation of resources from celestial bodies could have significant economic consequences if these resources are brought back to Earth. This paper examines this issue in detail and argues for the need for strong regulations to ensure that commercial space mining is conducted in an economically responsible manner.

Section 1 of this paper provides background information and context on commercial space mining and summarises existing research while outlining its purpose and scope. Section 2 examines the current state of international space law and its applicability to commercial space mining. This includes an analysis of the challenges and opportunities for regulating commercial space mining at the international level and the role of the United Nations in regulating commercial space mining. This section positions the paper's approach by detailing its research problem and problem statement.

Section 3 starts with an overview of countries and private companies that have established national space mining initiatives and programs, such as the United States' Artemis Program and Luxembourg's SpaceResources initiative. Private companies based in the United States and Japan, such as Planetary Resources and Deep Space Industries, are also mentioned. The section then delves into specific case studies of countries, such as the United States, Luxembourg, China, and Russia, pursuing commercial space mining. Section 4 considers the potential benefits and drawbacks of commercial space mining. This includes an analysis of the potential economic benefits and drawbacks of commercial space mining and its potential impact on international cooperation and competition.

This paper argues that there is a need for uniformity in international space law to provide a clear legal framework for commercial space mining. This includes clear guidelines on property rights in outer space, as well as strong environmental regulations to ensure that these activities are conducted responsibly and sustainably. The paper in Section 5 concludes with a summary of its key findings and a discussion of their implications for future research and policy-making.

II. INTERNATIONAL SPACE LAW AND COMMERCIAL SPACE MINING

(A) Overview of international space law

International space law is a specialised field of international law that governs the conduct of States and other actors in their exploration and use of outer space. This body of law delineates the rights and obligations of these actors concerning their activities in this domain. The fundamental principles and objectives of international space law include the peaceful utilisation of outer space, the prevention of harmful interference with space operations, and the facilitation of international cooperation in exploring and exploiting outer space.

A central tenet of international space law is the notion that outer space constitutes a global commons, implying that it is not subject to national sovereignty or appropriation claims. This principle is enshrined in several international legal instruments, including the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty)³, which is widely regarded as the foundation of international space law.

While existing provisions within international legal instruments may provide some guidance on regulating commercial space mining activities, there are also significant gaps and challenges

³ Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (adopted 27 January 1967, entered into force 10 October 1967) 610 UNTS 205 ILM 6 386.

within the current legal framework that must be addressed to ensure that commercial space mining is conducted responsibly and sustainably.

International organisations play a crucial role in developing and implementing international space law. The United Nations Committee on the Peaceful Uses of Outer Space (COPUOS) is responsible for promoting international cooperation in the peaceful uses of outer space and for developing legal instruments to govern space activities. The United Nations Office for Outer Space Affairs (UNOOSA) serves as the secretariat for COPUOS. It promotes access to space for all through various conferences and capacity-building programs.

The United Nations has established a framework for regulating commercial space mining through its treaties and agreements. One such treaty is the Outer Space Treaty⁴, which prohibits governments from claiming sovereignty over space for their own purposes. Additionally, the Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (Moon Agreement)⁵ stipulates that celestial bodies must be used only for peaceful purposes and that their natural habitats must not be disturbed.

The United Nations also has activities and programmes to support ethical commercial space mining in addition to these treaties and accords. For instance, through its Access to Space for All project,⁶ people worldwide may use and gain from space technology and applications. The United Nations is essential for a sustainable and responsible practice of commercial space mining. It does this by ensuring that the burgeoning business benefits humanity by creating and executing international space law, encouraging collaboration, and funding projects and programmes targeted at responsible space mining.

(B) Applicability of international space law to commercial space mining

a. Outer Space Treaty

Article II⁷ of the Outer Space Treaty stipulates, “Outer space, including the moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.”

A close reading of Article II's⁸ language shows that it expressly restricts the scope of the

⁴ Ibid.

⁵ Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (adopted 5 December 1979, entered into force 11 July 1984) 1363 UNTS 3 ILM 18 1434.

⁶ United Nations Office for Outer Space Affairs (UNOOSA), ‘Access to Space for All’ (UNOOSA) <https://www.unoosa.org/oosa/en/ourwork/access2space4all/index.html>

⁷ Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (adopted 27 January 1967, entered into force 10 October 1967) 610 UNTS 205 ILM 6 386, art II.

⁸ Ibid.

prohibition to apply only to states and not to other entities, such as private enterprises. The principle of *expressio unius est exclusio alterius*, which states that explicitly mentioning one item implies that the alternative is excluded, is frequently cited by proponents of this viewpoint. The main contention that the Outer Space Treaty⁹ does not seek to prohibit private ventures from exploiting space resources for commercial reasons is the failure to include private entities within the scope of this prohibition specifically.

It can be contended that the Outer Space Treaty¹⁰ permits the economic use of space resources, including celestial bodies like asteroids, by private persons and business enterprises (not subjects of governments). The preamble¹¹ of the Treaty, which acknowledges the shared interest of all humanity in the "exploration and use" of outer space, further supports this claim. Therefore, it can be argued that the Outer Space Treaty¹² implicitly permits individual and commercial endeavours to explore and exploit space resources by recognising the "usage and exploration" and explicitly prohibiting states from appropriating space resources.

b. The moon agreement

The amount of permissible resource extraction is covered in further depth in the Moon Agreement¹³. It demands that the exploitation of space resources occur within a global system that would mandate "equitable sharing by all States Parties in the benefits derived from space resources" and forbid any lone, governmental or private, endeavours to participate in resource extraction.

Additionally, Article 11¹⁴ of the Moon Agreement declares that the natural resources found on the Moon are a shared heritage of all humans. As a result, the Moon Agreement explicitly forbids the extraction of lunar natural resources, which conflicts with American space strategy. This subject was discussed during the Legal Subcommittee's 55th meeting of the UNCOPUOS. The United States, however, remained adamant that it is immune from the duties resulting from the Moon Agreement¹⁵ since it is neither a signatory nor ratified it.

The only way to make the case that the United States is economically exploiting space resources is by establishing a standard under customary international law. In other words, the Moon

⁹ Outer Space Treaty (adopted 27 January 1967, entered into force 10 October 1967) 610 UNTS 205 ILM 6 386.

¹⁰ Ibid.

¹¹ Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (adopted 27 January 1967, entered into force 10 October 1967) 610 UNTS 205 ILM 6 386, preamble.

¹² Outer Space Treaty (adopted 27 January 1967, entered into force 10 October 1967) 610 UNTS 205 ILM 6 386.

¹³ Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (adopted 5 December 1979, entered into force 11 July 1984) 1363 UNTS 3 ILM 18 1434.

¹⁴ Ibid, art 11.

¹⁵ Ibid.

Agreement¹⁶ prohibition must be raised and recognised as a standard of international law to apply to the United States.

No international agreement forces the United States to forbid private companies from engaging in commercial space mining¹⁷. Furthermore, there is no absolute prohibition in customary international law prohibiting the one-sided exploitation of space resources. Therefore, it can be asserted that the United States fully abides by its obligations under the international law of space by relying on the Lotus Principle¹⁸, which states that anything not expressly prohibited under international law is implicitly permitted.

c. The Artemis Accords

The Artemis Accords¹⁹ are principles for international cooperation in space exploration and utilisation, spearheaded by the United States. These principles include transparency, peaceful exploration, the use of resources in a sustainable manner, and the protection of heritage sites. They apply to commercial space mining because they provide a framework for nations and companies to work together in exploring and utilising resources in space while ensuring the responsible use and protection of those resources. The Accords encourage cooperation and coordination among nations, which is essential for developing a sustainable and equitable commercial space mining industry.

According to the Artemis Accords, "contracts and other legal instruments relating to space resources should be consistent with the [Outer Space] Treaty," and "the extraction of space resources does not inherently constitute national appropriation."²⁰ In other words, countries that mine the minerals on the Moon do not obtain any ownership or property rights over such resources.

In this way, the Artemis Accords continue to fall within the Outer Space Treaty's²¹ national appropriation clause. The Artemis Accords²² promote the first-come, first-served usage of space resources in practice since there is no legislative framework defining who gets access to space resources and under what conditions. States with the resources and technology to arrive first will therefore stand to gain the most. The use of space resources will not immediately benefit

¹⁶ Ibid.

¹⁷ Frans G von der Dunk, 'The Moon Agreement and the Prospect of Commercial Exploitation of Lunar Resources' (2018) 43 *Air and Space Law* 3

¹⁸ The Case of the S.S. "Lotus" (France v Turkey) 1927 PCIJ series A No 10, 18-19.

¹⁹ Artemis Accords: Principles for Cooperation in the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids for Peaceful Purposes (adopted 13 October 2020) THE ARTEMIS ACCORDS accessed 10 May 2023.

²⁰ Ibid, cl 10.

²¹ Outer Space Treaty (adopted 27 January 1967, entered into force 10 October 1967) 610 UNTS 205 ILM 6 386.

²² Artemis Accords: Principles for Cooperation in the Civil Exploration and Use of the Moon, Mars, Comets, and Asteroids for Peaceful Purposes (adopted 13 October 2020) THE ARTEMIS ACCORDS accessed 10 May 2023.

less developed or fledgling spacefaring governments.

A further requirement of the Artemis Accords²³, which adds specifics to the Outer Space Treaty, is for countries undertaking activities on the Moon to establish a "safety zone" to prevent harmful interference with other countries' activities. A safety zone is a small, temporary exclusion zone. Clause 9 of the Accords strives to preserve outer space heritage by establishing a safe zone. While protecting historical sites on Earth is widely accepted, there is no precedent for identifying a historic site in space. For example, the United States may proclaim the Apollo 11 landing site and Neil Armstrong's boot prints a historic site and establish a safety zone around them. This has been criticised for amounting to a de facto annexation of a portion of the Moon²⁴.

(C) Challenges in regulating commercial space mining at the international level

The current legal framework for commercial space mining has several gaps and challenges. While some countries like the US, Luxembourg and Japan have adopted domestic laws granting legal protection to rights of commercial entities to own, transport, use and sell mined space resources, uncertainty still exists due to states' obligations to international space treaties and under-evolved international norms on space mining.²⁵

Another issue is that governments enact their own national legislations to cover loopholes in international law, so increasing and regulating the activities of their people. However, those regulations have little to no effect on foreign nationals residing outside their country's space station or spacecraft.²⁶

Environmental protection is yet another challenge. The Moon Agreement²⁷ forbids any activity that will affect the moon's ecology and demands that any resources retrieved be shared by all governments. However, the Moon Agreement²⁸ has only been approved by a few countries, and the leading spacefaring states have yet to sign or ratify it. Therefore, there is no clear legal framework for protecting the environment in the context of commercial space mining activities.

(D) Role Of National Legislation

National legislation plays a vital role in regulating commercial space mining activities. The

²³ Ibid, cl 9.

²⁴ McKeown B, Dempster AG and Saydam S, 'Artemis Accords: Are Safety Zones Practical for Long Term Commercial Lunar Resource Utilisation?' (Space Policy, 24 August 2022) accessed 10 May 2023

²⁵ Avuthu VSR, "Commercial Space Mining: Economic and Legal Implications" (ORF2017) <<https://www.orfonline.org/research/commercial-space-mining-economic-and-legal-implications/>> accessed May 7, 2023

²⁶ K Muzyka 'The Problems with an International Legal Framework for Asteroid Mining' (2018) 1(1) Deep Space Commodities 123

²⁷ Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (adopted 18 December 1979, entered into force 11 July 1984) 1363 UNTS 3 (Moon Agreement) art 7

²⁸ Ibid.

legislation provides a legal framework for private companies to engage in commercial space mining activities while protecting their rights. National legislation can clarify the ownership and extraction rights of resources in space within a country's jurisdiction. National legislation can also set out environmental protection standards and regulations to ensure that commercial space mining activities do not harm the environment. A standardised licensing and permitting process for commercial space mining activities could be established by national legislation. This can ensure that companies meet the required standards and regulations before engaging in mining activities.

However, developing national legislation for commercial space mining activities can create legal and regulatory conflicts between countries. Therefore, it is crucial for national legislation to be consistent with international space law and to be developed in consultation with other countries and international organisations. It is important for the international community to work together to develop a legal framework that balances the interests of all the States, to ensure the sustainable and responsible use of outer space resources.²⁹

Some countries have already enacted national laws and regulations for commercial space mining activities. For example, the United States has passed the Commercial Space Launch Competitiveness Act³⁰, Luxembourg has enacted the Law on the Exploration and Use of Space Resources³¹ of 2017 and Japan has enacted the Space Resources Act³².

III. CASE STUDIES OF COUNTRIES AND COMPANIES PURSUING COMMERCIAL SPACE MINING

(A) USA

The United States passed the Commercial Space Launch Competitiveness Act (CSLSA) in 2015, which allows American companies to legally mine resources from asteroids and other celestial bodies³³. One of the key provisions of the CSLCA is the recognition of property rights for resources extracted from celestial bodies, such as asteroids and the moon. The Act states that any resources extracted from celestial bodies are the property of the entity that extracted them³⁴. This provision departs from the international legal framework, which generally

²⁹ Lee RJ, 'Meeting the Challenges and Balancing the Competing Interests in Creating a Legal and Regulatory Framework' (SpringerLink, 1 January 1970) accessed 10 May 2023

³⁰ U.S. Commercial Space Launch Competitiveness Act of 2015, Pub L No 114-90, 129 Stat 704

³¹ Loi du 20 juillet 2017 sur l'exploration et l'utilisation des ressources de l'espace (Law of 20 July 2017 on the Exploration and Use of Space Resources) Mémorial A n°674 (Luxembourg)

³² 宇宙資源活用法 (Space Resources Utilization Act) Law No 33 of 2020 (Japan)

³³ 'U.S. Commercial Space Launch Competitiveness Act, Pub. L. No. 114-90, 129 Stat. 704 (2015)'.

³⁴ Ibid

prohibits the national appropriation of celestial bodies and their resources. The CSLCA recognises that private sector investment in commercial space mining is critical to the development of the industry and provides a legal framework that promotes innovation and investment.

The CSLCA also provides regulatory certainty for companies engaged in commercial space mining³⁵. The Act requires the Secretary of Commerce to develop a licensing and permitting process for commercial space mining activities. This process includes a requirement for companies to demonstrate that their activities will not cause harmful interference with other space activities or the environment. The licensing and permitting process provides a clear framework for companies to engage in commercial space mining activities while ensuring they meet the required standards and regulations.

Section 403 of the CSLCA states that the President should discourage government barriers to developing economically viable, safe, and stable industries for the exploration and utilisation of space resources in manners consistent with the existing international obligations of the United States³⁶. This could imply that the President should promote international cooperation and coordination on space resource issues and respect the rights and interests of other countries in outer space.

(B) Luxembourg

Luxembourg has taken a proactive approach to promoting the sustainable and responsible utilisation of resources in space. It passed the Law on the Exploration and Use of Space Resources in 2017 to provide a legal framework for commercial space mining activities³⁷. The law is designed to clarify the ownership and extraction rights of resources in space and provide legal certainty for private companies engaged in commercial space mining. The law defines space resources as any natural resources found on or below the surface of celestial bodies, including minerals, water, and gases. Article 4 of the Act establishes the right of private companies to own and exploit these resources in accordance with the law³⁸. However, Article 7 also stipulates that the ownership and extraction of resources in space must be carried out sustainably and responsibly and in compliance with international law³⁹.

³⁵ Ibid

³⁶ 'U.S. Commercial Space Launch Competitiveness Act, Pub L No 114-90, § 403 (2015)'.

³⁷ 'Loi du 20 juillet 2017 sur l'exploration et l'utilisation des ressources de l'espace'.

³⁸ 'Loi du 20 juillet 2017 sur l'exploration et l'utilisation des ressources de l'espace (Law of 20 July 2017 on the Exploration and Use of Space Resources) Mémorial A n°674 (Luxembourg), art 4'.

³⁹ 'Loi du 20 juillet 2017 sur l'exploration et l'utilisation des ressources de l'espace (Law of 20 July 2017 on the Exploration and Use of Space Resources) Mémorial A n°674 (Luxembourg), art 7'.

It also establishes a licensing and regulatory regime for commercial space mining activities. Companies seeking to engage in commercial space mining must apply for a licence from the Luxembourg Space Agency (LSA)⁴⁰. The LSA is responsible for reviewing and approving licence applications and ensuring licence holders comply with the law and applicable regulations. Licence holders must also comply with international treaties and agreements, including the Outer Space Treaty and the Moon Agreement. The law requires licence holders to submit regular reports to the LSA on their mining activities and to adhere to environmental and safety standards⁴¹.

(C) China

China has taken a unique approach to commercial space mining by combining state control with private enterprise. The country does not have national legislation to provide a legal framework for exploring and utilising space resources. However, the China Aerospace Science and Technology Corporation (CASC), a state-owned enterprise, plays a crucial role in China's space mining industry. The company is responsible for developing China's space technology and has been involved in several space mining projects. In 2020, CASC announced plans to launch a mission to explore and extract resources from the moon, including helium-3, a rare isotope that could be used in nuclear fusion energy⁴².

While the Chinese government has supported the development of a space mining industry, it has also expressed concerns about the potential security implications of private companies engaging in space mining activities⁴³. To address these concerns, the government has established a system of state control over space mining activities, with private companies required to work with state-owned enterprises such as CASC to conduct mining operations⁴⁴.

(D) Russia

Russia's legal approach to commercial space mining is similar to China's in that it strongly emphasises state ownership and control of space resources.

Russia's approach to commercial space mining is primarily based on the Federal Space Law of

⁴⁰ 'Loi du 20 juillet 2017 sur l'exploration et l'utilisation des ressources de l'espace (Law of 20 July 2017 on the Exploration and Use of Space Resources) Mémorial A n°674 (Luxembourg), art 13'.

⁴¹ Ibid

⁴² Ariel Cohen, 'China's Space Mining Industry Is Prepping For Launch' (Forbes, 26 October 2021) <https://www.forbes.com/sites/arielcohen/2021/10/26/chinas-space-mining-industry-is-prepping-for-launch--but-what-about-the-us/> accessed 9 May 2023.

⁴³ 'CCP Announces Plan to Take Control of China's Private Sector' (Asia Financial, 17 September 2020) <https://www.asiafinancial.com/ccp-announces-plan-to-take-control-of-chinas-private-sector> accessed 9 May 2023.

⁴⁴ Ibid

1993⁴⁵, which outlines the basic principles of space activities in Russia. The law sets out the ownership and use of space resources, including the exploration and exploitation of space resources. It also establishes the regulatory framework for space activities in Russia, including licensing and permitting requirements for commercial space mining.

The Federal Space Law establishes that space resources are the state's property, and any commercial space mining activities must be conducted with the approval and supervision of the state⁴⁶. This approach reflects Russia's historical emphasis on state control of space activities and its desire to maintain its leadership in the field.

Another notable aspect of Russia's legal approach to commercial space mining is its emphasis on international cooperation. The country has been actively engaged in discussions on space resource utilisation at the international level and has advocated for establishing international norms and standards for the industry⁴⁷. Russia's participation in international discussions on space resource utilisation reflects its recognition of the global nature of space activities and its commitment to ensuring the responsible and sustainable development of the industry⁴⁸.

(E) Private Companies

Some of the private companies pursuing commercial space mining include Planetary Resources, Deep Space Industries, Deltion Innovations Ltd, Moon Express, ispace Inc., Trans Astronautica Corporation, and Asteroid Mining Corporation Limited⁴⁹.

Planetary Resources was founded in 2009 with the goal of robotically mining a near-Earth asteroid. The company's strategy was to use advanced robotics and inexpensive spacecraft to extract resources from asteroids. Deep Space Industries was founded in 2013 with a similar goal of mining asteroids for resources. The company's strategy was to use advanced propulsion technology and small spacecraft to extract resources from asteroids. However, both companies were acquired due to financial losses by companies that have nothing to do with asteroid

⁴⁵ LAW OF THE RUSSIAN FEDERATION "About space activities" (Federal Law of the Russian Federation on Citizenship of the Russian Federation) (the Russian House of Soviets).of August 20, 1993 No.5663-I

⁴⁶ Ibid

⁴⁷ 'The Strategic Implications of the China-Russia Lunar Base Cooperation Agreement' (The Diplomat, 19 March 2021) <https://thediplomat.com/2021/03/the-strategic-implications-of-the-china-russia-lunar-base-cooperation-agreement/> accessed 9 May 2023.

⁴⁸ 'Working Group on Space Resources' (UNOOSA) <https://www.unoosa.org/oosa/en/ourwork/copuos/lsc/space-resources/index.html> accessed 9 May 2023.

⁴⁹ 'Global Space Mining Market Growth, Trends and Forecasts 2020-2038' (Business Wire, 29 May 2020) <https://www.businesswire.com/news/home/20200528005926/en/Global-Space-Mining-Market-Growth-Trends-and-Forecasts-2020-2038---Featuring-Prominent-Players-Bradford-Moon-Express-ispac-and-Asteroid-Mining-Corporation-Ltd---ResearchAndMarkets.com>

mining^{50 51}.

One strategy that these companies have been using is to focus on mining water, iron and nickel, as well as platinum group metals (PGMs) from asteroids using robotics⁵². The advent of small and inexpensive CubeSats is a potential major boon for the space mining industry⁵³. These new-type spacecraft are spin-stabilised and do not last long, but the basic idea of having very inexpensive spacecraft which can be mass-produced are fortuitous for future asteroid mining efforts.

Private firms are also emerging as leaders in developing “NewSpace” activities — a catch-all for endeavours including orbital tourism, orbital manufacturing and mini-satellites providing specialised services. These companies are capitalising on decreasing costs for launch and space hardware, in general, to entice new entrants into this market.

(F) Possible Partnerships

There is potential for partnerships and collaborations between countries and companies in the pursuit of commercial space mining. Several countries, including Russia, Japan, India and the European Space Agency, all harbour space-mining ambitions of their own.

NASA has also selected commercial space partners for collaborative partnerships. The companies selected for the Collaborations for Commercial Space Capabilities and their projects include ATK Space Systems and Final Frontier Design⁵⁴. ATK Space Systems is developing space logistics, hosted payload and other space transportation capabilities, while Final Frontier Design is developing intra-vehicular activity space suits⁵⁵.

In Europe, an entrepreneurial wave is invigorating the European space sector and attracting funding for innovative products and services. The European Space Agency (ESA), which has

⁵⁰ GeekWire, ‘Bradford buys Deep Space Industries, shifting from asteroids ...’ (GeekWire) <https://www.geekwire.com/2019/bradford-buys-deep-space-industries-shifting-focus-asteroid-mining-green-propulsion/>

⁵¹ Future Timeline, ‘Asteroid mining market to be worth \$3.9bn by 2025’ (Future Timeline) <https://www.futuretimeline.net/blog/2019/07/2.html>

⁵² BBC News, ‘Asteroid mining: Helping to meet Earth’s natural resource demands’ (BBC News) <https://www.bbc.com/news/technology-61421787>

⁵³ ResearchGate, ‘Designing reliable detumbling mission for asteroid mining’ (ResearchGate) https://www.researchgate.net/profile/Mahdi-Jafari-Nadoushan-2/publication/341348266_Designing_reliable_detumbling_mission_for_asteroid_mining/links/6114dec31ca20f6f8617a4cf/Designing-reliable-detumbling-mission-for-asteroid-mining.pdf

⁵⁴ ‘NASA Solicits New Collaborative Partnerships with Commercial Space Industry’ (NASA 2014) <https://www.nasa.gov/press/2014/march/nasa-solicits-new-collaborative-partnerships-with-commercial-space-industry/>

⁵⁵ ‘NASA Selects Commercial Space Partners for Collaborative Partnerships’ (NASA 2014) <https://www.nasa.gov/press/2014/december/nasa-selects-commercial-space-partners-for-collaborative-partnerships/>

22 member nations, provides guidance and funding to help promote innovation. The European space sector has a rich, complex mix of stakeholders that can be divided into four main groups: Public agencies, Established companies, Disruptors and Investors. In making decisions, these stakeholders often balance complex and potentially competing priorities. Research has identified four major success factors applicable to collaboration in the European space ecosystem: a shared vision, geographical focus, start-up centricity and access and value⁵⁶.

IV. THE IMPACT OF COMMERCIAL SPACE MINING

(A) Potential benefits of commercial space mining

There are several other potential advantages countries can gain from commercial space mining. One potential benefit is the advancement of scientific knowledge. Space mining can provide valuable information about the composition and history of celestial bodies. This information can help scientists better understand the origins and evolution of our solar system. Another potential benefit is the development of new technologies. Space mining requires advanced technologies for extracting, transporting and processing resources. The development of these technologies can have spin-off benefits for other industries and lead to the creation of new products and services.

Commercial space mining can also help countries achieve their strategic goals. For example, governments can use space mining to secure a reliable supply of critical resources such as rare earth elements. These elements are essential for producing high-tech products such as smartphones, wind turbines and electric vehicles.

In addition, commercial space mining can help countries reduce their dependence on foreign sources of resources. This can enhance a country's energy security and reduce its vulnerability to supply disruptions.

Commercial space mining might result in substantial economic gains. Access to precious materials in short supply on Earth is one of the key advantages. Iron and titanium might be mined from the Moon or asteroids to build in-space dwellings or supply refuelling stations⁵⁷. This may result in the growth of new industries and the creation of jobs⁵⁸.

Many industries, including meteorology, energy, telecommunications, insurance, maritime,

⁵⁶ 'Strengthening collaboration among European space startups' (McKinsey & Company) <https://www.mckinsey.com/industries/aerospace-and-defense/our-insights/strengthening-collaboration-in-the-european-space-ecosystem>

⁵⁷ 'Space Mining Market - Growth, Trends, COVID-19 Impact, and Forecasts (2021 - 2026)' (Mordor Intelligence) <https://www.mordorintelligence.com/industry-reports/space-mining-market-industry> accessed 7 May 2023

⁵⁸ Ibid

aviation, and urban development, have benefited from deploying new space infrastructure⁵⁹. Encouraging asteroid mining technology may also be crucial for creating a future space economy that includes everything from settlement to tourism. However, there are some concerns about the potential negative impact of asteroid mining on the global raw materials economy⁶⁰.

(B) Potential drawbacks of commercial space mining

While commercial space mining has the potential to provide numerous benefits for different countries, there are also potential drawbacks that need to be considered.

One potential drawback is the risk of collisions between satellites and space debris. As space becomes more crowded and commercialised, the risk of collisions between satellites and space debris increases. This means that new regulations on the use of space are urgently needed. Another potential drawback is the lack of international regulations on the use of space resources. Under current international law, the benefits from commercial mining in global commons areas, including the international seabed, must be shared equitably by “all mankind”. However, there is currently no international legal framework for the utilisation of space resources and this has led to actions driven primarily by national interests.

A potential environmental drawback is the risk of pollution. Mining operations can produce large amounts of waste materials, including tailings and rock. If not properly managed, these waste materials can contaminate the surrounding environment and pose a threat to local ecosystems. Another potential environmental drawback is the impact on local ecological systems. The infrastructure created by mining operations in remote, untouched landscapes can lead to improved access to these regions which may result in further human-caused disturbance to the local ecological systems.

One source of concern is the possibility of more significant economic disparity.⁶¹ There may be significant discrepancies between those who can make use of the riches and others who are most vulnerable to exploitation⁶². There's also a chance that the early triumphs in asteroid mining will be the only ones, with competition from existing enterprises acting as an additional barrier

⁵⁹ Matthew Weinzierl and Mehak Sarang, ‘The Commercial Space Age Is Here’ (Harvard Business Review, 12 February 2021) <https://hbr.org/2021/02/the-commercial-space-age-is-here> accessed 7 May 2023.

⁶⁰ ‘Metals and mining mega-trends to 2050’ (Miningreview.com, 11 April 2018) <https://www.miningreview.com/top-stories/industry-trend-analysis-metals-mining-mega-trends-2050/> accessed 7 May 2023.

⁶¹ Douglas Broom, ‘Is the commercialization of space a risk too far?’ (World Economic Forum, 12 January 2022) <https://www.weforum.org/agenda/2022/01/what-are-risks-commercial-exploitation-space/> accessed 7 May 2023.

⁶² Matthew Weinzierl and Mehak Sarang, ‘The Commercial Space Age Is Here’ (Harvard Business Review, 12 February 2021) <https://hbr.org/2021/02/the-commercial-space-age-is-here> accessed 7 May 2023.

and a monopoly or cartel forming⁶³. Another issue to be concerned about is the influence on the terrestrial mining industry. Natural resources may be depleted as a result of resource extraction through mining. This might be detrimental to industries that rely on these resources.

The World Economic Forum's Global Dangers Report 2022 examines the expanding economic and geopolitical interests in space exploration⁶⁴. Some governments support commercial space activities to strengthen their military or defence-related presence as well as to advance national "territorial" claims or to promote the creation of high-value employment.

The space mining business is still highly speculative. As of 2023, humanity has yet to commercially mine even a single asteroid commercially. According to an article by CNBC, "Fast forward to 2022, and both Planetary Resources and Deep Space Industries have been acquired by companies that have nothing to do with space mining. Humanity has yet to commercially mine even a single asteroid"⁶⁵. Many challenges must be overcome before commercial space mining becomes a reality.

Despite these challenges, there are many potential future advancements in technology that could impact commercial space mining. For example, the advent of small and very inexpensive cubesats could be a major boon for the space mining industry. According to Jeff Kargel, a former U.S. Geological Survey (USGS) geologist who is now a senior scientist at The Planetary Science Institute in Tucson, Arizona, "The basic idea of having very inexpensive spacecraft which can be mass produced are fortuitous for future asteroid mining efforts"⁶⁶. Additionally, there is growing interest in using 3D printers to manufacture tools and even build habitats on the Moon or Mars using materials available on these celestial bodies⁶⁷.

In conclusion, while there are many potential advancements in technology that could impact commercial space mining, it is still a nascent industry with many challenges and uncertainties. Further research and development will be needed to fully realise its potential.

⁶³ Bruce Dorminey, 'Does Commercial Asteroid Mining Still Have A Future?' (Forbes, 31 August 2021) <https://www.forbes.com/sites/brucedorminey/2021/08/31/does-commercial-asteroid-mining-still-have-a-future/> accessed 7 May 2023.

⁶⁴ 'Global Risks Report 2022' (World Economic Forum) <https://www.weforum.org/reports/global-risks-report-2022/in-full/chapter-5-crowding-and-competition-in-space> accessed 25 April 2023

⁶⁵ Michael Sheetz, 'Asteroid mining was once the stuff of science fiction — now it's almost a reality' (CNBC, 23 December 2021) <https://www.cnbc.com/2021/12/23/asteroid-mining-was-once-the-stuff-of-science-fiction-now-its-almost-a-reality.html> accessed 7 May 2023.

⁶⁶ Bruce Dorminey, 'Does Commercial Asteroid Mining Still Have A Future?' (Forbes 2021) <https://www.forbes.com/sites/brucedorminey/2021/08/31/does-commercial-asteroid-mining-still-have-a-future/>

⁶⁷ 'NASA Looks to Advance Large-Scale 3D Printing for the Moon and Mars' (NASA 2020) <https://www.nasa.gov/centers/marshall/news/releases/2020/nasa-looks-to-advance-3d-printing-construction-systems-for-the-moon.html>

V. CONCLUSION

This paper has explored the legal framework surrounding commercial space mining at both the international and national levels. It has highlighted the applicability of international space law to commercial space mining, the role of the United Nations in regulating this industry, and the challenges and opportunities for regulating commercial space mining at the international level. The case studies of countries and companies pursuing commercial space mining have provided insights into the various approaches and strategies being adopted and the potential benefits and drawbacks for different stakeholders. Finally, this paper has examined the potential economic benefits and drawbacks of commercial space mining, its impact on international relations and cooperation, and prospects for the industry.

The rapid evolution of commercial space mining highlights the need for further research and policy-making. Given the challenges associated with regulating this industry at the international level, future research should focus on identifying effective regulatory mechanisms to ensure the sustainable and equitable use of space resources. Additionally, it is essential to recognize and consider space as a global commons. Space is a shared resource that belongs to all of humanity, and its sustainable and equitable use requires cooperation and responsible stewardship. Policies and regulations should be designed to protect and preserve the integrity of space as a common heritage for future generations. Policymakers should also consider the potential impacts of commercial space mining on international relations and cooperation and develop strategies to promote collaboration among countries and stakeholders. Moreover, the case studies of countries and companies pursuing commercial space mining provide valuable insights into the various approaches and strategies being adopted. Future research could focus on a comparative analysis of these approaches to identify best practices, challenges, and opportunities associated with different strategies.

Additionally, the potential economic benefits and drawbacks of commercial space mining underscore the need for policymakers to carefully assess this industry's costs and benefits. Policymakers should weigh the potential economic gains of commercial space mining against the potential environmental, social, and ethical costs associated with this industry. This would involve striking a balance between the pursuit of economic growth and the promotion of sustainable development.

Finally, the prospects for commercial space mining appear promising, but policymakers must be proactive in shaping the industry's trajectory. Future research and policy-making should aim to create a regulatory environment that fosters innovation and entrepreneurship while ensuring

the sustainable and equitable use of space resources. In this regard, international cooperation and collaboration are essential to ensure the peaceful and sustainable exploration and use of outer space for the benefit of all humanity.

In conclusion, the legal framework surrounding commercial space mining is complex and rapidly evolving. While there are challenges and opportunities associated with this industry, policymakers should adopt a proactive approach to promote sustainable and equitable use of space resources. This would involve careful consideration of the legal, economic, social, and ethical implications of commercial space mining and developing effective regulatory mechanisms to ensure the sustainable and peaceful exploration and use of outer space.
