



INTERNATIONAL SPACE LAW

ADDRESSING ETHICAL AND REGULATORY
CONCERNS



Meet Our Team



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INTRODUCTION TO COMMERCIALIZATION OF OUTER SPACE

International Space Law is an independent and sovereign branch of law covering the exploration, use, and activity in outer space. It is a group of treaties, agreements, principles, and norms of customary international law regulating the participation of states and private enterprise in space activities. It is founded upon the field of international public law in its widest sense and treats issues of such all-encompassing importance as the peaceful exploration of outer space, liability for damage, utilization of natural resources, domination of space, and protection of bodies in space.¹

With space exploration fast becoming a high-speed enterprise with satellite activity, space tourism, and space mining, International Space Law is going to have a very crucial role to play in opening up space and making it beneficial to the entire mankind. These are important space law treaties such as the 1967 Outer Space Treaty, the 1979 Moon Agreement, and the 1976 Convention on Registration of Objects Launched into Outer Space that lay down some general principles on national responsibility, non-appropriation of space objects, and international cooperation.²

Outer space has also witnessed radical change from state-sponsored activity that was chiefly marked by geopolitical competition to internationalized, multi-faceted enterprise spearheaded by private corporations and collaborative global action. The revolution has been preceded not only by revolutions in technology but also by growing regard for the importance of space as an interesting scientific frontier for research by the emerging economy and humanity. History of space commercialization, projected into the future based on existing and future trends, needs to have strong legal frameworks and ethics in place to continue to evolve and make space resources fairer.

¹ Michael J. Finch, 'Limited Space: Allocating the Geostationary Orbit' (1985-1986) 7 NW J Intl L & Bus 788

² Bulgakova D, 'International Law on Space Tourism Implementation' (2020) Legal Horizons

As commercial enterprises like SpaceX and Blue Origin push human beings out into space, so do their national spacefaring counterparts, raising issues of jurisdiction, property, environmental sustainability, and international cooperation. Irretrievably linked with intellectual property, environmental, and security law, the subject is highly dynamic and responsive, where scientific innovation is weighed against commercial advantage and respect for the last frontier.³

HISTORICAL DEVELOPMENT OF SPACE COMMERCIALIZATION

The space exploration enterprise was built during the Cold War era, an epoch characterized by intense rivalry between the United States and the Soviet Union. The Soviet Union's launching of Sputnik 1 in 1957 marked the beginning of the space age and heralded the promise of space technology as a tool for national prestige and military advantage. This age, which was epitomized by state-centric initiatives such as NASA's Apollo program, which landed men on the moon in 1969, was very emblematic of the technological acumen of the United States.⁴ During this period, commercialization of space was overshadowed by its strategic and scientific imperatives. However, it was the development of satellite technology that emerged in the 1960s which planted the seeds for commercial activities. For example, the founding of INTELSAT International Telecommunications Satellite Organization in 1964 helped enable international cooperation in satellite communications, forming a foundation for a future space economy⁵. The first round of space commercialization started in the 1970s and 80s, mainly in the telecom sector. Satellites emerged as an indispensable tool in broadcasting, weather forecasting, and GPS. Privately owned entities started to appear in the scene, but, the case at which governmental funding and

³ Weeks E, 'Applying International Space Law Precedent to Space Tourism, Space Mining and Space Settlement' (2006) 49 International Institute of Space Law 13.

⁴ R D Launius and others, 'Spaceflight: The Development of Science, Surveillance, and Commerce in Space' (2012) 100 Proceedings of the IEEE, Special Centennial Issue, 1785-1818

⁵ 'INTELSAT Agreement and Operating Agreement' (1964) (1971) 10(5) International Legal Materials 909

infrastructures were needed was normally seen to emphasize the importance of the state in making such activities possible. Under these circumstances, the legal framework for space activities, as established under international treaties such as the Outer Space Treaty of 1967, the non-appropriation of outer space, and the peaceful use of the domain, have highlighted principles governing commercial ventures today⁶.

The Cold War of the 1990s dramatically transformed the space industry. Budgetary constraints and lower geopolitical tensions resulted in fewer state-funded programs, leaving private companies with a more significant share. The provision of mobile communication services globally marked this trend, as exemplified by satellite service providers such as Iridium and Globalstar. At the same time, a rapid miniaturization of satellites and launch vehicles made entry easier by reducing entry costs for space activities by smaller countries and companies from the private sector. The above steps opened doors for democratization in terms of approaches toward space exploration and utilization⁷.

THE RISE OF PRIVATE SPACE LEADERSHIP

The early 21st century marked the beginning of a new era of space commercialization, led by visionary entrepreneurs as well as groundbreaking innovations. SpaceX, founded by Elon Musk in 2002, exemplified this transformation by introducing cost-effective solutions, such as reusable rockets, which drastically reduced the cost of accessing space. Other companies, including Blue Origin and Virgin Galactic, entered the market with ambitious goals, such as enabling space tourism and establishing human settlements on other planets. These innovations marked a transition from state-led exploration to private-led ventures in which profit or revenue-and market

⁶ Outer Space Treaty (adopted 27 January 1967, entered into force 10 October 1967) 18 UST 2410, 610 UNTS 205, 61 ILM 386, Articles I-III

⁷ Nandasiri Jasentuliyana, *International Space Law and the United Nations* (Brill 2023)

forces, drive efforts⁸. The possibility of space tourism, as represented by the suborbital flights provided by Virgin Galactic, captured the public imagination and marked the increasing accessibility of space for non-professional astronauts⁹.

TRENDS IN COMMERCIALIZATION

There are a number of emerging trends that are changing the scope and scale of commercial activity today in this new space economy, but surely one of the most impactful drivers is satellite mega-constellations: the new transformative innovation. Thousands of small satellites orbiting low Earth are envisioned by such ventures as SpaceX's Starlink and Amazon's Kuiper to offer broadband internet coverage all over the world.¹⁰ These developments have the potential to help bridge the digital divide by bringing access to underserved regions while raising significant concerns about ongoing risks. The growth of satellites increases the possibility of orbital congestion and space debris, leading to well-known problems for long-term sustainability and safety in outer space¹¹.

Private space stations represent an emerging trend in the commercialization of space. Companies like Axiom Space and Blue Origin are busy building commercial platforms for research, manufacturing, and tourism that can be used when the International Space Station is due to retire in 2030¹². Such stations could offer a wide range of functions, including performing scientific experiments, producing industrial goods,

⁸ Rajeswari Pillai Rajagopalan and Narayan Prasad (eds), *Space India 2.0: Commerce, Policy, Security and Governance Perspectives*

⁹ A Bosch Martínez, *Study of the Benefits and Applications of Passenger Supersonic Transport Vehicles: Case Study of Supersonic 2.0-Virgin Galactic* (Bachelor's thesis, Universitat Politècnica de Catalunya 2023).

¹⁰ de Selding PB, 'SpaceX's Shotwell on Falcon 9 Inquiry, Discounts for Reused Rockets and Silicon Valley's Test-and-Fail Ethos' (*SpaceNews*, 5 October 2016) <https://spacenews.com>

¹¹ Michael Byers and Aaron Boley, *Who Owns Outer Space?: International Law, Astrophysics, and the Sustainable Development of Space* (Vol 176, Cambridge University Press 2023).

¹² Leonard David, 'After ISS: The private space station era is dawning' (space.com, 1 Aug 2024) accessed on 16 February 2025

and perhaps even operating as space hotels.¹³ Renewed interest in lunar exploration has also unleashed a flurry of public-private partnerships as seen with NASA's Artemis program, which aims to create sustainable human presence on the Moon¹⁴. These initiatives underscore how a growing role of private enterprise is defined by space exploration.

Finally, space mining and resources constitute a new frontier in space commercialization. Other such companies Planetary Resources and Deep Space Industries are seeking to identify the possibility of expelling valuable minerals and water out of asteroids and the Moon. These resources might enable supporting in-situ manufacturing and fuel production, cutting costs for deep-space missions. But exploiting extraterrestrial resources raises serious legal and ethical questions in light of the Outer Space Treaty provisions concerning non-appropriation and the common heritage of humankind¹⁵.

Access to space tourism is trying to be democratized, though the costs of entry will be astronomically beyond the reach of many individuals. Companies are looking to expand their offerings beyond suborbital flights. For example, SpaceX has announced private missions to the Moon and even firms like Orbital Assembly Corporation conceptualize space hotels.¹⁶ The sector has also garnered public interest and investment through the participation of high-profile figures such as Jeff Bezos and Richard Branson.¹⁷

CONTRIBUTIONS OF EMERGING SPACE NATIONS

¹³ Anderson C, 'Rethinking Public-Private Space Travel' (2013) 29 Space Policy 266

¹⁴ Barbara Cohen, 'Artemis Program Overview' (Endurance Science Workshop 2023).

¹⁵ Outer Space Treaty (adopted 27 January 1967, entered into force 10 October 1967) 18 UST 2410, 610 UNTS 205, 61 ILM 386, Articles II

¹⁶ Kathryn Armstrong, 'SpaceX Rocket launches private missions to moon' (BBC.COM, 15Jan2025) <<https://www.bbc.com/news/articles/cn8x5gm4k1xo>> accessed on 16 February 2025

¹⁷ Baiocchi D and Welser W, 'The Democratization of Space' (2015) 94 Foreign Affairs 98.

The UN, in spearheading the Space 2030 agenda, advances that space-based information, infrastructure, and applications will play a significant role in the UN Sustainable Development Goals. The four pillars of the socio-economic integrity restoration the space economy, space society, space accessibility, and space diplomacy, which aim at achieving equal distribution of space benefits.¹⁸

New space nations such as India, the UAE, Singapore, and Morocco are at the forefront of this changing environment. Through the Indian Space Research Organisation (ISRO), which is known for its low-cost and technically able satellite launches for other countries, India has adopted leadership in the commercial space industry.¹⁹ The Mars Mission of the UAE stands as testimony to this burgeoning ambition of a flourishing stake in the space industry.

These countries put their space activities in sync with climate action, water management, sustainable land use, and economic growth goals, all of which feed into the Space2030 vision. Investments in the space industries drive local and international growth and collaboration. Yet, still, access to financing, regulatory reform, and competition with traditional space powers remain hurdles. Public-private partnerships and international cooperation are key ways in which these challenges would be practically resolved.

Importantly, increased investments from these countries will most likely introduce a new planetary governance in space so that space technologies can adequately support sustainable development and inclusive growth across the world. In part, this will very much depend on how new entrants establish the course of future international space commercialization.

¹⁸ PWC, 'Emerging space nations: supporting sustainable development and economic growth' (PWC, February 2020) <<https://www.pwc.fr/fr/assets/files/pdf/2020/03/en-france-pwc-space-practice-emerging-space-nations-paper.pdf>> accessed on 16 February 2025

¹⁹ K Kasturirangan, 'Challenges and Achievements of ISRO Satellite Missions' (1992) 9(5) IETE Technical Review 334-343

TECHNOLOGICAL INNOVATIONS AND NEW BUSINESS MODELS.

Innovations such as 3D printing, AI, and robotics cost money less and require fewer efforts for space operations. For example, construction using 3D printing can indeed be built directly in-situ habitats and parts on the Moon or Mars to reduce logistics.²⁰ AI enhances the operation of satellites as well as data analysis, and robotics is totally crucial for autonomous exploration and resource extraction.

The idea of SPaaS is changing the industry by enabling customers to access space-based infrastructure and services without owning or operating hardware. This trend, to be led, companies such as Rocket Lab and Planet Labs, will make satellite data, launch services, and other capabilities accessible to academic institutions, small businesses, and developing nations²¹.

CHALLENGES AND FUTURE OUTLOOK IN MANAGING SPACE COMMERCIALIZATION(ETHICAL AND REGULATORY)

Commercialization of Space activities will reshape human ambition and industry in unprecedented ways. However, this transformation has its multifaceted challenges and demands urgent attention to make it sustainable and equitable.

The ethical issues in space commercialization include unequal access between the developed and developing nations, difficulties in fair resource allocation, an urgent need for strengthening international cooperation, and environmental issues. The regulatory challenges involve managing space debris, the problem of overcrowding by satellites, clarifying the international and national jurisdictions of law, and establishing liability frameworks for space flights and tourism. Further issues such as

²⁰ Curt Hall, '3D Printing & the Future of Space Exploration' (cutter.com, 29feb2024) <<https://www.cutter.com/article/3d-printing-future-space-exploration#:~:text=By%20using%20locally%20available%20materials,goal%20of%20NASA's%20Artemis%20mission>>. accessed on 16feb2025

²¹ I Steenmans, JC Mauduit, J Chataway and N Morisetti, Emirates Mars Mission: A Mission to a Transformative Future. A Transformative Value Analysis Report for the Mohammed Bin Rashid Space Centre (2020).

insurance frameworks, risks of weaponization, cybersecurity threats to critical infrastructure, and ambiguities in governance require updated treaties and implementation of sound sustainability protocols.

Addressing these challenges requires comprehensive legal, ethical, and financial frameworks to ensure the safe, inclusive, and sustainable development of space activities.

1. Disparities in Access to Space

Space commercialization has elicited acerbic distinctions between developed and developing countries in the sense that space activities fall largely within the purview of the economic, technological, and professional capacity of a few advanced nations and large private corporations. Spacefaring countries heavily invest in satellite technology, missions to the moon, and maybe extraction of resources. Developing countries struggle to weigh constrained resources against economic and social priorities. This multi-leveled development is an extremely strong moral issue pertaining to fair distribution of space-gained advantages, looking at a complete range of sky granted assets for various developmental endeavors, like satellite-dependent services and potential asteroid mining, to bestow great economic and strategic advantages. The rising supremacy of a few choice and influential actors may then convert outer space into a theater of geopolitical competition to place interests over those of humanity. Such differences are best addressed by international cooperation in developing new updated regimes of law, technology transfer processes, and facilitating institutions for facilitating open access to the utilization of space resources, following norms such as those in the Outer Space Treaty.²²

2. Sustainability and Shared Humanity

²² Sogobaetso B, Ethical Implications of the Colonization, Privatization and Commercialization of Outer Space (2018).

The Outer Space Treaty of 1967 declared space as the "province of all mankind," yet contemporary national legislations such as Section 51303 of the US Commercial Space Launch Competitiveness Act of 2015 contradict this ideal by giving a right to private ownership over celestial resources. Ethical and legal structures must therefore evolve to reflect shared responsibility for sustainable and equitable activities in space to uphold the collective ownership of space.²³

3. Environmental Impact

It will extend beyond Earth the environmental footprint of space commercialization: space debris, launch-induced pollution, and potentially adverse impacts on celestial bodies. There is a strong imperative to develop green technologies and regulatory frameworks for sustainable exploration.

4. Space Traffic and Debris Management

The rapid proliferation of satellites in low Earth orbits, similar to the Starlink project by SpaceX, has posed risks of collisions and space debris. Multilateral cooperation becomes necessary for effective space traffic management systems and debris remediation strategies. Updated international treaties and standardized sustainability protocols are important for long-term orbital stability.²⁴

5. Liability and Legal Jurisdictions

Legal jurisdictions and liability are very necessary for controlling activities across countries, such as space exploration, aviation, and marine activities. Commercial ventures outside Earth, such as commercial space mining. In international space law, the Liability Convention of 1972 makes states liable for any damage done by their

²³ Stephen Samuel Buono, *The Province of All Mankind: Outer Space and the Promise of Peace* (Indiana University, 2020).

²⁴ R Buchs and MV Florin, 'Collision Risk from Space Debris: Current Status, Challenges and Response Strategies' (2021).

space objects on the surface of the earth, in the atmosphere, or outer space, thereby compounding the problems. But establishing liability when actors from different jurisdictions act in concert poses another set of difficulties. One legislative step to deal with liability is the US Commercial Space Launch Competitiveness Act (2015), under which American companies gained rights over resources obtained from celestial bodies, while the need for adherence to international obligations was acknowledged. Likewise, the provisions under the European Union's General Data Protection Regulation (GDPR) are also testimonies to how legal structures can extend jurisdiction beyond geographical confines while the data is processed at the global stage. Efforts have been made by some scholars towards more precise frameworks in assigning liability in new sectors such as space mining: the continued calls for establishing a harmonized international regime to regulate resource extraction and potential environmental damage. Conversely, failure to have this regime could lead to a dispute and slow growth for the industries in question, thus establishing the importance and the need for further innovation in law to balance national interests with international obligations.²⁵

6. High Costs of Entry and Insurance Gaps

Space ventures are too expensive, with a requirement of billions of dollars in investment. Even though private space exploration has seen some progress through the efforts of individuals like Elon Musk and Jeff Bezos, the traditional investors are still very skeptical due to high risks and historical failures, such as satellite-based mobile networks in the 1990s. Financing mechanisms, including public-private partnerships, subsidies, and venture capital incentives, need to be developed to lower the barriers to entry. The lack of robust insurance infrastructures for space ventures increases financial risks, further discouraging new entrants. It is only through

²⁵ F.G. von der Dunk and M.M.T.A. Brus, editors – *The International Space Station, Commercial utilisation from a European legal perspective*. Martinus Nijhoff Publishers (Leiden, Boston)

comprehensive insurance frameworks that exploratory costs can be reduced and innovation encouraged in the space economy.²⁶

7. Cybersecurity and Weaponization

Space assets, satellites, and navigation are exposed to contrary and horrific cyber threats in the form of data interception, signal spoofing, and satellite hijacking with extremely alarming implications on budgetary issues, security, and privacy. The threat based on interception, especially during sensitive communication, allows for powerful cyber-criminals or hostile governments to intercept private communications, GPS location coordinates, and remote-sensing imagery. The compromise of GPS signals makes civilian privacy, key infrastructure, and national security increasingly vulnerable due to the severity of effects on reality-of-transport, financial activity, and even military action. For example, identifying spurious location information, intercepting defence communications, or disabling defence equipment would obfuscate the scenario with uncertainty, and that will destabilize the geopolitics. With the advent of commercial space activities and endeavors, protection of space-based information requires international cooperation in implementing sound cybersecurity practices and regulations to render space accommodation a secure and peaceful space for everyone.²⁷ Commercialization of space is more than a business initiative-it represents the enhancement of human ambition by leaps and bounds beyond existing boundaries. Opening up the opportunities to extract resources, tourism, and technology, space is the new frontier that redefines human potential. Success will require beating back challenges in financing, regulation, and sustainability. Reflecting on the words of Carl Sagan, "We have a basic responsibility

²⁶ D Bensoussan, 'Space Tourism Risks: A Space Insurance Perspective' (2010) 66 *Acta Astronautica* 1633

²⁷ N Krasilich, 'Legal Problems of Insurance Protection Against Cyber Risks in Space Activities' (2021) *Yearly Journal of Scientific Articles "Pravova Derzhava"* 268

to our species to venture to other worlds," it is the cosmic leap forward in human history.

REVISING INTERNATIONAL SPACE LAW TO ADDRESS ETHICAL CHALLENGES IN SPACE COMMERCIALIZATION

This problem is multifaceted, as the allocation of space resources and the growing divide in access between developed and developing nations is a challenge on all three dimensions of ethics, law, and sustainability. The root cause of the problem lies in the technological, financial, and institutional gaps between countries, which becomes even more prominent with the fast advancement of space exploration and resource utilization. With the space programs they have, strong private sectors, and healthy economies, developed nations are best placed to use the resources that currently abound in outer space. Every resource deployed in satellites, mining, lunar exploration, and commercialization of space shall gather economic and strategic benefits for such countries. Most of the underdeveloped countries are constrained most of the time by limited infrastructure, financial resources, and technical expertise and are therefore on the fringes of this increasingly important sector. Such inequality not only makes the global disparities deeper but also poses some key ethical questions about equitable access to space resources and the likelihood that commercialization of space may further widen already existing imbalances.²⁸

UNEQUAL ACCESS TO SPACE RESOURCES: THE TECHNOLOGICAL AND ECONOMIC DIVIDE

This is due to the uneven availability of technological and economic resources among developed and developing nations. Such countries that have well-developed technology, strong private sectors, and established space agencies are better positioned to exploit space for economic benefits. Their space programs, often sponsored with billions of dollars in public and private investment, have empowered them to be the masters of endeavors such as launching satellites, space mining, and

²⁸ Annette Froehlich, *Space Resource Utilization: A View from an Emerging Space Faring Nation* (Vol. 12, Springer 2018).

even setting up space stations. The benefit is not merely economic gains, but it also ensures that they have the geopolitical strategic advantage because they are leading control over the production of space research and exploration activities.²⁹

The developed nations have been lagging behind the underdeveloped nations, as most of the needed infrastructure, capital, and technical know-how for serious game participation are largely lacking. To give an instance, while America, Russia, China, and Europeans can place satellites, manufacture space stations, and send humans to the moon, the latter does not even have the primary infrastructures which are supposed to gain access to break into the game. A shortage of financial capital and skilled labor greatly limits their involvement in this rapidly growing space economy. The enormous technical capabilities required for space exploration, an area most developing nations cannot muster because of incompetence in their respective education systems and technical training, further ingrains global disparities, almost ensuring that developing nations are pushed to the periphery to enjoy the resultant economic and strategic benefits of venturing into outer space.³⁰

THE OUTER SPACE TREATY AND THE PRINCIPLE OF EQUITABLE ACCESS

The Outer Space Treaty, from 1967, provides a basis for space law on a global level: it maintains outer space is there for all people in Earth, and clearly makes a declaration saying space research or exploitation and all other space-bound scientific studies and exploration mustn't be conducted exclusively by only one country, nor one grouping of nations. It is underpinned by the principle that space is a global commons, a domain that should remain accessible to all countries regardless of their technological or economic capabilities.

²⁹ Jun Du, Chunxiao Jiang, Jian Wang, Yong Ren, Shui Yu, and Zhu Han, 'Resource Allocation in Space Multi Access Systems' (2017) 53(2) *IEEE Transactions on Aerospace and Electronic Systems* 598.

³⁰ R Frieden, 'Why Has Multilateral Space and Spectrum Resource Management Become More Difficult?' (2022) 46(10) Telecommunications Policy 102426.

The implementation of these principles in practice is still highly imbalanced in favor of developed nations. The absence of a uniform international framework that would ensure fair access to space resources has let the wealthy nations set the rules for space activities. The Moon Agreement, meant to provide a guideline for the fair sharing of space resources and for the sustainable use of celestial bodies, has failed to be adopted. Major spacefaring nations like the United States, China, and Russia have not ratified it, thereby stopping its potential for creating a legal framework for the equitable distribution of resources. This legal void thus worsens disparities between developing and developed countries; wealthier countries and the private sector profit by exploiting outer space resources while gaining little accountable check or meaningful mechanism for their just share from its benefits.³¹

Among these manifestations, the recent US Space Act 2015 grants private corporate ownership of asteroids that contain space minerals. Similarly, Luxembourg's Space Resources Act gives private companies the right to extract resources from celestial bodies and own those resources. These acts, while facilitating private enterprise and innovation, further concentrate control over space resources in the hands of a few wealthy nations and multinational corporations, marginalizing developing countries and exacerbating global inequalities.³²

THE REGULATION OF SPACE TRAFFIC AND DEBRIS: A GLOBAL CHALLENGE

With commercialization of space, new avenues of opportunity also present a plethora of ethical and logistical challenges some of which are of pressing need: regulation of space traffic and mitigation of space debris. Satellite launches have accelerated exponentially; large satellite constellations such as those associated with SpaceX's

³¹ Deplano, Rossana. "Inclusive space law: The concept of benefit sharing in the outer space treaty." *International & Comparative Law Quarterly* 72, no. 3 (2023): 671-714.

³² C Foster, 'Excuse Me, You're Mining My Asteroid: Space Property Rights and the US Space Resource Exploration and Utilization Act of 2015' (2016) *U. Ill. JL Tech. & Pol'y* 407.

Starlink have led to overcrowded orbits. NASA has estimated the objects tracked in orbit to be greater than 27,000 as of 2023.³³ However, pieces much smaller than these also have a huge risk of threatening the operational satellites. As orbits fill up with additional satellites and debris, the threats from collisions also escalate, which adds to the formation of more debris to make matters worse. This phenomenon is known as the Kessler Syndrome, describing a scenario in which the accumulation of space debris leads to cascading collisions, rendering entire orbits unusable and severely hindering future space operations. There is no unified global framework for managing space traffic and debris that could help to address these risks. Space activities would turn unsustainable if left unregulated resulting in degrading orbits of valuable space assets and loss of operational satellites. This placed an enormous urgency on collective action towards creating a framework of global governance that oversees the operation of satellites, the responsible de-orbiting of dead ones, and technology development that makes reusability with less debris created. This again has brought an immense concern toward the long-term sustainability of activities in space, as it remains a fragile resource that must be preserved for later generations. Not only will unchecked commercial activity jeopardize the viability of future space operations, but also believe the fundamental principle of equity is to be attained through access to space without sacrificing future generations' chance to share in this initiative, especially for newly developing countries with nascent space programs.³⁴

SUSTAINABILITY AND ENVIRONMENTAL STEWARDSHIP IN SPACE EXPLORATION

The topic of space resource utilization and space exploration incorporates really important ethical concerns. Often, space is seen as the frontier that has an available pool; the truth however is that space is a very fragile and very limited environment.

³³ Mitchell, S. (2023). Opportunities and Challenges facing the Commercialisation of Outer Space.

³⁴ M Clormann and N Klimburg-Witjes, 'Troubled Orbits and Earthly Concerns: Space Debris as a Boundary Infrastructure' (2022) 47 Science, Technology, & Human Values 960.

The European Space Agency revealed that just 6% of all the tracked orbital objects are operational satellites, leaving the rest being inert spacecraft or even space debris. This statistic underlines the need for responsible space practices, such as de-orbiting defunct satellites and advancement of reusable technologies in order to prevent the creation of space debris as much as possible.³⁵

Responsibility in extracting resources from celestial bodies, for example, from asteroids and the Moon characterizes sustainability in space. A more critical aspect raised by the growth in interest on asteroid mining and lunar resource extraction is long-term questions regarding impacts on the ecological integrity of celestial bodies. If the retrieved resources would really benefit humans in advancing human space exploration or support life back on Earth, then uncontrolled exploitation would inevitably do irreparable damage to those environments. Preservation of those celestial bodies, therefore, as a moral consideration should be included in the governance to be used among space resources.³⁶

In this regard, sustainability demands the building of international regulatory frameworks in the name of guiding space responsibly. So, such frameworks should ensure first of all that exploration and exploitation of space are made to serve the betterment of the entire human race while not violating ecological integrity in outer space.

INCLUSIVENESS AND INTERNATIONAL COOPERATION IN SPACE EXPLORATION

This calls for another primary ethical consideration-inclusiveness-space exploration and use of its resources. So far, it seems that a number of highly industrialized countries or private space venture companies remain mainly in control over space

³⁵ JA Vedda, 'Challenges to the Sustainability of Space Exploration' (2008) 6 *Astropolitics* 22.

³⁶ Ram Jakhu and Maria Buzdugan, 'Development of the Natural Resources of the Moon and Other Celestial Bodies: Economic and Legal Aspects' (2008) 6 *Astropolitics* 201.

ventures to the disadvantage of developing countries due to such significant resource demand, thereby hampering their capabilities and participation. The present exclusion only perpetuates the inequalities the current world has managed to retain throughout. This kind of exclusion further negates the vision for space as an opportunity for humankind's growth. This means that the exploration and use of space by all nations should really become inclusive in nature, and this can be achieved by establishing a global framework for space governance that enables each nation, with whatever technological and economic capabilities, to meaningfully participate in activities related to space.

Such an architecture has to bridge the following deficits: clear definition of ownership rights on resources clearly, equitable extraction of natural resources, mechanisms for benefit sharing in an equitable and reasonable way, and proportionate representation in decision-making procedures for developing country interests. Joint programs in regions or multilaterally, as for example the space programs will help bridge these gaps between spacefaring states and emerging countries. These can be used to give developing countries the technical capabilities and financial means necessary to conduct space activities and enjoy space resources.³⁷

THE FUTURE OF SPACE GOVERNANCE: BALANCING INNOVATION AND EQUITY

Other ethical issues arise from space commercialization, which are more or less related to the monopolization of space resources by the wealthier nations and corporations. Questions are being raised on how space benefits will be shared among various entities since private companies increasingly gain control over space exploration and resource utilization. Therefore, without proper regulation of outer space commercialization, space will be filled with a field dominated by very few rich nations and corporations, which is a recipe for intensifying inequalities at the world level.

³⁷ J M Determann, *Diversity, Equity, and Inclusion in Astronomy: A Modern History* (Springer Nature 2023).

Such a scenario will, therefore not only be discreditable to the very principles of equity and inclusiveness but also a continuation of history's trend at global levels by this manner.

Such challenges would require imaginative governance structures that balance technological ingenuity with values of equity, sustainability, and inclusiveness. There is an urgent need for a comprehensive international framework in the regulation of space resources, space traffic, and environmental stewardship to ensure that space activities are beneficial to all humankind. That framework should be founded on the principle of international cooperation and solidarity so that the fruits of space exploration are equitably shared among nations.

ESTABLISHING LEGAL FRAMEWORKS FOR THE REGULATION OF COMMERCIAL SPACE FLIGHTS AND SPACE TOURISM

This creates unprecedented challenges to the legal, technical, and environmental fields involved in the commercialization of space activities. With this growth, there is an expectation that the regulatory frameworks need to evolve such that the benefits from space exploration and utilization are equitably shared and risks from such activities are properly managed. It challenges some of the most complex problems relating to the jurisdiction of international and national laws, liability, and insurance frameworks on space debris, overcrowding satellites, weaponizing space, threats from cybersecurity to a myriad of other issues. Meeting all these regulatory challenges requires new multilateral solutions involving deep international cooperation, proactive mechanisms of governance, and rapid development in terms of commercialization and space exploration.

INTERNATIONAL AND NATIONAL LEGAL JURISDICTIONS AND LIABILITY FRAMEWORKS

It makes space, in the 1967 Outer Space Treaty (OST), the "province of all mankind," promoting the peaceful use and forbidding nations from claiming sovereignty over

celestial bodies.³⁸ However, the treaty is increasingly being put to the test by national law and commercial interest. For example, the U.S. The Space Launch Competitiveness Act of 2015 and the Luxembourg Space Resources Act of 2017 grant the right to private organizations to extract and exploit space resources. This would violate the fundamental principle of the OST: the principle against appropriating celestial bodies.³⁹ This, too, created fear that space resources extracted from asteroids or the Moon would be monopolized by wealthy corporations, not fairly and equitably in space governance.

This calls for harmonized international regulations on both international treaties and national laws. The international supervising authority or reforms in existing conventions will be a guarantee that, on the basis of equality among nations who became spacefaring nations, equity and fairness should once again reflect any further venture into space. Even the emergence of private parties increasingly participating in all space operations now creates additional complex liabilities issues. Under the 1972 Liability Convention, launching states are liable for damages caused by their space objects, both on Earth and in outer space.⁴⁰ But when private companies get into the business, the old liability framework gets harder to apply, especially with incidents involving private operators. Take the case of the 2009 collision between Russia's Cosmos 2251 and the U.S. The Iridium 33 satellite, which has left a trail of debris in low Earth orbit (LEO), exposed a limitation of the current liability regime: it has not taken into account the participation of private actors. International

³⁸ Kröll H, *Beyond the Outer Space Treaty—A Comprehensive Analysis of Current Challenges in Space Policy* (PhD thesis, 2023)

³⁹ Oleksandr Svetlichnyj and Diana Levchenko, 'Commercialization of Space Activities: Correlation of Private and Public Interest in the Pursuit of Outer Space Exploration' (2019) 4(1) *Advanced Space Law* 21.

⁴⁰ Carl Q Christol, 'International Liability for Damage Caused by Space Objects' (1980) 74(2) *American Journal of International Law* 346.

frameworks need to be updated to bring private sector responsibility into space law, making space law more resilient to the current realities of the space economy.⁴¹

With the increased pace of commercial space activities, there will be issues concerning the ownership and appropriation of space resources. For instance, such national laws as the U.S. Space Act allow private entities to own space resources and, contrarily to OST, which prohibits national appropriation of celestial bodies. Legal gaps may present a solution to international disputes concerning property rights and resource extraction. For this reason, international agreements will be drafted where explicit international understanding will provide fair and equal accessibility to the whole world instead of private corporations from those spacefaring countries. Such standards would apply to space exploration and the usage of resources worldwide, like those created by the International Seabed Authority regarding the mining of the deep seabed.⁴²

SPACE TOURISM: JURISDICTIONS, LIABILITY, AND INSURANCE

What could have been regarded as a still-far-fetched future dream for many is fast becoming reality. A number of space tourism players are sending civilians to space, such as SpaceX, Blue Origin, and Virgin Galactic. In so doing, the commercialization of space tourism presents novel legal, regulatory, and liability issues that are accordingly met with spaces in international and national legal frameworks. These have to accommodate the unique nature of travel in space and yet fit within the broader principles articulated by the OST.⁴³ Theoretically, states are held accountable for space activities conducted by their nationals, which includes commercial space tourism. According to the 1972 Liability Convention, launching states shall be liable

⁴¹ C M Zaefen, 'Handling "Space Debris" under the International Space Treaties Regime: Case Studies Analysis' (2021) 33(3) *Environmental Claims Journal* 194.

⁴² N Iliopoulos and M Esteban, 'Sustainable Space Exploration and Its Relevance to the Privatization of Space Ventures' (2020) 167 *Acta Astronautica* 85.

⁴³ S Tiwari, 'Space Tourism: An Initiative Pushing Limits' (2021) 3(1) *Journal of Tourism Leisure and Hospitality* 38.

for any damage caused on Earth or space by their space objects, and according to the 1975 Registration Convention, space objects must be registered with the United Nations to clear any legal jurisdiction.⁴⁴⁴⁵

The advent of private space tourism companies complicates these provisions. National laws, particularly in countries like the United States, regulate space tourism operations through agencies such as the Federal Aviation Administration (FAA), which licenses commercial space launches and requires operators to inform passengers of the risks involved. The U.S. has also provided the Commercial Space Launch Act, which allows operators of space tourism to have liability waivers signed by passengers acknowledging risks associated with the journey. In this regard, the framework shields the space tourism operators from liabilities but does not excuse gross negligence.⁴⁶

European space tourism operators, particularly in France and the UK, have to comply with strict licensing, safety, and insurance requirements imposed by their countries' developed space laws. India is going to develop the space laws independently, but it may soon introduce legal provisions to guide the emerging practice of space tourism. There is a rising trend of international space tourism; with such tourism comes the growing demand for the need of international harmonization in norms to promote the safety, accountancy, and sustainability of such tourism.⁴⁷

Another key issue involved in space tourism is liability. Accidents involving spacecraft or passengers could cause significant damage and raise very complex legal questions. Operators are generally held liable for accidents. Most countries require

⁴⁴ UNGA Res 2777 (XXVI) (1971) 'Convention on International Liability for Damage Caused by Space Objects'.

⁴⁵ UNGA Res 3235 (XXIX) (1974) 'Convention on Registration of Objects Launched into Outer Space'.

⁴⁶ Juan Davalos, 'International Standards in Regulating Space Travel: Clarifying Ambiguities in the Commercial Era of Outer Space' (2015) 30 *Emory International Law Review* 597.

⁴⁷ Jai Galliot, *Commercial Space Exploration: Ethics, Policy and Governance* (Routledge 2016).

operators to carry insurance policies that would cover possible damages. Questions such as liability caps, the extent of insurance coverage, and passengers' ability to sue for damages in case of accidents remain unclear and are different in different jurisdictions. It is expected that the international community will clarify all these issues through the updating of international treaties like the Liability Convention in order to include commercial space operations with clearer guidelines regarding liability in cases of accidents.

This also adds another menace to the problem created by this kind of tourism space debris. Satellite activities increase, and so do mega-constellations like the one from SpaceX's Starlink, thereby increasing the risk of collision involving debris or raising the risk of danger to the lives of space tourists. It now calls for a tremendous amount of international agreements on managing space debris, introducing mandatory end-of-life satellites, and the introduction of active debris removal technologies.

SPACE DEBRIS AND SATELLITE OVERCROWDING

Space debris is the biggest regulatory challenge facing the commercialization of space, and this refers to a gigantic concern concerning the safety and sustainability of activities in space since it entails all the space debris such as defunct satellites, rocket stages, and space object fragments. This threat is the Kessler Syndrome, a theoretical event in which impacts between space objects create a chain reaction of debris, which renders certain orbital areas unusable and complicates the operations of satellites for both commercial and governmental bodies.⁴⁸

The issues related to space debris need a well-rounded approach involving technological innovations along with regulation measures. One of the concepts is Active Debris Removal or ADR, which describes sets of technologies that can capture and remove defunct satellites and other types of debris in orbit. For example,

⁴⁸ Donald J Kessler, Nicholas L Johnson, J C Liou and Mark Matney, 'The Kessler Syndrome: Implications to Future Space Operations' (2010) 137(8) *Advances in the Astronautical Sciences* 2010.

deorbiting devices may make use of robotic arms or harpoons and drag sails to capture space debris into orbit. These will require much investment and international cooperation, however, since space debris concerns all the spacefaring nations and calls for collective action.⁴⁹

International regulatory frameworks also have to be updated to include space debris management. This is feasible by making satellite design include debris mitigation measures through statute, requiring end-of-life procedures about disposal, and creating a global registry of space objects to track the existence of such debris. International agreements on SSA must be developed further to enhance the tracking and collision prediction capability so that real-time data on the movement of debris are available to space operators and precautionary measures are taken against collision.⁵⁰

CYBERSECURITY AND WEAPONIZATION OF SPACE

As the importance of space-based infrastructure for communication, navigation, and national security grows, so does the threat of cyberattacks on space assets. More and more satellites and other space-based systems are vulnerable to hacking, which can cause problems in critical services or even result in the loss of spacecraft. For this reason, space operators must implement robust cybersecurity protocols, including encryption, regular software updates, and intrusion detection systems. There should also be international cooperation to share information on new types of cyber attacks and the best practices of guarding space systems. There must be redundancy and a

⁴⁹ C Bonnal, JM Ruault and MC Desjean, 'Active Debris Removal: Recent Progress and Current Trends' (2013) 85 *Acta Astronautica* 51.

⁵⁰ Ram S Jakhu, Yaw Otu M Nyampong and Tommaso Sgobba, 'Regulatory Framework and Organization for Space Debris Removal and On-Orbit Servicing of Satellites' (2017) 4(3-4) *Journal of Space Safety Engineering* 129.

backup system formulated to allow operational continuity critical for survival during any cyber attack.⁵¹

The second key challenge would indeed be the weaponization of space. The more countries and private entities become involved in space activities, the greater the threat of deploying weapons in space. While the 1967 Outer Space Treaty prohibits the placement of weapons of mass destruction in orbit, it has unclear enforcement mechanisms to address the ever-increasing militarization of space. It, therefore, calls for new treaties or protocols that would have the effect of absolutely excluding the stationing of weapons in space and of providing for the verification of their non-stationing. Confidence and security-building measures, such as an international monitoring system and dialogue among the spacefaring nations, would reduce the chance of an arms race in space.⁵²

Commercializing space is one event of huge proportion and immense promise, yet the challenge lies with it coming associated with an innumerable multitude of regulatory complexity. As space activities quickly gather speed into a domain with the participation of private sector activities and even a spate of new technology involving space tourism, the question would pose on updating the present legal framework of this space-activities-landscape. International cooperation, technological innovation, and the establishment of sound regulatory frameworks are the best guarantees that space activities will be safe, equitable, and sustainable for the benefit of all humanity. Future issues such as space debris, overcrowding of satellites, legal ambiguities, and liability concerns need to be addressed in the future so that the commercialization of space may bring benefits to all of humanity with minimum risks related to these innovative efforts.

⁵¹ David P Fidler, 'Cybersecurity and the New Era of Space Activities' (Digital and Cyberspace Policy Program, April 2018, 2018).

⁵² M Mowthorpe, *The Militarization and Weaponization of Space* (Lexington Books 2004).

A WAY FORWARD

This commercialization of outer space fundamentally transformed from being a government-led, geopolitically charged undertaking during the Cold War to an increasingly rapidly growing, private-sector-led global industry. Technological advances opened doors for private players like SpaceX and Blue Origin and propelled space tourism, satellite mega-constellations, space mining, and private space stations into the mainstream. While these developments throw up many opportunities, they also throw up complex challenges, including the ethical, legal, and environmental risks.

General conclusions from the discussion of space commercialization are that it will have a concentration of power by a few rich nations and corporations, and it only threatens to worsen the disparities in global space access. The difference between developed and developing nations makes this a pressing issue for an approach to governance of space that is more equitable and representative. The lack of a robust, integrated, and meaningful international framework to manage problems such as space debris, resource extraction, and liability complicates the sustainability of space activities. Rising risks from space tourism, satellite overcrowding, and cybersecurity require updating international treaties, such as the Outer Space Treaty, to keep pace with the fast-changing commercializing space economy.

International cooperation, legal reforms, and technological innovation must come together to produce an all-encompassing framework for space governance in light of these challenges. A framework of this nature must focus on equitable access to space resources, ensure the sustainability of space activities, and resolve pressing environmental and ethical concerns. This encompasses national and international coordination of regulations and liability frameworks for private sector involvement, cooperation over debris mitigation and cybersecurity. Only through a global collaboration effort can space become a global commons that benefits all of humanity as the promise of space exploration comes to be inclusive, safe, and sustainable.