Natural Resources for Human Health
eISSN: 2583-1194

Original Research

Received 21 May 2026
Revised 30 June 2026
Accepted 13 July 2026

Natural Resources for Human Health 2026, Vol. 6 (12s): 282–296

KEYWORDS:
Outer Space Treaty, Res Communis and Non-Appropriation Principle, Global Commons and Space Governance

The Evolving Corpus Juris Spatialis: Treaty Limitations and Contemporary Challenges in Outer Space Governance

Akshay Garg[1*], Dr. Ramakant Tripathi[2], Harsh Vardhan Srivastava[3], Jahnnvi Mishra[4]

[1]Research Scholar in Law (Ph.D. Pursuing), Law College Dehradun, Uttaranchal University, Prem Nagar- 248007, Dehradun, Uttarakhand, India. akshaygrg756@gmail.com ORCID ID: 0009-0004-1819-1367
[2]Associate Professor, Law College Dehradun, Uttaranchal University, Prem Nagar-248007, Dehradun, Uttarakhand, India. ramakanttripathi91@gmail.com ORCID ID: 0009-0000-0302-7741
[3]School of Law, Shri Vile Parle Kelvani Mandal's Narsee Monjee Institute of Management Studies (Deemed to be University), Mumbai. India. srivastavaharsh1221@gmail.com ORCID ID: 0009-0006-2217-7626
[4]School of Law, Shri Vile Parle Kelvani Mandal's Narsee Monjee Institute of Management Studies (Deemed to be University), Mumbai, India. jahnnvi.521@gmail.com ORCID ID: 0009-0000-1752-2364

ABSTRACT: Since the inception of the Outer Space Treaty (OST) in the year 1967, it has constituted the foundational basis of corpus juris spatialis. Drafted under the auspices of United Nations during Cold War, it was established with the core principles to guide the human's extraterrestrial engagement. It was formed with the core idea of res communis – "the province of all mankind".

In the intervening decades, the space domain has evolved dramatically, once the realm of only superpowers is now transformed into a far more complex arena. This research examines the relevance of not just the OST but other treaties governing the use of outer space. It considers various provisions governing the use of outer space and celestial bodies and examines how the contemporary challenges remain unaddressed. Further the authors of this research paper try to investigate the reason behind the lack of active engagement by the states to address the drawbacks of these treaties and the ambiguities regarding the terminologies used in these treaties.

The study uses doctrinal research methodology, relying predominantly on the secondary resources and also examines treaties, United nations resolutions, scholarly articles, research papers and policy paper issued by the spacefaring agencies and the intergovernmental agencies.

INTRODUCTION

With nations signing the Artemis Accords and private companies planning lunar mining expeditions, outer space is rapidly shifting from a scientific frontier to a commercial battleground (NASA, 2020; Nelken-Zitser, 2025). The regulation of the outer space is becoming one of the most consequential questions of the international law in the 21st century. With increasing technological advancement and participation of private entities in extraterrestrial activities, concern surrounding the state ownership or sovereignty, commercialization of outer space, liability in case of default of both state and non-state actors and equal distribution of the celestial resources has also been intensified. In the backdrop of these challenges, revisiting the established framework especially the Outer Space Treaty and other treaties becomes fundamental in order to evaluate their capacity to address the contemporary and foreseeable developments.

International space law is governed by several United Nation Treaties such as Principles Governing the Activities of States in the Exploration and Use of Outer Space or Outer Space Treaty (OST) which happen to be the magna carta for outer space governance. Together with other subsequent treaties such as the Rescue Agreement (1968), the Liability Convention (1972), the Registration Convention (1975), and the Moon Agreement (1979), these instruments form the "corpus juris spatialis" a Latin term that means the body of space law (Vereshchetin, 2021). Despite the importance of these treaties, there was a major period wherein, space exploration was largely preserved by two superpowers that was USA and USSR or the Soviet Union. Accordingly, the provisions of these treaties though too broad and aspirational but at time are silent on the issues that have become a major concern in the contemporary period.

The OST was drafted in an era when private space enterprises were inconceivable. Today, the commercialization of space by companies such as SpaceX, Blue Origin, and others highlights the inadequacy of the current regime which primarily focuses on state responsibility in outer space. Similarly, the absence of clear enforcement mechanisms and dispute resolution procedures has left a big lacuna and questioned the effectiveness of the current treaties. Without binding institutions, the regime depends heavily on voluntary compliance and customary practices, making it vulnerable to unilateral interpretations.

In addition, other than commercialization various other interrelated issues further complicate the legal landscape. First, whether any country can claim sovereignty over areas of the Moon or other celestial bodies especially in the time when there is significant advancement in technology. Second, the rise in rivalry among the major power economies demonstrates how celestial exploration is becoming the extension of terrestrial competition. Moreover, the rise of private actors in the past one decade, often operating directly or indirectly working under the umbrella of the state, further blurs the boundaries of responsibility and accountability if any default occurs. Additionally, the Treaty on the Rescue of Astronauts highlights the humanitarian dimension of space law, yet its adequacy remains in question. With the evolving scenarios of space tourism makes it necessary to revisit and critically assess the existing space law framework as the treaties which once provided stability and guidance, are now becoming obsolete.

The revolutionary optimism of the makers of space treaties has, in many respects, become a conservative obstacle to innovative regulation in the present era. Taking all these considerations into account, it has become imperative to re-examine the jurisprudence of extraterrestrial engagement. By critically examining the contemporary issues, this study evaluates the adequacy existing treaties to address the lacunae in the existing regime and suggests the potential solution.

CONTEMPORARY CHALLENGES TO THE TREATY FRAMEWORK

Sovereignty

The territorial sovereignty system that underlies today's system of global governance does not apply to outer space (Ghanie, 2024). So, the question pertinent to space governance takes the center stage. The colonization of space is becoming less of a science fiction as more projects associated with development of colonies on outer celestial bodies are multiplying. Recently, Elon Musk divulged his plan of colonizing Mars and sending one million people over there by 2050; nevertheless, many experts question the practicality and attainability of such projections (Martin, 2021). Such a planetary migration also brings new dimensions for legal scholars such as determination of nationality, laws governing such people etc. While the air and space laws are still young, the treaties on principles governing the activities of state in the exploration and use of Outer Space, including the Moon and Other Celestial Bodies (OST), serve as an important legal framework to deal with this new frontier. The member states to these treaties opted to shy away from any notion of sovereignty for the reasons best known to them.

The concept of sovereignty has evolved over time but remains the center of debate among international powers. While some consider it as an obsolete and an abandoned thought, for others it is considered the new form of political authority and integration as an extension and reaffirmation of such a concept (Scuderi, 2026). Nations retain the right to "juris-dicere" which means to regulate the conduct the matters not exclusively of domestic concern yet to interpret the question in outer space is a discussion to be put forward (Scuderi, 2026).

In Mare Liberum (The Freedom of the Seas), Hugo Grotius argued that there are certain elements of nature, such as air and the sea, which cannot become subjects to private or sovereign appropriation (Grotius, 2004). This principal rests on two grounds: first, their inherent resistance to permanent occupation, and second, their natural destination for the common use of all humanity. On this basis of this argument, Grotius classified the seas as 'res communis', available for navigation and use by

all. Drawing an analogy, the same reasoning applies to outer space. Like the high seas, space is also limitless, incapable of permanent possession, and intended for the shared benefit of humankind. Consequently, its legal status is best understood in continuity with Grotius's doctrine of common spaces beyond sovereignty.

The historical background, the sovereignty over space above the territory has its essence back to the Roman Empire which mentions of Latin principles "cuius est solum, eius est usque ad coelum (ad sidera), et usque ad inferos" which rules that whoever owned the land, he possessed the space above the land "whoever's is the soil, it is theirs all the way to the sky and to the depths" (Cardellini Leipertz, 2024). Such ownership is questioned, but this logic reflected the reality of those times where there was no major need to set a legal boundary as there were no activities carried out in the airspace. Later the 40-year long Cold War led to the space race where both United States and the Soviet Union started to work on reinforcing their military and space powers. Leading to enactment of Outer Space Treaty which not only gave rise to legal concerns among scholars but also ignited space race among the nations to pioneer lunar launch missions (Cardellini Leipertz, 2024). A major concern was about the absence of any legal remedy in case when there is damage to people and objects on earth from the collisions with spacecraft or any satellite.

When it comes to the discussion of the potential solutions to this urgent problem, we must necessarily begin with the revision or amendment of the Outer Space Treaty, which currently forbids the claim of sovereignty over any portion of outer space. The Treaty, though fundamental, is indicative of the geopolitical reality of the Cold War period, as opposed to the multifaceted realities of the present and future space activities. Therefore, it is essential to reconsider its provisions in the context of contemporary developments.

The second possible solution is that of the idea of safety zones, which is suggested by the Artemis Accords. These areas, which do not imply sovereignty, may offer mechanisms for the peaceful use of outer space by avoiding interference in the areas where states or other actors are undertaking legitimate activities (Ferreira-Snyman, 2021; NASA, 2020). This idea may also develop into the creation of the so-called special economic zones in space. Though it would not establish sovereign status but it would grant limited rights for scientific purposes for, e.g., extraction of resources or residence, without undermining the overall principle of outer space as a global common. However, the main problem is the principle of consensus.

Nevertheless, the idea of creating special economic zones has its own complications. There will always be first movers' advantage which can lead to exploitation of resources by few. This possible disparity threatens to duplicate the hierarchies and imbalances that already exist in the geopolitics of the earth.

Therefore, there are many suggestions, but they are all filled with considerable gaps. No half-way measure, such as safety zones, economic zones, etc., will be adequate in itself. The only solution that is sustainable is a complete reform of the Outer Space Treaty.

Laws governing the commercialization of outer space

- ***Outer Space Treaty* (OST)**: Signed in 1967 it has established the fundamental rules for state conduct in outer space and has set the legal status of it as "global commons" (Wortman, 2020). OST provides the basic framework for international space law as it guarantees that space shall be free for exploration and not be subjected to any kind of sovereign status (Wortman, 2020). However, OST does not contain any such principles which could regulate economic activities for the purpose of exploring and extracting natural resources. Article VI of the treaty mentions about "bear international responsibility for national activities in outer space . . . whether such activities are carried on by governmental agencies or by non-governmental entities" (United Nations, 1967, art. VI) this leads to acceptance of non-governmental activity with the supervision of government, that allows for creation of commercial sectors such as telecommunications, remote-sensing, and spacecraft launching (Buono, 2020). Article VIII of the treaty states that "Ownership of objects launched into outer space, including objects landed or constructed on a celestial body, and of their component parts, is not affected by their presence in outer space or on a celestial body" (United Nations, 1967, art. VIII) which confirms that private enterprises retain ownership and possession over the equipment they sent into the outer space.

- ***U.S. Commercial Space Launch Competitiveness Act (SPACE Act) (2015)*:** It aims to facilitate a pro-growth environment for the developing commercial industry; this was enacted to encourage private sector investment and create a more stable regulatory framework and conditions. Chapter 513, Section 513033 of the said act provides ownership rights for

the minerals that have been extracted from outer space. It states: "A United States citizen engaged in commercial recovery of an asteroid resource or a space resource under this chapter shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell the asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of the United States." Though, the United States is not a party to the moon agreement but under circumstances where a state tries to establish its dominance over moon or other celestial bodies, it is the prerogative of the Secretary of State to object to any attempt made by any state or international organization to treat the Moon Agreement as reflecting or otherwise expressing customary international law. It is an open invitation to private enterprises to get their launch vehicles registered in the US and launch them from the land of the former itself, in order to gain ownership rights on Moon and other celestial bodies.

- ***The Artemis Accords-*** signed on October 13, 2020 with eight counties (NASA, 2020). It was promoted, drafted and initiated by the United States with the intention of bringing about a new era of exploration and inspiring the future generations to explore Moon, Mars and other celestial bodies. The Accords introduce the concept of "safety zones" for "Deconfliction of space activities"; this is outlined under section 11 (NASA, 2020, sec. 11) and serves as a de jure mechanism for granting the private commercial entities a fundamental element of property ownership: the right to exclude. This may be misused by the dominant countries causing a disadvantage to the other developing spacefaring nations.

Privatization of outer space

The privatization of outer space represents a fundamental shift in space exploration, moving away from a long-standing government monopoly to a competitive, global, commercialized industry now recognized as the "Space Sector" (Vereshchetin, 2021). Privatization generally means the transfer of ownership of the business or its resources to a private entity (Christol, 1982). The acceptance of non-governmental activities under government oversight allowed for the subsequent creation of commercial enterprises (Thomas, 2005). Initially, this included the commercial telecommunications, remote-sensing, and spacecraft launching industries, which were in their infancy then and are thriving today. Historically, in the decades following World War II, space exploration was entirely under the control of space nations. Private entities came into commercial markets in the early 1980s (Thomas, 2005). Post Cold War (1900s-2000s), budget constraints and shifting priorities in many counties led to deregulation, privatization and public-private partnerships. With the entrepreneurial start-ups, there was push for lower cost access to orbit, reusable technologies, small satellites, and novel models with U.S. Space Companies making the first move. (e.g. SpaceX, Blue Origin) (Simberg, 2012; Tracz, 2023).

There is a broad categorization of space privatization, as it encompasses several industries. The key areas included in this commercialization are:

(1) Launch and Transportation:

This category describes the emerging industry focused on moving people and payloads into and through space, encompassing both commercial transport for government agencies and space tourism.

• ***Companies and activities:*** SpaceX is actively engaged in commercial activities which include delivering payloads into space for a fee and providing cargo routes between earth and the International Space Station (Orta et al., 2024). It also continues to make news with its commercial activities, and innovation in reusable rockets which has drastically reduced the cost of transporting people and goods to and from outer space. SpaceX as a private entity, backed by the United States Government, is leaving no stone unturned to revolutionize every aspect of space travel.

• ***Space tourism:*** Virgin Galactic is explicitly mentioned as a pioneer in commercial spaceflight, which focuses on suborbital flights. The company has been working on developing commercial spacecraft which aims to provide suborbital flights for tourists who wish to experience weightlessness and view the Earth from space (Orta et al., 2024). Blue Origin, founded by Jeff Bezos, focuses on space tourism, ferrying high-paying tourists into the nearest reaches of space, and offers customers the opportunity to become astronauts for a day in a weightless environment (Simberg, 2012).

• ***Government engagement***: Both SpaceX and Blue Origin have become involved in the Artemis Project. SpaceX has a contract with NASA, as does Blue Origin. The United States plans to replace the publicly funded Russian Soyuz shuttle with American private space companies' crews, including SpaceX's Dragon spacecraft, by the end of 2017 (Tracz, 2023).

(2) Resource Exploitation

This category focuses accurately on the space mining industry aimed at collecting valuable materials from celestial bodies for commercial use.

• ***Activity and resources:*** The fundamental goal is the exploitation of outer space resources. Outer space contains valuable resources, and this industry relates to space mining. Celestial bodies contain resources that are scarce or non-existent on Earth. An example is helium-3, a substance common on the moon but exceedingly scarce on Earth, which has better potential for providing clean, efficient energy (Tracz, 2023). Asteroids are also known to be rich in valuable elements like platinum, palladium, and iridium.

• ***Companies:*** Planetary Resources was recently formed and funded with the intent of mining asteroids and is focused on the exploitation of near-earth asteroids. Moon Express, founded by Naveen Jain, plans to use robots to start mining the Moon (Delgado, 2018). Texas-based Shackleton Energy Company plans to mine ice in Shackleton Crater at the lunar south pole of the moon to provide propellant for future energy needs (Delgado, 2018).

(3) Private mining

The emergence of private mining ventures in outer space is motivated by the substantial economic value of the extraterrestrial resources and a compelling need for in-situ resource utilization (ISRU) (Orta et al., 2024). This becomes important because transporting massive amounts of materials, especially propellants, into deep space is prohibitively expensive, time consuming and complex. Celestial bodies including asteroids, harbor valuable materials such as rare minerals like platinum group metals, nickel, etc. are in high demand by the technological entities (Wasser and Jobes, 2008). The extraction of water from these bodies leads to production of rocket fuel (hydrogen and oxygen) which reduces the time and cost connected with launching fuel from Earth (Wasser and Jobes, 2008). The core legal framework the 1967 Outer Space Treaty contained in its Article II prohibits the "national appropriation" of outer space and celestial bodies (United Nations, 1967, art. II). However, the OST does not explicitly prohibit the ownership of resources which are being extracted by the non-governmental enterprises. The U.S. policy the Commercial Space Lunch Competitiveness Act of 2015 (SPACE Act) explicitly grants U.S citizens the right to possess, own, transport, use and sell space resources obtained. The subsequent Artemis Accord further mentions resource utilization not inherently constituting national appropriation under the OST (Tracz, 2023).

Specific examples of private companies actively pursuing space mining include:

- ***Moon express (MoonEx):*** it is a privately led American company, authorized by the U.S. Federal Aviation Administration (FAA) for the first lunar mission in August 2016. The vision of it is to mine the moon for valuable natural resource and return it back to earth.
- **Astro forge:** this company is based in Los Angeles, focused on M-type asteroids and is developing and testing space mining technology. It also plans to deploy spacecraft in 2024 to observe a target asteroid.

The unilateral nature of the national laws of various nations regarding the promotion of privatization of space can be seen as violative of the non-appropriation principle which leads to lack of global consensus on space resource appropriation.

The weaponization of outer space

The term 'Weaponization of Outer Space' has not been comprehensively defined anywhere; however, it can be broadly defined as the deployment of weapons of any grade in space or the development systems designed to attack targets in, form or through space (Khalid, 2021). This process signifies a fundamental transformation from a long-standing militarization of space which even pertains to the use of space-based assets such as satellites for communication, navigation and reconnaissance for supporting terrestrial military operations (Khalid, 2021). While the militarization of space has been an established reality for decades which marks an inherently destructive and qualitative shift toward active military engagement beyond Earth's atmosphere.

The absence of a universally accepted definition of "space weapon" has been a roadblock to execute an effective arms control regime in the outer space. One of the definition states "any asset, whether Earth-based or space-based, designed to attack

targets in space or to strike terrestrial targets from space" but this definition run into ambiguity as it fails to take into account the dual use technology i.e. technology that is being used for both civilian and military purposes (Aggarwal, 2024).

Key example of dual-use technologies include:

1. ***Space Launch Vehicles (SLV's)*** **-** Launch vehicles are used for satellite deployment; however, the same launch vehicles are capable of being modified into ballistic missiles and missile defense interceptors. Thus, these vehicles can also be used for weapon delivery in the space.

2. ***Maneuverable satellites (RPOs and OOS)*** - these are technologies developed for rendezvous and proximity operations (RPO) or on-orbit servicing (OOS) such as inspection, repair or refueling missions which possess the inherent capability to function as co-orbital anti-satellite (ASAT) systems (Aggarwal, 2024).

3. ***Active Debris Removal (ADR) System:*** these technologies are critical for mitigating space debris, and could be repurposed to disable or remove any adversarial satellites without even generating the extensive debris associated with kinetic attacks, offering distinct strategic advantages (Johnson-Freese and Burbach, 2019).

Orbital debris

Orbital debris can be defined as any human made object that orbits around the earth and no longer serves a functional purpose (Bongers and Torres, 2024). This debris consists a wide range of discarded material such as derelict spacecraft, non- functional upper stage of the launch vehicle, discarded mission related hardware and countless fragments resulting from hypervelocity collision (European Space Agency, n.d.).

After the launch of Sputnik 1 the first ever human made satellite, a total of 14,700 tons of debris is revolving around the earth as of September 2025. This recorded debris as of 2025 illustrates that despite decade of awareness, mitigation efforts remain largely reactive rather than preventive. The debris population was dramatically increased by major fragmentation events, notably the intentional destruction of the Fengyun-1C weather satellite in 2007 and the accidental collision between the American communications satellite Iridium-33 and the retired Russian spacecraft Cosmos-2251 in 2009 (Black and Butt, 2010). Such catastrophic fragmentations underscore the risk of reaching a "critical density," a condition known as the Kessler Syndrome, where the rate of debris generation through mutual collisions exceeds the rate of natural removal via atmospheric drag, leading to an inherently unstable and self-sustaining growth of the debris population (Doboš and Pražák, 2022).

The magnitude of orbital debris presents around the volume of space surrounding the Earth varies in different bands, known technically as orbital regimes. Based on the altitude, the natural process and the risks to remove the debris varies accordingly:

Orbital Regime	Altitude Range & Characteristics
Low Earth Orbit (LEO)	Below 2000 km
LEO Low Altitudes	Below 600 km (approx.)
Medium Earth Orbit (MEO)	between 2,000 km and the Geosynchronous layer
Geostationary Orbit (GEO)	Near 36,000 km altitude

Low Earth Orbit (LEO) contains the vast majority of orbital debris (Doboš and Pražák, 2022). The greatest concentration, and consequently the highest collision risk, is found near 750 km to 1000 km. At these altitudes (above 600 km), atmospheric drag is minimal, meaning debris can remain in orbit for centuries or even a thousand years or more (Khalifa, 2015).

Geostationary Orbit (GEO) is another highly congested region because about 40% of all operational spacecraft reside here, primarily for communications. Due to the high altitude, debris here is often boosted into higher, disposal ("graveyard") orbits at the end of their mission to protect this valuable natural resource. Debris can be classified on two basis, either by its source and function or by its physical size.

Orbital debris presents not just a significant technical threat but also a environmental threat. There is the direct risk to the existing space systems, driven by the extreme speed of the objects in the orbit. The average velocity the debris is approximately 10km/s, meaning a simple collision involve a considerable energy (Khalifa, 2015). At such a high speed, a very small particle which is less than a 10 cm can cause severe damage. The environmental risks are associated with the long-term degradation of

the near-earth space environment. The most concerning threat is the Kessler syndrome, studies have indicated that the environment, particularly in the high traffic regions like 800 km to 1000km altitude, has alredy reached a point where the collision among the existing objects will lead to a growing debris population even without new launches (Black and Butt, 2010). The U.S. policy acknowledges that orbital debris poses a risk to the safety of persons and property on Earth, though no serious injury or significant property damage from reentering debris has been confirmed in the past 50 years.

Nations across the globe approach the problem of the debris through two major strategies: mitigation and remediation, also called the active debris removal. Currently the most significant and widely implemented efforts is reducing the creation of the new debris. Clearing the environmental debris remains a major technical and economic challenge (Sullivan and Ben-Itzhak, 2023).

United States efforts

The official Policy of US since 1988 includes the mitigating and minimizing the creation of the new debris. The US National Space Policy is tasked with the preserving the space environment through mitigation. The U.S. Government Orbital Debris Mitigation Standard Practices (ODMSP), updated in 2019, sets forth requirements governing the design and operation of spacecraft and upper stages to limit the growth of the debris population. These practices manage and control the debris that are released in the space during the normal operation, minimization of the debris generated by the accidental explosion and the post mission disposal of space spectrum, which also includes the 25year rule for decay. The 25year rule says, "Any spacecraft or upper stage in low Earth orbit (LEO) should be removed from orbit — either through atmospheric reentry or transfer to a disposal orbit — within 25 years of the end of its operational mission." In other words, once a satellite stops functioning or serves its function, it must deorbit within 25 years to minimize long term accumulation (Sullivan and Ben-Itzhak, 2023).

Other notable efforts taken by US includes the advancement of research and development initiative which focuses on Active Debris Removal (ADR) primarily led by NASA and its department of defense. Further, the department of defense plays a critical role in global collision avoidance by providing free conjunction warnings to all space operators, irrespective of nationality, thereby contributing to the prevention of potential on-orbit collisions. Additionally, U.S. federal agencies—including the Federal Aviation Administration (FAA), the National Oceanic and Atmospheric Administration (NOAA), and the Federal Communications Commission (FCC)—incorporate orbital debris considerations into their licensing and regulatory processes for spacecraft and launch vehicle upper stages, ensuring that debris mitigation remains a key element in national and international space governance.

China's role and efforts

China has played a mixed role in orbital debris situation, both contributing to the problem as well as engaging in the mitigation efforts. It plays a major role in increasing the number of large debris in the orbit through intentional destruction of the Fengyun-1C weather satellite. This anti-satellite (ASAT) weapon test created the largest orbital debris cloud in history and was conducted at an altitude (near 860 km) resulting in very long-lived debris. To mitigate the problem of orbital debris China has issued his own debris mitigation guidelines. Further, since the adoption of UN orbital debris mitigation guidelines in 2007, China has refrained from any other debris-generating tests of anti-satellite systems.

Beyond USA and China other major nations and international bodies focus and coordinated mitigation and exploring active removal technologies. Countries like Russia, Japan, France and European Space Agency (ESA) have all issued orbital debris mitigation guidelines. These national guidelines were closely coordinated with the consensus guidelines developed by the Inter-Agency Space Debris Coordination Committee (IADC) and later adopted by the UN Committee on the Peaceful Uses of Outer Space (COPUOS) (Johnson, 2014).

Concerns Related to Debris Cleaning (Remediation)

- ***General security concerns with Active Debris Removal (ADR):*** The idea of Active Debris Removal (ADR) has not been widely adopted due to technical and economic challenges, as well as specific security concerns.
- ***Military implications and intentional harm:*** Discussions around orbital debris management frequently intersect with military and national security issues. In the year 2007, with the creation of large cloud of orbital debris which was the result of the destruction of Chinese satellite Fengyun-1C, there was a major disruption in the generally stable environment of the civil

and commercial space activities (Black and Butt, 2010). Any close-up approach or manipulation of satellites even for a Bonafide purpose can be viewed with suspicion.

- ***Reluctance to share sensitive trajectory data*:** In the general context of collision avoidance (which precedes cleaning operations), satellite operators, including governments, are reluctant to release their orbit data and manoeuvres for reasons of competition or national security. This reluctance creates roadblocks to solving debris dilemmas (Finkleman, n.d.).
- ***Risk of providing false or harmful data*:** National interests and competition may hinder collaboration on space operations. Some parties might take advantage of the systems by providing false data to force an expensive and disadvantageous maneuver on a competitor. Also, conjunction partner may have to bear the expenses as other may refuse to cooperate (Finkleman, n.d.).
- ***Legal and ownership hurdles to clean space debris:*** Under International law any defunct satellite is considered private, thus removing debris becomes a major challenge as it requires the express permission of the owner. Thus, any country possessing technology to clean up debris would require careful negotiations with another country in regard to ownership and liability.
- ***Use of lasers (Dual-Use Technology):*** Contemporary techniques such as such use of ground or air-based lasers to evaporate debris, raises concern in regard to arms control. These technologies have the potential to cause serious threat to other space systems deployed by individual countries or entities.

DOCTRINAL AND INTERPRETATIVE AMBIGUITIES

The Outer Space Treaty, 1967 till date remains the principal legal framework that governs the outer space activities ensuring that it remains a domain of mankind and can be used for the advancement of the humanity (de Zwart et al., 2023). Yet it still remains a product of cold war and carries with itself inherent doctrinal and imperative ambiguities which makes it ill-suited for contemporary challenges in space domain.

The bone of contention that plagues Outer Space Treaty or OST is what includes permissible "use" of outer space and what constitutes as prohibited "national appropriation" of celestial bodies. While Article I states that "the activities in outer space shall be carried out for the benefit of humanity and shall be accessible to all" (United Nations, 1967, art. I), Article II prevents "any state to claim sovereignty over outer space or any celestial body in any form or manner" (United Nations, 1967, art. II). The treaty is silent on whether the commercial extraction and private ownership of the space derived resources such as lunar or asteroid minerals constitute a form of appropriation which has substantial legal and governance gaps.

In the absence of an explicit guidance there are several technologically advanced states, including the United States, Luxembourg and Japan which have adopted the domestic legislation which recognizes private property rights over the resources that are extracted from outer space. These measures rest on a textualist interpretation which distinguishes territorial sovereignty from the ownership of materials once removed from their natural context, asserting that the latter does not contravene the prohibition mentioned in Article 2 (Anderson et al., 2019; Pershing, 2019).

Such unilateral interpretations mark criticism on the grounds that it risks enabling de facto sovereignty, and thereby undermines the Treaty's commitment to share of equity, non-appropriation and benefit of all states (Ferreira-Snyman, 2021; Pershing, 2019). The ambiguity in interpretation of national legislation and the principles of Outer Space Treaty creates legal uncertainty for both the states and commercial actors. The provisions of the OST have been drafted in Cold War era and fails to address contemporary issues such as orbital congestion, resource utilization, commercial participation and others. Thus, it becomes difficult for national actors to determine whether national laws align or divert from international obligations. To ensure the stability in outer space governance it has become imperative for legal scholars to go back to drawing board for a system evaluation of all the ambiguities.

Undefined boundary between airspace and outer Space

One of the biggest lacunae in air space governance is the absence of an internationally agreed boundary between outer space and sovereign airspace. It leads to significant jurisdictional uncertainty between domestic air space laws under Chicago Convention and the non-appropriation principle of Outer Space Treaty (Cardellini Leipertz, 2024). Though Karman Line i.e. 100 Kilometers above the sea level is considered as the line of bifurcation, there have been various scientific assessments which

suggests that aerodynamic lift is lost at approximately 80 Kilometers. This all invites regulatory and practical challenges and affects outer space activities in every form and manner.

The case for a flexible boundary or mission-based definition

Against this backdrop of increasing technological complexity and persistent legal inactivity. Thus, a more precise and adaptive analytical framework appears necessary. Rather than focusing on the pursuit of a singular, immutable demarcation, a number of scholars advocate for the establishment of an international legal regime that will act as a buffer zone between sovereign airspace and outer space. This model implicitly calls for the recognition of both spatial location and functional purpose which carry legal significance and therefore seeks a balanced and inclusive approach.

1. ***Intermediate zone ("Near Space" or "Mesospace")*:** One influential purpose that envisioned the creation of an intermediate region is variously termed "Near Space," Mesospace," or a "Protozone" covers an altitude which generally ranges between 18 and 160 kilometres.

Such a zone could be regulated analogously to the maritime zones which is delineated under the United Nations Convention on Law of the Sea (UNCLOS) which differentiates areas between areas of full sovereignty (Territorial Sea) limited sovereign rights (Exclusive Economic Zone) and the sovereign global commons (high seas) (Cardellini Leipertz, 2024).

Under this regime, qualified or "innocent" passage could be recognized for commercial or scientific aerospace operations while still permitting the subsequent State to retain limited sovereign entitlement, including a defined security or economic rights.

Establishing the lower and upper boundaries of this intermediate zone marks the cessation of airspace and the commencement of boundary of outer space would not only provide essential legal certainty but also reduce the jurisdictional ambiguity that is currently confronting States and operators.

2. ***A mission-based or hybrid functional/spatial approach:*** With the increasing prevalence of hybrid aerospace vehicles. A craft that is capable of operating through combinations of aerodynamic lift and rocket propulsion, demonstrates the insufficiency of a purely spatial or purely functional standard. In such circumstances, a blended or mission-based analysis is often indispensable.

For hybrid vehicles, the applicability of air law or any other space law may depend on the operational phase i.e. air law may govern prelaunch ascent or atmospheric gliding during descent whereas phases that involve rocket propulsion or exo-atmospheric flight may more appropriately fall under the space law (Leepuengtham, 2017).

Nonetheless, on one hand the overarching purpose of the mission is orbital or suborbital spaceflight, there are many scholars who argue that the space law regime should apply from law through recovery. Thus, this approach avoids the interpretive contortions which are associated with mid-flight and shifts in legal regimes and also enhances regulatory predictability for operators and states alike.
Therefore, creation of an intermediate "Near Space" regime provides a flexible legal architecture which will operate as a transitional "gear shift" between the two dominant legal domains i.e. air law, characterized by complete State sovereignty, and space law which is defined by non-appropriation and global commons principles. By accommodating limited yet meaningful State rights while facilitating the safe and predictable conduct of emerging aerospace activities, such a regime mirrors the graduated governance structure of the law of the sea where coastal States may exert oversight in adjacent zones to safeguard security and resource interests before activities reach the fully international domain.

Ambiguity of core terms in the OST

The foundational legal architecture governing the outer space activities is articulated in the 1967 Outer Space Treaty which contains significant legal ambiguities in the several core terms, creating legal uncertainty as there is improvement in technological innovation and commercial activity.

"Province of all mankind"

Article 1 of the OST characterizes outer space as the "province of all mankind" and along with that it allows for its exploration and use for the benefit of all mankind. Thus, leads to formulation of divergent interpretations. Developing states often formulate this language as a reflection of common heritage of mankind principle which requires collective management, equitable

distribution of benefits and the space resources (Gupta, 2016). Conversely, there are major nations that interpret this provision as aspirational, permitting resource extraction and ownership so long as no claims of territorial sovereignty are asserted (Khatwani, 2019). The 1979 Moon Agreement, aiming to formulize the common heritage approach through an international explorational regime (Gangale, 2008). Still it failed in gaining acceptance from space powers. Most recently, the Artemis Accords affirm peaceful use and broad benefits and rejected the characterization of outer space as global commons. Therefore, endorsing domestic laws which allows for private ownership of extracted resources.

"Peaceful purpose"

The outer space treaty mandates the use of outer space for "peaceful purpose" but it leads to significant interpretative flexibility due to absence of precise definition of the term. This ambiguity is further compounded by the prevalence of dual-use space technologies which blur the distinction drawn between civilian and military activities. Legal debate around this focuses on whether "peaceful" denotes a non-military standard or a non-aggressive one. The latter interpretation permits military activities in prevalence of threat or widely adoption of force by major spacefaring states. While the treaty explicitly prohibits placement of nuclear weapons and other weapons of mass destruction in orbit or on celestial bodies, still it does not impose any comparable restrictions on conventional weapons (Su, 2010). Ongoing development and testing revolving around military capabilities including anti-satellite weapons have consequently raised concerns over the weaponization of outer space. The same was illustrated by the debris-generating 2007 Chinese ASAT test and its adverse implications for orbital safety.

"Harmful contamination"

Article IX of the OST calls for the States to conduct space exploration in a manner which avoids harmful contamination but neither this article defines concept nor it establishes concrete mitigation standards (Lively, 2025). Therefore, leads to creation of normative ambiguity that has increasingly become problematic as space activities grow in scale and technological sophistication. Contemporary concerns extend beyond the biological contamination, focusing on planetary protection, particularly with respect to potentially habitable bodies present, such as Mars to include environmental degradation associated alongside resource extraction. The proposed lunar and asteroid mining activities introduce additional risk such as extensive dust and release of particular matter into orbit which in the long run may lead to exacerbation of orbital debris (Lively, 2025). In an environment which is already burdened with fragmentation events, resulting from anti-satellite tests. The legislative gap of a clear regulatory standard for environmental impacts of commercial extraction further complicates this issue and needs efforts to maintain up a safe and sustainable outer space environment.

Minimal ratification and weak effectiveness of the Moon Agreement

The governing agreement for the activities taking place on the Moon and other celestial bodies (1979) commonly referred as the Moon Agreement (MA) (Van Bogaert, 1981) has achieved only minimal ratification till date. Thus, led to limiting its effectiveness as an international legal instrument for governing extraterrestrial resource activities.

The Central Challenge: Minimal Ratification and the Absence of Major Space Powers:

Primarily, the undermining relevance of the Moon Agreement is its extremely limited level of participation. Having being ratified by only 18 States, the treaty remains one of the least adopted instruments in space law. Notably, none of the major spacefaring nations such as the United States, Russia, China, and Japan, are parties to the Agreement. Although several states with emerging moderate space capabilities like, Australia, India, and France, have signed or ratified the treaty yet their comparatively limited engagement in advanced lunar exploration has further reduced its practical significance. Therefore, explicit rejection of the Moon Agreement by key actors, for say The United States has reinforced its marginal status. This position was formally articulated in 2020 order of President Donald Trump which declared United Nations not being party to the agreement and rejected its characterization as reflective of customary international law.

Lack of a binding resource framework and emerging fragmentation

The Moon Agreement's weak ratification record has led to production of significant legal and practical consequences for the governance of lunar resources (Christol, 1999).

Absence of a binding regime for resource extraction: The moon agreement sought to elaborate upon and operationalize the principles of the Outer Space Treaty (OST) (David and Lee, 1999). Article 11 of the treaty designates the Moon and its natural resources as the "common heritage of mankind" (CHM) (United Nations, 1979, art. 11(1)) and anticipates the

formulation of an international regime to govern resource exploitation once it becomes technologically feasible (United Nations, 1979, art. 11(5)). However, there are concerns raised about the concept of the common heritage of mankind as it particularly implicates mandatory benefit-sharing, international oversight and is often perceived as limitation on commercial freedoms (Beldavs and Sommers, 2017; O'Brien, 2018) prompting major spacefaring nations to refuse accession. The result of this ultimately led to neglect of an international regime which is universally accepted or binding mechanisms which exist to monitor and regulate resource extraction on the Moon.

Rise of unilateralism and fragmented norms: Governance vacuum left by the moon agreement has catalysed the emergence of alternative, nonbinding frameworks most notably the Artemis Accords led by the United States (de Zwart, 2021). The Accords reject the 'common heritage of mankind' regime that is envisioned by the moon agreement and the advance a contrasting interpretation of Outer Space Treaty Article II (de Zwart, 2021). They affirm that resource extraction does not constitute prohibited national appropriation and endorse the permissibility of private ownership national appropriation and endorsement of private ownership of extracted materials. With 56 signatories as of 2025, the Accords reflect the growing international alignment around a U.S. cantered model of resource governance. Critics argue that such frameworks contribute to normative fragmentation and also encourage the development of parallel governance regimes that are aligned with geopolitical blocs.

The State-level reluctance towards the ratification of the Moon Agreement has shifted the central legal debate from whether resource extraction should occur to how the unilateral national practices can be reconciled with the cooperative foundations of the OST. The failure to secure a broad acceptance for a comprehensive, multilateral governance regime has created a patchwork of legal which is characterized by prescriptive inconsistencies, competing interpretations, and growing geopolitical divergence. Against this backdrop, the moon agreement's unattained objective underscores much broader challenge facing international space law i.e. reconciling commercial incentives, national interests, and collective stewardship within an increasingly contested extraterrestrial environment.

State practice and international response

Having delineated the foundational basis for the international space law, it becomes important to compare and analyze the domestic space laws of the prominent countries and examine how perfectly, these norms govern the domestic legal framework of the individual states. In this context, National space legislation functions as the operative mechanisms through which the state fulfill their international obligation.

The development of national space laws has not maintained a coherent trajectory over time. Rather, each state's legislative approach reflects its historical relation with the space activities, institutional capacities, strategic intrest and the economic priorities (De Man, 2017). While the domestic laws largely comply with the shared international space commitments yet significant divergence persists in their regulatory structures, licensing procedures, compliance mechanism and the approaches to evolving space related issues.

This section of the research will undertake a systematic analysis of the selected domestic space law regimes with the aim of outlining the similarities and the divergence. Such a comparison not only highlights the diversity of the national practices but also shows diversity in these laws and the potential areas aligning within the developing global space landscapes.

The space governance frameworks across countries like, the United States, India, Luxembourg, Russia, and the UAE universally prioritize adherence to the Outer Space Treaty (OST), primarily by establishing robust systems for state authorization, continuing supervision of private activities and mandating financial responsibility regimes to manage international liability for damages. All these jurisdictions mandate licensing for non-governmental activities, with the US (via the CSLA) and Luxembourg extending their regulatory control extraterritorially over nationals and legal persons established under their law engaging in space activity. Furthermore, a commitment to managing international liability risk is evident across all frameworks, with the US (CSLA), Russia (Law on Space Activity), India (Draft Bill), and Luxembourg (General Law on Space Activities) all mandating or requiring financial assurance or liability insurance in consideration of their international obligations.

A major area of difference lies in legalizing space resource utilization; notably Luxembourg pioneered legislation as it explicitly grants entities the right to ownership of space resources upon recovery, a position which is largely mirrored in India's modern space policy (Policy 2023) and along with that supported by the UAE's policy ambitions. Even with prudence, there are

requirements for consistency with international obligations. Regarding environmental safety and debris mitigation, Russia is a notable country which stands out for having mandatory technical standards (GOST R 52925-2018) which filters out post-mission disposal requirements, such as limiting LEO orbital lifetime to no more than 25 years and demanding spacecraft passivation, objectives shared by the US and UAE through formal policy commitments to address increasing orbital congestion and the necessity of promoting sustainability standards. Finally, policy shifts across the US (SPD-3) and India (IN-SPACe) reflect a trend toward modernizing regulatory structures by either formally separating **civil and** military domains (US moving SSA/STM data oversight toward the Department of Commerce) or establishing centralized civilian "single-window" regulatory bodies to promote commercial sector expansion.

Towards reform: recommendations and future directions

Space Laws must be developed in a manner which prioritizes the modernization and strengthening of the basic legal framework administering outer space activities, as the world witnesses the rapid transformation of space domain from a mere state and scientific activity towards becoming a commercial hub influenced by multipolar world. Though, Outer Space Treaty of 1967 remains the foundational stone for international space law, contemporary challenges demand not only interpretation of existing laws and norms but calls for stricter compliance, dispute resolution and new verification mechanisms so as to ensure that the space remains the common domain of mankind so as to ensure sustainable development in literal sense.

The biggest policy priority must be the establishment of international regime for space utilization. The regime will hold a great value as space travel and inter-planetary mining comes into focus (including asteroid mining). Without a uniform policy, space can be exploited by spacefaring nations as they have developed the essential technology and mature it which will leave non spacefaring nations as the mercy of the former. The need of the hour is to develop a uniform licensing system, strict sustainability guidelines and mandatory benefit sharing criteria to ensure that the space remains the common heritage of mankind. The thirst to hoard resources can be reflected in the limited acceptance of Moon Treaty. This calls for a novel Space Resolution Convention under the auspices of United Nations to ensure inclusivity and broader state participation.

Space traffic has emerged as a new domain. Private companies have uninterrupted access to space, promoting them to launch endless satellites for commercial gains. At the same time government entities are more and more driven towards snooping and espionage activities in this multipolar world which prompts them to heavily invest in spy satellites and at the same time increasing their launch frequencies. This all have raised alarming concerns about orbital congestion and at the same increasing the risk of collisions. There is an urgent need for a globally coordinated body to regulate and manage space traffic and set satellite threshold limit for respective orbits. It must comprise of transparent procedures, standardized safety protocols, emergency protocols and penalties and sanctions approved by majority to ensure compliance.

The most critical future challenge will be in relation of space debris proliferation. Millions of small particles float in the space, majority of them untraceable, posing threat to satellites, human space missions and long-term space access. International community will require to be brought to come on a same page in order to ensure the effective disposal of such debris post mission completion. This calls for sustainable investment to develop affordable technology and finding ways to recycle these debris. There is a need to develop mechanism to assess environmental impacts and also find the application of “Polluters Pay Principle” in the domain of space. Another emphasis can be on the debris removal credits prompting private sector to heavily invest in the technology and at the same time ensuring sustainable orbital stewardship.

Legal intervention is also required in the domain of militarization and weaponization of outer space. Humanity has witnessed continued testing of Anti-Satellites (ASAT) weapons in the name of self-defence. There has been deployment of dual use technology in the outer space prompting nations to invest heavily in Anti-Satellite weapons. There is a need to strengthen global commitments towards Prevention of an Arms Race in Outer Space (PAROS), bring transparency among nations and initiate confidence building measures so as to ensure that space remains non-aggressive and compatible with international law.

Dispute resolution is the most under developed domain of the space laws. Contemporary diplomatic channels are cumbersome, inefficient and politically constrained. There is an urgent need of creation of specialised space arbitration forums, digital evidence platforms, mandatory dispute submission clauses to track technical incidents. The focus should also be given to reform institutional mechanisms such as Permanent Court of Arbitration’s space rules for effective and timely disposal of cases.

As the humanity makes rapid advancement towards human spaceflight and extra-terrestrial habitat development, new legal framework is the need of the hour to address jurisdiction issues, criminal liability, property rights, labor rights for space workers, disaster response mechanism and space experimentation.

CONCLUSION

The creation of Outer Space Treaty owes it foundation to the doctrine of Res Communis as it was drafted with an objective to create outer space as place for a global common, where exploration could take place for the benefit of humanity. The treaty has following core norms- forbidding national appropriation, stopping the usage of weapons of mass destruction, freedom of exploration, liability on states for their domestic space activities and damage caused by space objects. The treaty reflects the aspiration of having a non-territorial regime based on cooperative and equity.

Half a century after it came into existence, the space arena has witnessed a huge transformation- growth lead by private sector, asteroid mining, space tourism, growth of new spacefaring nations in multipolar world. These developments have exposed the limitations of the treaty regime. The concept of national appropriation and sovereignty have also become a contested topics as national legislations have permitted claims by commercial enterprises and at the same time allowed exploitation of natural resources.

Moreover, there is a threat to sustainability, equity and tranquillity in outer space with increase in orbital congestion, proliferation of space debris, unregulated private sector, and environmental risks. There is a clear threat to original blanket ban on the prohibition of sovereignty as the same is not tenable in the contemporary era.

This research suggests a complete re-evaluation of the doctrine of Res Communis on which the magna carta of space law is based i.e. Outer Space Treaty. The need of the hour is not the mere selective interpretation but a comprehensive overhaul of the international space laws. The overhaul must accommodate commercial interests at the same time ensuring sustainability in the space arena. At the same time, it must make room for new players so that developing nations do have a piece of pie in this emerging sector. There is also additional responsibility on all the stakeholders to deliberate via various forums on how space laws can be rigid when it comes to sustainability and flexible when it comes to innovation and greater good of humanity. Humanity must look at an evolution where ethical and moral considerations must complement commercial interests in the space law. A greater amount of finance must be channelized for future oriented mechanisms that can safeguard the outer space from the exploitation and ensure that it remains a "common heritage of humankind".

REFERENCES

[1] Aggarwal, J., 2024. Space policy imperative: The urgency for a new international space governance system. *Astropolitics* 22(1–2), 102–113. https://doi.org/10.1080/14777622.2024.2379089.

[2] Anderson, S.W., Christensen, K., LaManna, J., 2019. The development of natural resources in outer space. *Journal of Energy & Natural Resources Law* 37(2), 227–258. https://doi.org/10.1080/02646811.2018.1507343.

[3] Beldavs, V., Sommers, J., 2017. The emerging field of space economics: Theoretical and practical considerations. *The Space Review*, 18 December.

[4] Black, S., Butt, Y., 2010. The growing threat of space debris. *Bulletin of the Atomic Scientists* 66(2), 1–8. https://doi.org/10.2968/066002001.

[5] Bongers, A., Torres, J.L., 2024. Star wars: Anti-satellite weapons and orbital debris. *Defence and Peace Economics* 35(7), 826–845. https://doi.org/10.1080/10242694.2023.2208020.

[6] Buono, S., 2020. Merely a "scrap of paper"? The Outer Space Treaty in historical perspective. *Diplomacy & Statecraft* 31(2), 350–372. https://doi.org/10.1080/09592296.2020.1760038.

[7] Cardellini Leipertz, R., 2024. Sovereignty beyond borders: Unraveling the enigma of airspace and outer space interplay. *International Journal of Law and Policy* 2(7), 1–15. https://doi.org/10.59022/ijlp.201.

[8] Christol, C.Q., 1982. *The Modern International Law of Outer Space*. Pergamon Press, New York.

[9] Christol, C.Q., 1999. The 1979 Moon Agreement: Where is it today. *Journal of Space Law* 27(1), 1. https://doi.org/10.56702/PJKX6569/jspalaw_2701.2.

[10] David, M., Lee, R., 1999. Twenty years later—The Moon Agreement and its legal controversies. *Australian International Law Journal*, 9.

[11] Delgado, N., 2018. *The Policy Evolution and Privatization of Commercial Space Systems*. Honors thesis, University of Mississippi.
[12] De Man, P., 2017. State practice, domestic legislation and the interpretation of fundamental principles of international space law. *Space Policy* 42, 92–102.
[13] de Zwart, M., 2021. To the Moon and beyond: The Artemis Accords and the evolution of space law. In: de Zwart, M., Henderson, S. (Eds.), *Commercial and Military Uses of Outer Space*. Springer, Singapore. https://doi.org/10.1007/978-981-15-8924-9_6.
[14] de Zwart, M., Henderson, S., Neumann, M., 2023. Conceptualising sustainability in outer space resource utilisation. *Griffith Law Review* 32(4), 481–505. https://doi.org/10.1080/10383441.2024.2393064.
[15] Doboš, B., Pražák, J., 2022. Master spoiler: A strategic value of Kessler Syndrome. *Defence Studies* 22(1), 123–137. https://doi.org/10.1080/14702436.2021.1997095.
[16] European Space Agency, n.d. DisCos Web statistics (Space Environment Statistics). DisCos Web. https://sdup.esoc.esa.int/discosweb/statistics/. Date accessed: 10 December 2025.
[17] Ferreira-Snyman, A., 2021. Challenges to the prohibition on sovereignty in outer space—A new frontier for space governance. *PER / PELJ* 24(0). https://doi.org/10.17159/17273781/2021/v24i0a8685.
[18] Finkleman, D., n.d. The dilemma of space debris. *American Scientist*, Sigma Xi. https://www.americanscientist.org/article/the-dilemma-of-space-debris. Date accessed: 10 December 2025.
[19] Gangale, T., 2008. Myths of the Moon Agreement. *AIAA Conference Proceedings*. https://doi.org/10.2514/6.2008-7715.
[20] Ghanie, N., 2024. Res communis and the space race: A lesson (yet to be) learned. *Florida Atlantic University Undergraduate Law Journal* 11(1), Article 5.
[21] Grotius, H., 2004. *The Freedom of the Seas*. Project Gutenberg, n.p.
[22] Gupta, V., 2016. Critique of the international law on protection of the outer space environment. *Astropolitics* 14(1), 20–43. https://doi.org/10.1080/14777622.2016.1148462.
[23] Johnson, N.L., 2014. Saving space: The multilateral approach to orbital debris. *Georgetown Journal of International Affairs* 15(1), 130–138.
[24] Johnson-Freese, J., Burbach, D., 2019. The Outer Space Treaty and the weaponization of space. *Bulletin of the Atomic Scientists* 75(4), 137–141. https://doi.org/10.1080/00963402.2019.1628458.
[25] Khalid, M., 2021. Space legal regimes, militarization, and weaponization of outer space. *Astropolitics* 19(1–2), 128–144. https://doi.org/10.1080/14777622.2021.2008768.
[26] Khalifa, N.S., 2015. Dynamical study of low Earth orbit debris collision avoidance using ground based laser. *NRIAG Journal of Astronomy and Geophysics* 4(1), 25–31. https://doi.org/10.1016/j.nrjag.2015.02.001.
[27] Khatwani, N., 2019. Common heritage of mankind for outer space. *Astropolitics* 17(2), 89–103. https://doi.org/10.1080/14777622.2019.1638679.
[28] Leepuengtham, T., 2017. International space law and its implications for outer space activities. In: *The Protection of Intellectual Property Rights in Outer Space Activities*. Edward Elgar Publishing, Cheltenham, UK. https://doi.org/10.4337/9781785369629.00005.
[29] Lively, M., 2025. It's time to take out the trash: Does Article IX of the Outer Space Treaty require the development of active debris removal technologies? *Arizona Journal of Environmental Law and Policy* 15(2), 148–166. https://doi.org/10.2139/ssrn.5015656.
[30] Martin, N., 2021. Mars settlement likely by 2050, says UNSW expert—but not at levels predicted by Elon Musk. *UNSW Newsroom*, 8 March. https://www.unsw.edu.au/newsroom/news/2021/03/mars-settlement-likely-by-2050-says-unsw-expert-but-not-at-levels-predicted-by-elon-musk. Date accessed: 10 December 2025.
[31] NASA (National Aeronautics and Space Administration), 2020. Artemis Accords. NASA Website, 13 October. https://www.nasa.gov/artemis-accords/. Date accessed: 10 December 2025.
[32] Nelken-Zitser, J., 2025. Mining the moon for minerals could be worth billions, but astronomers warn it's bad news for science. *Business Insider*, Insider Inc., February. https://www.businessinsider.com/mining-moon-minerals-lucrative-bad-news-science-research-astronomists-2025-2. Date accessed: 10 December 2025.
[33] O'Brien, D., 2018. Why it's a bad idea to weaken the Moon Treaty. *The Space Review*, 5 March. https://www.thespacereview.com/article/3444/1. Date accessed: 7 January 2026.
[34] Orta, A.K., Lopez, J., Ontiveros, C., 2024. Ethical implications of space colonization. *Young Scientists and Philosophers on the Border* 1(1), Article 2.

[35] Pershing, A.D., 2019. Interpreting the Outer Space Treaty's non-appropriation principle: Customary international law from 1967 to today. *The Yale Journal of International Law* 44, 149–178.
[36] Scuderi, E.I., 2026. On sovereignty, outer space, and taxation. *Nebraska Law Review* 104(3), 421. https://digitalcommons.unl.edu/nlr/vol104/iss3/2/. Preprint version: https://doi.org/10.2139/ssrn.5357685.
[37] Simberg, R., 2012. Property rights in space. *The New Atlantis*, Fall. https://www.thenewatlantis.com/publications/property-rights-in-space. Date accessed: 10 December 2025.
[38] Su, J., 2010. The "peaceful purposes" principle in outer space and the Russia–China PPWT proposal. *Space Policy* 26(2), 81–90. https://doi.org/10.1016/j.spacepol.2010.02.008.
[39] Sullivan, K., Ben-Itzhak, S., 2023. Securing the space domain with active orbital debris removal: Lessons from Europe and Japan towards a U.S. strategy. *Astropolitics* 21(2–3), 127–149. https://doi.org/10.1080/14777622.2023.2274922.
[40] Thomas, J., 2005. Privatization of space ventures: Proposing a proven regulatory theory for future extraterrestrial appropriation. *BYU International Law & Management Review* 1(1), 191.
[41] Tracz, E.T., 2023. Markets, regulation, and inevitability: The case for property rights in outer space. *University of Miami International & Comparative Law Review* 30(2), 42.
[42] United Nations, 1967. *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies*. UNOOSA Space Law, United Nations Office for Outer Space Affairs; webpage undated. https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html. Date accessed: 10 December 2025.
[43] United Nations, 1979. *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies (Moon Agreement)*. Online Library, International Institute of Humanitarian Law; webpage undated. https://www.onlinelibrary.iihl.org/wp-content/uploads/2021/04/Moon-Agreement-EN.pdf. Date accessed: 10 December 2025.
[44] Van Bogaert, E., 1981. The Moon Treaty: Achievements and future problems. *Studia Diplomatica* 34(6), 655–673.
[45] Vereshchetin, V.S., 2021. Outer space. *Max Planck Encyclopedia of Public International Law*.
[46] Wasser, A., Jobes, D., 2008. Space settlements, property rights, and international law: Could a lunar settlement claim the lunar real estate it needs to survive. *Journal of Air Law and Commerce* 73(1), 37.
[47] Wortman, R., 2020. Research viewpoint: Modernizing the Outer Space Treaty for national appropriation. *Astropolitics* 18(2), 170–182. https://doi.org/10.1080/14777622.2020.1789276.