INTERNATIONAL JOURNAL FOR LEGAL RESEARCH AND ANALYSIS

Open Access, Refereed JournalMulti Disciplinary
Peer Reviewed Edition :

www.ijlra.com

 ISSN: 2582-6433

DISCLAIMER

 ISSN: 2582-6433

Mrs.S.Kalpana

Assistant professor of Law

Mrs.S.Kalpana, presently Assistant professor of Law, VelTech Rangarajan Dr. Sagunthala R & D Institute of Science and Technology, Avadi.Formerly Assistant professor of Law,Vels University in the year 2019 to 2020, Worked as Guest Faculty, Chennai Dr.Ambedkar Law College, Pudupakkam. Published one book. Published 8Articles in various reputed Law Journals. Conducted 1Moot court competition and participated in nearly 80 National and International seminars and webinars conducted on various subjects of Law. Did ML in Criminal Law and Criminal Justice Administration.10 paper presentations in various National and International seminars. Attended more than 10 FDP programs. Ph.D. in Law pursuing.

Avinash Kumar

Avinash Kumar has completed his Ph.D. in International Investment Law from the Dept. of Law & Governance, Central University of South Bihar. His research work is on "International Investment Agreement and State's right to regulate Foreign Investment." He qualified UGC-NET and has been selected for the prestigious ICSSR Doctoral Fellowship.He is an alumnus of the Faculty of Law, University of Delhi. Formerly he has been elected as Students Union President of Law Centre-1, University of Delhi.Moreover, he completed his LL.M. from the University of Delhi (2014-16), dissertation on "Cross-border Merger & Acquisition"; LL.B. from the University of Delhi (2011-14), and B.A. (Hons.) from Maharaja Agrasen College, University of Delhi. He has also obtained P.G. Diploma in IPR from the Indian Society of International Law, New Delhi.He has qualified UGC – NET examination and has been awarded ICSSR – Doctoral Fellowship. He has published six-plus articles and presented 9 plus papers in national and international seminars/conferences. He participated in several workshops on research methodology and teaching and learning.

ABOUT US

INTERNATIONAL JOURNAL FOR LEGAL RESEARCH & ANLAYSIS ISSN
2582-6433 is an Online Journal is Monthly, Peer Review, Academic Journal, Published online, that seeks to provide an interactive platform for the publication of Short Articles, Long Articles, Book Review, Case Comments, Research Papers, Essay in the field of Law & Multidisciplinary issue. Our aim is to upgrade the level of interaction and discourse about contemporary issues of law. We are eager to become a highly cited academic publication, through quality contributions from students, academics, professionals from the industry, the bar and the bench. INTERNATIONAL JOURNAL FOR LEGAL RESEARCH & ANALYSIS ISSN 2582-6433 welcomes contributions from all legal branches, as long as the work is original, unpublished and is in consonance with the submission guidelines.

ENSURING SUSTAINABLE SPACE EXPLORATION AND MITIGATING SPACE POLLUTION

AUTHORED BY - AMAN
Student B.A. LL.B(H.), 5th Year, Law College Dehradun,
Uttaranchal University, Dehradun- 248007, Uttarakhand, India

CO-AUTHOR - DR. KHALEEQ AHMAD
Assistant Professor, Law College Dehradun,
Uttaranchal University, Dehradun-248007, Uttarakhand, India

Abstract

This research paper revisits the key challenges of space sustainability and the dilemma of space pollution, and suggests viable solutions in promoting the long-term sustainability of humanity's activities in outer space. This research paper reflects an interdisciplinary perspective encompassing environmental, technological and economic aspects to provide some policy recommendations. Starting from the dual perspective of prevention and treatment, this paper proposes that, given the exponential growth of space debris and space traffic in the next 20 years, it's of paramount importance for us to create better legal frameworks, both within countries and among nations, to manage the situation. Drawing from international experience and practice, this paper lays out the legal frameworks that can be easily introduced, including both prescriptive and preventive rules and standards to curb space pollution. These frameworksinclude international cooperation among the space-faring nations and private entities, relevantliability and insurance regulations, and the establishment of global space traffic management mechanisms and systems.

Keywords: Space Pollution, Sustainable Outer Space, Space Traffic Management, Environmental Sustainability, Space Law

1.1 INTRODUCTION

As space has been colonized, this footprint has grown larger and more complex. But with the growing complexity, a coherent framework for the sustainable use of outer space has become critical with the challenges the growing litter of space poses to the safe use and the future of sustainable use and development of outer space. There are many satellites slated for launch, and intertwined with every one of them, literally, are pieces of Pollution created as a result of operations in space. It is not an exaggeration to say that one day outer space might look more like garbage-filled outer space than the clean expanse of its current designation. This Article isan attempt at laying out the contours of such a framework in order to allow for a sustainable use of outer space. Legal research has been synthesized with case laws and specific statutes tobalance the requirement of a pressingly important area of law with the accessibility that requires breaking the mould of specialization in a manner that allows for a fine-lined storyboardto be told with all the necessary depth and detail that such a nuanced subject deserves.

So far, it's the only part of the Universe that we've altered, and we alter it for a purpose: by producing more waste, we make space more accessible to those who follow us. Cosmic archaeologists of the millennia hence will be able to explore our garbage to learn about our activities. By far the most pervasive type of space Pollution is any defunct or fragmented objectin orbit around Earth. There are currently more than 34,000 objects larger than 10 cm in diameter and up to millions of even smaller ones which, according to the European Space Agency (ESA), could inflict catastrophic damage on satellites and manned spacecraft.[1]

This ever-expanding cloud of Pollution magnifies the threat of Kessler Syndrome, a scenario where the density of objects is high enough in Low Earth Orbit (LEO) to allow or induce objects to collide, create more Pollution, and precipitate a runaway effect – when 'if an objectof the right size and speed is present… a collision will occur'. Such a scenario risks making activities in space, and the use of satellites, unsustainable, potentially crippling everything from global communications and weather forecasting to national security.

Consequently, requirements for space sustainability are thus as much about protecting and ensuring the continuity of the outer space environment as they are about continuing the use ofthe most vital space-based systems important to modern civilizations.[2]

There is a two fold challenge with space Pollution: the mitigation of current Pollution and the prevention of negligible. There is currently no international agreement on how to dispose of

[1] N. A. Ashford & R. P. Hall, "The Importance of Regulation-Induced Innovation for Sustainable Development", 3 S 270-292 (2011).
[2] C. Bosquillon, "Relevance of Composable Governance to the Space Domain and Sustainable Lunar Activities: Re-imagining a Computational Jurisdiction to Deal with Safety Zones on the Moon", 14 MIT Computational Law Report 97 (2023).

Pollution and it is a a growing problem.[3]

As the number of satellites increases, including large constellations (perhaps hundreds of thousands of satellites) that are being envisioned by several companies to bring the internet to everyone on Earth, space traffic management becomes even more important. At present, space traffic management revolves around voluntary guidelines with no mechanism for enforcement.

After all, the danger of collisions is caused by all of the problems mentioned above. These collisions can lead to loss of operational satellites, endanger manned missions to space, and contribute to the explosion of the space Pollution problem. But we have seen what can happenin space when situational awareness and space traffic management are not exercised carefully.When an active commercial Iridium satellite collided with a decommissioned Russian militarysatellite in 2009, it created more than 2,000 separate pieces of space Pollution.

- Statutory mitigation and remediation measures: Suggesting legal steps that can be taken in order to encourage those who launch objects into space to adopt mitigation measures and contribute to efforts to remove Pollution, potentially through amendments to existing space legislation or new legislation at the national and international levels.
- Space Traffic Management (STM) – Develop a framework for transnational STM law, including provisions for object registration, tracking and management. International standards will need to be developed and integrated into national laws.
- Liability and Insurance: Defining and extending the current legal framework on liability for damage caused by space objects and requiring insurance for space missions as a condition of approval, so that loss or potential damage can be adequately compensated as much as possible.
- International Cooperation and Governance: Enhancing international cooperation and governance to facilitate the enforcement of the legal regime. This may include the role of international organisations (existing and new), such as the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS).

In so doing, this fantastically ambitious tour of space law seeks to take us, here and now, ever closer to a legal framework for space activities that anticipates and can adapt to our needs as we come together to endeavor to sustain space exploration activities – not just those of those who came before us, but also those who lie ahead.

[3] G. Brachet, "The origins of the 'Long-term Sustainability of Outer Space Activities' initiative at UN COPUOS", 28 SP 161-165 (2012).

 ISSN: 2582-6433

1.2 THE CONCEPT OF SUSTAINABILITY IN OUTER SPACE

A sustainable space practice is one that makes sure not only that the environment is protected,but that space operations are able to continue — in principle, indefinitely. Sustainability entailsan ideal governance that is encompassing enough to maintain the integrity and usability of space for the long term.[4]

1.2.1 Definition and Dimensions of Sustainability

Environmental Sustainability: The capacity to enable the continued and responsible use of outer space for present and future generations. This aspect is primarily concerned with space Pollution and the avoidance of biocontamination, and necessitate: (i) mechanisms for responsible satellite disposal and (ii) mitigation solutions to ensure perpetual usability of key orbits.

Technological Sustainability: advancing space technologies in a manner that enables sustainable space activities for the long-term, including the development and deployment of technologies for satellite designs, propulsion systems and space Pollution removal that minimize space Pollution creation and enable sustainable and responsible use of space resources.

Economic Sustainability: Space activities can be carried out safely and sustainably forcurrent and future generations, to bring economic and social benefits while minimizingadverse environmental impacts, such as the long-term sustainable use of space resources, the efficient use of orbital space, and the establishment of sound regulationspromoting sustainable space commercial activities.[5]

Taken together, these dimensions suggest, quite simply, that engaging in space activities in a ‘sustainable’ manner across all four dimensions will be exceedingly difficult to achieve without coherent and robust national regulatory regimes (whether through public or private means), aswell as effective international regulations and standards.

1.2.2 The Kessler Syndrome and Space Pollution: Understanding the Risks to Sustainable Space Operations

A major threat to safe, long-term space operations is Kessler Syndrome – a situation in which the number of objects in Low Earth Orbit (LEO) is high enough that a collision between objects will

[4] N. A. Ashford and R. P. Hall, "The importance of regulation-induced innovation for sustainable development", 3 S 270-292 (2011).
[5] Arindam Basu & Shimul Dutta, "Environmental Refugees – A Quest for Justice", 14(1) DLR 27 (2022).

create a cascade of further collisions. Donald J Kessler originally described this scenario in 1978. Space Pollution – the stockpile of non-functional satellites, spent rocket stages and fragments from disintegrations, collisions and explosions – is a serious hazard to further space activity.[6]

the higher the risk of collisions between space Pollution and operational spacecraft and satellites, with potentially catastrophic effects on essential services such as global positioning systems (GPS) navigation, weather forecasting and communications Translation: safely operating spacecraft and satellites is more challenging as more space Pollution crowds into ever-smaller orbital areas. Just two examples of recent historically problematic space- environmental interactions are the 2007 test firing of a Chinese anti-satellite missile, raising fears of a new space arms race and complicating future long-term human spaceflight (think: creating a new historical waste dump with no means to reach it), and the 2009 collision of a Russian satellite with an Iridium satellite, compounding the growing threat that space Pollutionposes to sustainability in space.[7]

Ensuring technological standards to avoid the creation of orbital junk and establishing international Pollution mitigation guidelines are possible avenues to mitigating the problems posed by space Pollution and Kessler Syndrome. End-of-life disposal requirements for satellites must be adopted and, for a more complete solution, technological means for the removal of Pollution must be funded and developed. The legal realm must also change in orderto account for these strategies. Space actors should be created obligations to take practical steps towards the prevention of Pollution generation and the collective clean-up of Pollution.[8]

1.2.3 Space Traffic Management (STM): The Role of STM in Achieving Sustainability

Space Traffic Management (STM) is a critical component of sustainable outer space operations. It refers to any service or technology needed to prevent collisions in outer space orto coordinate satellite orbits including the tracking of space objects, the distribution of conjunction (close-approach) data, and the coordination of maneuvers to mitigate collisions.[9]

---

[6] Kessler Syndrome and the space pollution problem, available at: https://www.space.com/kessler-syndrome- space-pollution (Visited on March 05, 2024).
[7] A. Ferreira-Snyman, "Outer space exploration and the sustainability of the space environment – An uneasy relationship", 26 PELJ 1-52 (2023).
[8] A. Ferreira-Snyman, "Outer space exploration and the sustainability of the space environment – An uneasy relationship", 26 PELJ 1-52 (2023).
[9] C. Bosquillon, "Relevance of composable governance to the space domain and sustainable lunar activities: Re-imagining a computational jurisdiction to deal with safety zones on the Moon", MIT Computational Law Report (2023), available at: https://law.mit.edu/pub/relevance-of-composable-governance-to-the-space (Visited on March

The effective use of STM requires international, multilateral cooperation, which inevitably means the establishment of global standards and norms, and advances in space situational awareness (SSA) capabilities that help pinpoint accurately the location, trajectory and potentialcollisions of an increasingly huge number of objects operated in space. In turn, the existing legal frameworks need to be upgraded, improved and adapted to reflect these requirements by fostering the conditions for sharing SSA data, allocating responsibility for avoiding collisions,and enabling future technological development.

Further, STM can mitigate the risks of space Pollution and the Kessler Syndrome by preventing collisions leading to more Pollution. From an environmental perspective, by preventing such collisions, STM directly mitigates efforts to decongest space Pollution. From an economic view, it ensures that space operations remain viable by protecting satellites and spacecraft fromdamage caused by Pollution. Technologically, it drives innovation in SSA, mitigating and avoiding space Pollution, and collision avoidance.[10]

1.3 MEANING OF SPACE POLLUTION

Space pollution (or space junk) is the accumulation of human-made objects that no longer servetheir intended purpose while orbiting or travelling through the space environment. Space pollution consists of the presence of spacecraft stages, non-functional satellites, stray fragmentsof in-orbit pollution, and even ablated paint from surface re-entry partitions that accumulate inspace. This collection of broken and discarded human-made space artefacts slowly builds up in space, with potentially dire consequences for space operations and the space environment. Potential hazards of space pollution are collisions with functioning spacecraft and satellites, activities directed towards the mitigation of space pollution are vital to the survival of space aswe experience it today. For instance, the possibility of high-velocity collisions might result inspace junk crashing into other satellites and ultimately causing catastrophes. What’s more, space pollution – especially the use of plastics – has a lasting impact on the sustainability of Earth’s communities, and we are just beginning to understand how human-generated space pollution is affecting life on Earth as well.

1.4 IMPACT OF SPACE POLLUTION

What has come to be known as space pollution, or space pollution or space junk, is the accumulation of defunct human-made objects in a space environment. The objects can be of

01, 2024).

[10] Lakshmi Priya Vinjamuri, "Institutionalizing the Draft Corporate Environment Policy (CER) through Corporate Environmental Responsibility - A Perspective", 12(1) DLR 87 (2020).

different sizes, from spent rocket stages and dead (non-operational) satellites to small fragments originating from collisions and explosions. The consequences of space pollution can be profound and multifaceted:[11]

- Collision Risk: The most pressing and provocative conception of an adverse impact from space junk is the heightened risk that collisions will occur in orbit. Such collisions can generate more pollution in a kind of space junk feedback loop known as Kessler Syndrome: if the density of objects in (for example, low Earth orbit: LEO) becomes sufficiently high, collisions will take place at such a pace that certain portions of the paved roads in space will become unusable.
- Threat to Spacecraft and Satellites: Orbital pollution is a real threat to operational spacecraft and other satellites. Even small fragments could cause serious damage to spacecraft in orbit. Smaller satellites such as the International Space Station (ISS) and other crewed missions cannot manoeuvre to change their orbits as easily, thus they face a higher risk of collision.
- Satellite functionality: pollution impacts also disrupt satellite function and could cause total loss of satellites. For example, a satellite that sustained a pollution impact might no longer be able to function or could be lost altogether, thereby affecting communications, weather forecasting, navigation or Earth observation services.
- Space Sustainability: The more pollution there is, the more difficult it is to operate in space in a sustainable manner. Future space missions, especially crewed missions to the Moon or Mars, might face an elevated level of operational risk and operational challenges because pollution will reside in Earth orbit.
- Economic consequences: Pollution remains one of the most damning obstacles space businesses have to overcome. Crashes tend to destroy one or several expensive satellites and spacecraft, hence writing off investments for many companies and governments. Not to mention potential mission financial losses due to designing space pollution mitigation measures into a mission (pollution avoidance manoeuvres or spacecraft shielding), should the pollution risk be deemed substantial.
- Long-Term Environmental: Space pollution would also have serious long-term environmental issues. Space pollution has been found to persist for decades or even centuries, so it will remain a persistent threat to any space missions later in time. The build-

[11] Environmental Impact of Space Debris: How to Solve It, available at: https://www.weforum.org/agenda/2022/07/environmental-impact-space-debris-how-to-solve-it/ (Visited on March 12, 2024).

up of space pollution could eventually start affecting humanity's ability to access outer space: if enough pollution gathers in orbit, there could come a point where some orbital regions become so dangerous to navigate through that outer space may be off- limits to human activities for a long time.

It will take international cooperation to chart the best course for addressing this challenge, and to implement collective efforts to mitigate its consequences. Among the manoeuvres will be pollution removal missions, better space traffic management and the design of spacecraft that create as little pollution as possible.

1.5 SUSTAINABLE DEVELOPMENT GOALS (SDGS) AND SPACESUSTAINABILITY

Created by the United Nations in 2015, the Sustainable Development Goals are a collection of increasingly urgent global aspirations and targets to end poverty and create a more resilient and prosperous future for all by 2030. The 17 SDGs tackle a wide range of social, economic and environmental issues, most often with a terrestrial focus. But space is being recognised as playing an ever-greater role in realising the goals' objectives. By considering the SDGs in the context of space, it becomes clear that the use of outer space must adhere to the same principles of responsibility, equity and rationality as the pursuit of our ambitions on the ground.[12]

1.5.1 Environmental Sustainability (SDG 6, 12, 13, 14, 15)

SDG 6 (Clean Water and Sanitation): This goal is closely associated with the sustainability ofthe Earth's water resources, but both its aims and means can be applied to the sustainability ofspace environments.

SDG 12 (Responsible Consumption and Production): Encourages sustainable management and efficient use of natural resources. In space, this means minimising space debris, promoting responsible end-of-life management of satellites and promoting the development of clean technologies.

SDG 13 (Climate Action): Action on climate also extends to space environments, since space-based technologies are either already used, or will also become important in monitoring and

[12] Sustainable Development Goals, available at: https://sustainabledevelopment.un.org/topics/sustainabledevelopmentgoals (Visited on March 12, 2024).

 ISSN: 2582-6433

mitigating climate change. For example, we should sustain these technologies over time.

SDG 14 (Life Below Water) and SDG 15 (Life on Land): These goals encompass marine and terrestrial ecosystems, but the general principle about protecting natural environments appliesto the space domain, too, with the aim of minimising (where possible) harmful operations in space that potentially could affect the Earth's environment.

1.5.2 Technological Sustainability (SDG 9, 11)

SDG 9 (Industry, Innovation and Infrastructure): Develop resilient infrastructure that promotes sustainable industries and innovation. In the context of space sustainability, this meansdeveloping interference-free technologies such as novel satellite designs and propulsion systems, as well as technologies for active debris removal.

SDG 11 (Sustainable Cities and Communities): Space habitats and infrastructures should be built according to the principles of sustainable urbanisation – space stations and habitats that minimise waste and make maximum use of the available resources.

1.5.3 Economic Sustainability (SDG 8)

SDG 8 (Decent Work and Economic Growth): to promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all SDG 8 aligns directly with the concept of space economic development, which means ensuring that space activities are economically self-sustainable and contribute to the world economy, and that orbital resources are not wasted. Regulatory policies play a key role in stimulating the persistent development of a sustainable and viable commercial space sector.

1.5.4 Global Partnership (SDG 17)

SDG 17 (Partnerships for the Goals): "Strengthen the means of implementation and revitalisethe global partnership for sustainable development." Global partnerships are key for space sustainability. International cooperation can help develop and enforce international regulationsand standards for space activities, share space situational awareness (SSA) data and develop international cooperative mechanisms in response to space debris and for tracking space traffic.

1.6 ROLE OF UN TREATIES AND CONVENTIONS

The quest for sustainability in outer space is intrinsically linked with the development and deployment of international space law – the legal framework that regulates space activities through a set of rules promulgated under the auspices of the United Nations. These laws have evolved alongside space activities themselves, but as such activities have grown both in scopeand in magnitude, there is now a renewed debate concerning the extent to which these laws remain fit for purpose in ensuring the long-term sustainability of outer space.[13]

1.6.1 The Outer Space Treaty: Overview and Analysis of Its Principles Relevant to Sustainability

International norms provide a fundamental framework for congress to work within to mean Congress can survive Codified in 1967 and entering into force five years later, the Outer Space Treaty (OST) –which forms the bedrock of international space law – is a quintessential aspirational document: It embodies the objectives of the Treaty, of which the principal one is: The exploration and use of outer space, including the Moon and other celestial bodies, shall be carried out for the benefit and in the interests of all countries, irrespective of their degree of economic or scientific development, and shall be the province of all mankind.– Article I The principles enunciated within the document are many and interrelated. Those that are germane to sustainability are:

- No appropriation of Outer Space: The prohibition of 'national appropriation of celestial bodies' contained in Article II OST is a clear and unambiguous conflict-avoidance rule. It excludes from the outset the meaningful appropriation of any part of outer space, severing the relationship of control over space operations that could otherwise lead to a space race, and its potential equivalent in space, free from any such qualifications to the basic rule.
- Freedom of Exploration and Use: Article I state that 'outer space is not subject to national appropriation' and thus 'shall be free for exploration and use by all States without discrimination of any kind'. This would imply a shared duty not to endanger long-term sustainability of space.
- Article VI: State Responsibility for National Space Activities: Each state party to the Treaty shall bear international responsibility for national activities within the meaning of Article I of the Treaty.

[13] Circular economy | Enabling a space circular economy by 2050: ESA's vision, available at: https://blogs.esa.int/cleanspace/2024/01/11/circular-economy-enabling-a-space-circular-economy-by-2050- esas-vision/ (Visited on March 01, 2024).

 ISSN: 2582-6433

- International Cooperation and Assistance: Article IX, which recommends international consultations and cooperation to avoid harmful contamination of space, is also specifically relevant to sustainability issues.

The OST states guidelines but its open-ended nature demands more implementation-focused specifications to apply to modern sustainability challenges connected to space traffic management and space Pollution.[14]

1.6.2 The Liability Convention: Liability Issues and Their Implications for Sustainability

The Convention on International Liability for Damage Caused by Space Objects (the Liability Convention [LC]) fleshes out the liability regime of the OST, providing a satellite operator strictly liable for any damage their object causes on the surface of the Earth or to aircraft in flight, while they are liable for damage in space only if they are at fault. Absolute liability prior to fault, at least for spacecraft damage on the surface of the Earth or to aircraft in flight, provides a welcome deterrent against negligent behaviour in space activities. This convention on civil liability provides a key to understanding sustainability, since it is designed to induce responsible conduct. However, the Liability Convention's post-damage liability scheme has been critiqued for lacking to preventive features to adequately incentivize the reduction of space Pollution.

1.6.3 The Registration Convention: The Role of Satellite Registration in Sustainability

At least ostensibly, the Convention on Registration of Objects Launched into Outer Space (known as the Registration Convention) obliges states to provide information concerning everyspace object to the United Nations. This registry serves as a public record of space objects, which is useful for space traffic management and Pollution tracking. Making space activities more transparent through compliance with the Registration Convention will indirectly supportsustainability by enabling better monitoring and tracking of space objects. However, shortcomings in compliance and the difficulty of tracking small Pollution limit the value of theRegistration Convention in alleviating the current Pollution problem.

[14] United Nations Office for Outer Space Affairs (UNOOSA), available at: https://sdgs.un.org/un-system-sdg-implementation/united-nations-office-outer-space-affairs-unoosa-24523 (Visited on March 01, 2024).

1.6.4 The Rescue Agreement: Implications for Human Spaceflight and Sustainability

The Agreement on the Rescue of Astronauts, the Return of Astronauts, and the Return of Objects Launched into Outer Space (Rescue Agreement) addresses the rescue and return of astronauts in distress (Article II) and the return of space objects landed outside the territory ofthe launching state (Article III). This agreement is void with respect to matters not covered byit. But, that aside, the Rescue Agreement does touch specifically on the principle of sustainableuse – by emphasizing cooperation. Sustainable use is not possible without this spirit of cooperation.[15]

1.7 ISSUES AND CHALLENGES TO SUSTAINABLE SPACE ACTIVITIES

The road towards a more sustainable space is riddled by many legal, technological and geo-political hurdles, which would require a coordinated effort from the international community to draft strong regulatory frameworks for sustainable space activities. This outlines the major obstacles to sustainable space activities and offers possible legal and technical solutions.

1.7.1 Space Pollution Mitigation: Legal and Technological Challenges

Outer space activities are threatened by increasing volumes of outer space Pollution, and the collision hazard to operational satellites and manned spacecraft in orbit is becoming a serious concern. The escalation of Pollution may ultimately lead to what is known in space science asthe Kessler Syndrome, the point at which the orbital Pollution-density is high enough so that any random collision in low Earth orbit results in a cascade of collisions, making certain orbits unusable.[16]

- Legal challenges: At the international level, guidelines on space Pollution mitigation (e.g., those developed by the Inter-Agency Space Pollution Coordination Committee (IADC) and adopted by the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOS) are non-binding, i.e., voluntary and not enforceable. The most serious legal challenge is the development of a binding international treaty or agreement that mandates compliance with technical mitigation standards by states and non-state actors.
- Technical hurdles: The technical challenges of removing existing Pollution are formidable.

[15] United Nations, The future is now: Science for achieving sustainable development, available at: https://sustainabledevelopment.un.org/content/documents/24797GSDR_report_2019.pdf (Visited on March 01, 2024).
[16] Long term sustainability (LTS) of outer space activities - Goals and ways ahead, available at: https://www.isro.gov.in/LTS.html "Sustainability in space" Observer Research Foundation October 11, 2022.

 ISSN: 2582-6433

Existing technologies for Pollution removal, such as nets, harpoons and lasers, are still at the experimental stage. Until they are ready for deployment, they also need to be developed and tested, demanding large investments and the participation of multiple international stakeholders. There are also legal issues of sovereignty (does active removal constitute an intervention on the space objects of another country?) and liability.

1.7.2 Collision Avoidance: Legal Frameworks for Cooperation and Information Sharing

Space-object tracking and collision avoidance measures are essential for the continued sustainability of space operations. This requires governments and space actors to share their space-object information in a timely and responsible manner.

- Legal frameworks for cooperation: There currently aren't any existing legal frameworks that require countries or government and private sector actors to share SSA data – a condition for cooperative engagement would be an agreement on the standards for data exchange, levels of confidentiality, and protections of sensitive data.
- Shared knowledge: The problem here is creating an incentive structure in which space actors are willing to share SSA data and information. There is often mistrust, especially between governments who implement civilian and military uses of dual-use technologies. One possible solution could be an independent international body with a mandate to collect, verify and distribute SSA data to all space actors.

1.7.3 Spectrum and Orbital Slot Management: Legal Issues Related to Overcrowding and Interference

This requires careful coordination since the radio-frequency spectrum and slots in geostationary orbit are finite, and overcrowding and interfering can compromise their integrity and reliability.

Although ITU serves as the central reservation system for the radio-frequency spectrum and orbital slots, it has started showing signs of stress due to the growing demand. As the number of satellites continues to grow, as well as the number of mega constellations, the question of whether the existing regulatory frameworks can effectively prevent interference among satellites and with terrestrial systems, which also use the same frequencies, is a promising research field to explore. In particular, multilateral enterprises must also manage these issues in a way that avoids the negative consequences of just-in-case thinking and instead furthers thegoal of more sustainable

 ISSN: 2582-6433

and equitable access to space in the decades ahead.[17]

1.7.4 Dual-Use Technology and Security Concerns: Balancing Peaceful Use with Security

The dual-use nature of space technology (in other words, technologies that can be used for both civilian and military purposes) pose some of the greatest challenges to ensuring the sustainability of space activities. Security concerns about those technologies can hinder international cooperation and the sharing of data or technology.

Despite the spirit of the pronouncement in the Outer Space Treaty of 1967 regarding the peaceful use of outer space, few space technologies nowadays can claim to be exclusively civilian or exclusively military in nature. This ambiguous nature between civil and military capabilities presents a challenge in formulating space policies given the requirements for equitable access to and the societal benefits derived from space technologies, combined with the fear of the misuse of these same technologies in times of war and insecurity. Currently, therelevant international legal regimes tend to foster transparency and encourage confidence- building measures to address such apprehensions among space-faring countries. These are sound starting points, but agreements on the non-weaponization of outer space – and embargoes on an arms race in outer space – as well as the broader adoption of sustainable practices could greatly enhance the space environment's protection.[18]

1.8 CONCLUSION

The ballooning of space activities and the growing amount of space pollution further shows the importance of a strong and far-sighted legal regime to govern the safe and sustainable use of outer space. Today, the cornerstones of the current international space law system include theOuter Space Treaty (OST) and the Liability Convention, but these conventions do not even begin to tackle the issues posed by space pollution and commercialisation. A key obstacle is how to manage and mitigate space pollution, critical to the future viability of space operations.The threat of 'Kessler Syndrome', in which collisions between space pollution create further pollution, could eventually make LEO unusable – a scenario that would be catastrophic for satellite operations,

---

[17] J. Robinson, "The role of transparency and confidence-building measures in advancing space security" European Space Policy Institute September 28, 2010, available at: https://www.files.ethz.ch/isn/124827 /ESPI_Report_28_online.pdf (Visited on March 01, 2024).

[18] Astra Carta — To care for the infinite wonders of the universe, available at: https://www.sustainable-markets.org/AstraCarta_charter.pdf (Visited on March 01, 2024).

global communications, weather forecasting and national security. It is vital that we apply mandatory pollution mitigation standards to all space activities, including developing and deploying technologies for the active removal of pollution and having end-of- life disposal requirements for satellites.

STM requires enhanced international cooperation and requires the creation of global standardsand norms. Improved space situational awareness (SSA) will be necessary so that we can accurately determine the location and trajectory of space objects to reduce the risk of collisionsand the creation of new pollution. A transnational STM regime that integrates into national laws would help to coordinate satellite orbits and exchange conjunction data.

Correspondingly, the legal and regulatory framework governing liability and insurance must be strengthened to ensure that those actors responsible for space pollution are held accountablefor their actions. The current regime under the Liability Convention – which is based on ex- post, damage-based compensation – fails to sufficiently incorporate preventive measures. Extending liability to encompass non-state actors and requiring the taking out of insurance forspace missions can incentivise responsible behaviour and provide a financial safety net for mitigating potential damages. Any guidelines for sustainable activities in space would requireinternational cooperation and governance. Existing organisations, such as the United Nations Committee on the Peaceful Uses of Outer Space (often referred to by the acronym UNCOPUOS), would need to be empowered to enforce legal regimes and facilitate cooperation among space-faring nations. Also, new international agreements (or treaties) would be needed to require compliance with pollution mitigation standards and principles of equitable use. Hereagain the private sector can be engaged, as space activities increasingly are. In this sphere, legalframeworks should enable commercial interests while also balancing them againstenvironmental protections, and include sustainability considerations in licensing requirements and enable markets for pollution-mitigations technologies. Educational and awareness-raisingefforts to foster a sustainable space culture in new space actors can be implemented by international organisations, space agencies and universities to help stakeholders understand thelegal, technical and ethical implications of space activities. Public outreach and advocacy can also scale support for sustainable approaches to address space activities, and provide inspirationabout how the benefits of space use manifest, and contribute to our real world.

In conclusion, sustainability in outer space is a complex and urgent challenge, which can onlybe

 ISSN: 2582-6433

resolved in a coordinated global fashion. For this purpose, strict pollution mitigation standards, a global STM system, more robust liability regimes and insurance frameworks, andincreased levels of international cooperation are essential to ensure the short- and long-term sustainability of space activities. The road towards a clean, safe and sustainable outer space islong, and will require constant innovation, cooperation and responsible behaviour. The future of space activities is in our own hands, but we run the risk that, should we fail to exercise good stewardship, it may fail us in the long term.the way, but it is a goal that can be achieved throughinnovation and cooperation.

1.9 SUGGESTIONS

Humanity's space activities, and especially the establishment of a sustainable space economy, depend on developing and innovating, technologically and legally. This goes beyond the current state of play to briefly explore possible future developments and innovations: the complex relationship between technological and legal change; the role of space sector actors beyond traditional stakeholders in designing and implementing innovations; and the role of education and awareness in developing a sustainable future for space activities, especially for new space actors.

1.9.1 Technological Innovations and Legal Adaptations: How Emerging Technologies Could Shape Future Legal Frameworks

The pace of technical innovation is increasing – providing a mix of challenges and opportunities for stable and durable legal frameworks designed to help achieve sustainability. Promising technologies include on-orbit servicing; active Pollution removal; space solar power; and in-situ resource utilization.

- Legal flexibility for emerging technologies: Legal frameworks should be nimble enough to enable these innovations, as operating in the space domain introduces unique and sometimes unprecedented legal problems. Repairing and refueling ageing satellites through on-orbit servicing operations could extend their functional lifetimes and reduce the creation of Pollution, but who is liable for collisions, accidents or SoS, what safety standards must they adhere to, and how is ownership transferred? In the near future, new frameworks could include provisions that address these novel rights and obligations, similar to existing space laws that draw on equivalent maritime laws.
- Active Pollution removal also challenges our space law understandings of ownership and liability. Possible legal adaptations include creating a new class for Pollution deemed 'abandoned' for which removal is not contingent on consent from the launching state or

agreement with the launching state, along with international agreements limiting liability for entities performing such Pollution removal.

- Enabling Space-Based Solar Power and In-Situ Resource Utilization: similar legal frameworks would be needed for space-based solar power activities and in-situ resource utilization. This may even lead to constituting a regulatory body to oversee such activities.

1.9.2 The Role of the Private Sector: Balancing Commercial Interests with Sustainability

As the private sector grows more influential, it is leading the way in finding new uses for space, and making space more accessible than ever before. Yet this commercialization is raising questions about whether the pressures of profit will undermine environmental and safety standards.

- Finding the Right Role for the Private Sector: Develop legal frameworks that allow forthe private sector to play an equal role with governments but in a way that also preservesthe sustainability of space. For example, licensing schemes might include sustainability considerations through the licensing requirements used to regulate private activity, for instance, by requiring that private entities demonstrate that their activities will not negatively impact the space environment. Controlling costs to license private industry that employs advanced Pollution-mitigation technologies could also incentivize sustainability goals, allowing commercial interests and sustainability objectives to support each other.

1.9.3 Education and Awareness: Promoting a Culture of Sustainability Among New Space Actors

Moreover, we must ensure that whenever new players arrive in the space realm, as more and more are doing today, they understand why it is critical to adopt sound sustainability practices or good space conduct, be it through education at school or, when more self-conscious, through well-directed awareness-raising campaigns and space responsibility-driven initiatives.

- Advancing a Culture of Sustainability: International organisations, space agencies and academic institutions can serve as leaders in building this important aspect of the international space basin. They should develop curricula and resources that deal with legal, technical and ethical implications of these activities. In addition, forums and conferences dedicated to space sustainability can foster an open exchange of ideas and best practices among stakeholders.

- Public Outreach and Advocacy: Fostering public involvement in discussing space sustainability can help to broaden the demographic base of support for sustainable practices and policies. Advocacy efforts that highlight the real-world benefits of sustainable space use (e.g., the continuity of satellite-based services) remind the public of the relevance of these issues more broadly.

REFERENCES

1. N. A. Ashford & R. P. Hall, "The Importance of Regulation-Induced Innovation for Sustainable Development", 3 S 270-292 (2011).
2. C. Bosquillon, "Relevance of Composable Governance to the Space Domain and Sustainable Lunar Activities: Re-imagining a Computational Jurisdiction to Deal with Safety Zones on the Moon", 14 MIT Computational Law Report 97 (2023).
3. G. Brachet, "The origins of the 'Long-term Sustainability of Outer Space Activities' initiative at UN COPUOS", 28 SP 161-165 (2012).
4. N. A. Ashford and R. P. Hall, "The importance of regulation-induced innovation for sustainable development", 3 S 270-292 (2011).
5. Arindam Basu & Shimul Dutta, "Environmental Refugees – A Quest for Justice", 14(1) DLR 27 (2022).
6. Kessler Syndrome and the space pollution problem, available at: https://www.space.com/kessler-syndrome-space-pollution (Visited on March 05, 2024).
7. C. Varughese, L. Henry, A. Morris, S. Bickerton, N. Rattenbury, C. Mankelow, A. Gorman, S. Katavich-Barton, and P. Dhopade, "The intersection of space and sustainability: The need for a transdisciplinary and bi-cultural approach", 211 AA 684-701 (2023).
8. Ferreira-Snyman, "Outer space exploration and the sustainability of the space environment – An uneasy relationship", 26 PELJ 1-52 (2023).
9. Bosquillon, "Relevance of composable governance to the space domain and sustainable lunar activities: Re-imagining a computational jurisdiction to deal with safety zones on the Moon", MIT Computational Law Report (2023), available at: https://law.mit.edu/pub/relevance-of-composable-governance-to-the-space (Visited on March 01, 2024).
10. Lakshmi Priya Vinjamuri, "Institutionalizing the Draft Corporate Environment Policy (CER) through Corporate Environmental Responsibility - A Perspective", 12(1) DLR 87 (2020).

11. Circular economy | Enabling a space circular economy by 2050: ESA's vision, available at: https://blogs.esa.int/cleanspace/2024/01/11/circular-economy-enabling-a-space-circular-economy-by-2050-esas-vision/ (Visited on March 01, 2024).
12. United Nations Office for Outer Space Affairs (UNOOSA), available at: https://sdgs.un.org/un-system-sdg-implementation/united-nations-office-outer-space- affairs-unoosa-24523 (Visited on March 01, 2024).
13. United Nations, The future is now: Science for achieving sustainable development, available at:
14. https://sustainabledevelopment.un.org/content/documents/24797GSDR_report_2019. pdf (Visited on March 01, 2024).
15. Long term sustainability (LTS) of outer space activities - Goals and ways ahead, available at: https://www.isro.gov.in/LTS.html "Sustainability in space" Observer Research Foundation October 11, 2022.
16. J. Robinson, "The role of transparency and confidence-building measures in advancing space security" European Space Policy Institute September 28, 2010, available at: https://www.files.ethz.ch/isn/124827 /ESPI_Report_28_online.pdf (Visited on March 01, 2024).
17. Astra Carta — To care for the infinite wonders of the universe, available at: https://www.sustainable-markets.org/AstraCarta_charter.pdf (Visited on March 01, 2024).