SUSTAINABLE ORBIT AND THE EARTH SYSTEM: MITIGATION AND REGULATION

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ABSTRACT

The aim of this paper is to implement an interdisciplinary approach to sustainability and protection of the orbital environment. We argue that orbital and planetary sustainability, and the corresponding evolution of domestic, international, and regional regulatory instruments, need to take place in conjunction with sustainability of the Earth System. We engage with complex systems of multiple environments and their interconnectivities from the perspective of two disciplines: engineering and social sciences (law and economics). We look at the existing regulation of orbital debris and more recent Guidelines for the Long-term Sustainability of Outer Space Activities (hereinafter "the LTS Guidelines").[2] The paper argues that an interdisciplinary and mutually supportive effort is needed to achieve long term sustainability of outer space activities. One of the proposals is the Space Sustainability Rating (SSR) [3] initiative that seeks to foster voluntary action by satellite operators to reduce the risk of space debris, on-orbit collisions, and unsustainable space operations.

This paper explores long-term sustainability issues related to increasing activities in outer space, with a particular focus on orbital debris. Adequately addressing these challenges requires a coordinated international and transdisciplinary approach to the evolving regulatory framework. Space sustainability holds particular significance for the achievement of Sustainable Development Goals (SDGs) in the Earth System.[1] Satellites are used to monitor climate change induced variances, and are especially useful for more remote areas, such as the Arctic, the ocean and the atmosphere. Hence, in addition to commercial uses of outer space, it is important to consider a more holistic interrelation between the Earth System and orbital sustainability.

Our aim is to implement an interdisciplinary approach to sustainability and protection of the orbital environment. We argue that orbital and planetary sustainability, and the corresponding evolution of domestic, international, and regional regulatory instruments, need to take place in conjunction with sustainability of the Earth System. For this reason, we engage with complexities of multiple environments and their interconnectivities from the perspective of two disciplines: engineering and social sciences (law and economics). We look at the existing regulation of orbital debris and more recent Guidelines for the Long-term Sustainability of Outer Space Activities (hereinafter "the LTS Guidelines").[2] We argue that an interdisciplinary and mutually supportive effort is needed to achieve long term sustainability of outer space activities. One of the proposals is the Space Sustainability Rating (SSR) [3] initiative that seeks to foster voluntary action by satellite operators to reduce the risk of space debris, on-orbit collisions, and unsustainable space operations.

Orbital debris poses a risk to functional satellites and threatens observation of the complex variables involved in climate change and environmental degradation. As explored in the framework Environment-Vulnerability-Decision-Technology (EVDT) [4] of MIT's Space Enabled Research Group, capturing together the environment, social impact, human decision-making, and technology as four domains with complex interaction, can enable us to engage with important challenges that lie at the intersection of these domains. This paper addresses these challenges in three broader sections. First, we will address ongoing complexities of interrelatedness between the Earth System and the orbit. Second, we will give a brief overview of current debates on the regulation, prevention, and mitigation of space debris, and finally, we will discuss the practical applications of SSR.

1. Complexities of the Earth System and Outer Space

The main objective of our paper is to present how different disciplines work together to address the issue

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of sustainability in outer space in general, and orbital debris in particular. The "resource rush" in outer space reveals the short-sightedness of attempts to instrumentalize and colonize these spaces while sidestepping environmental problems.[5] The new space race is leading to a saturation of orbital carrying capacity unless we holistically understand and can predict the behaviours of the anthropogenic space object population, both dead and alive. Outer space is subject to the current state-extractive industry promotion of a "rush" for resources, in the context where contemporary international regimes that do not yet directly respond to the magnitude of the ongoing environmental degradation. The orbital space also has capacity limits, which are not only determined by the number of anthropogenic space objects in a specific orbital neighbourhood, but also the uncertainty in how these objects will behave in the future.[6]

One of the current challenges in outer space activities regulation is the balancing of plural interests and an integration of different perspectives in such a diverse field (outer space sustainability in particular-but also humanity's relationship with what is generally understood as non-human, and in different domains). While disciplines and relevant methods can differ, if an overall objective is to be reached, the transdisciplinary approach will require a convergence on that objective. In the context of outer space sustainability, global intergovernmental reports and academic research, articles, are arguing for system wide actions and transformative change in space regulation. How then do we build knowledge to support these transformations? This article seeks to implement the transdisciplinary approach and/or theory and practice, demonstrating also what sort of education/institutions need to be set in place to support this kind of knowledge. Transdisciplinary knowledge emerges from learning and experimentation with multiple ways of knowing. This is required for the support of intentioned design and sustainability interventions.

In the context of sustainability, this does not mean only action/result-oriented pragmatism. Rather, the convergence of normativity and pragmatism are taken for granted in sustainability and environmental protection-oriented research. In order to do so, this article has an interdisciplinary approach with a common aim. The actions for sustainability can include the following: recognizing complexity of change, human intervention (unintended/unknown results); clear normative objectives (and recognition of what the outcomes might be in each case). For the purpose of this paper we will recognize two examples of complex systems: a. the Earth System and b. Complex Adaptive Systems (CAS) [10].

a. The field of Earth System Science (ESS) [11] studies the planet's oceans, lands, and atmosphere as an integrated system. It is an interdisciplinary field integrating the principles of biology, chemistry, and physics to study problems involving processes occurring at the Earth's surface, such as climate change and global nutrient cycles, providing a foundation for problem solving related to environmental sustainability and global environmental change. And finally, the studies have extended even beyond the Earth System to include the Earth's orbit (EO) as an integrated space as humans increasingly rely on it for commercial and scientific purposes. On the one hand, satellites are used to monitor changes in the Earth System, while others contribute to the increasing pollution of the orbit, and even endangering such operations. They are especially useful for remote regions such as the Arctic, and the ongoing monitoring of deglaciation.

b. Complex-Adaptive Systems, such as markets and laws, are interconnected with a myriad other systems, such as politics, society, biosphere, the orbital environment, and so on. While each of these has a corresponding and distinct scientific discipline (economics, ecology, sociology, behavioural science, law) recent tendency in sustainability sciences has been to recognize the complex interactions among them.

We identify the complex interconnections between social and ecological systems and the varying spatial and temporal scales; the complex feedback effects; rapid and accelerating rate of change and dynamic; and nonlinear nature of environmental processes in the orbit; all of which lead to uncertainties in assessing the consequences of decision-making. These uncertainties can relate to all phases of implementation, starting from the designing of the representative monitoring programs; through assessing the current and target status; to estimating the costs and impacts of management measures. Uncertainty in predicting the long-term and cumulative effects stem from the complexities and constant change. This poses a challenge to knowledge production required for decision-making in response to the problem of orbital debris.

2. **Regulation of orbital debris** [12][13]

The cultural, legal, political, economic, infrastructural, and logistical processes of the contemporary space race have clearly measurable environmental footprints on Earth and in outer space. Environmental impact of activities in space unfolds on multiple scales: local and stratospheric emissions from space launches, the placement of outer space related infrastructure in so-called peripheral places, and the role of power in determining whether the use of such infrastructure aids socio-environmentally constructive or destructive practices. Importantly, space debris [14] has an impact on the fragility of the outer space environment [15] and qualify as contamination.

The UN Committee on the Peaceful Uses of Outer Space ('UN COPUOS') [16] has created a space for debates on legal mechanisms relating to space debris mitigation resulting in development of a compendium of space debris mitigation standards adopted by states and international organizations. The aim of the compendium is to inform states of the current instruments and measures that have been implemented by states and international organizations. However, as will be discussed below, the general orientation of the compendium is on the use of outer space for the benefit of 'humanity' (i.e. common heritage of humanity), and state and non-state actors, rather than on the space environment as an end in itself.[17] Its status is that of 'soft law' set of guidelines, which have yet to be incorporated and interpreted by all States. Legal scholars have identified the lack of enforcement mechanisms of voluntary guidelines. Some suggest compliance through state-enforced legislation and regulations.[18]

Orbital space is also used to monitor a complex set of phenomena driving climate change.[19] Indeed, space activities are increasingly indispensable to humanity. Orbiting spacecraft serve vital roles as communications links, navigation beacons, scientific investigation platforms, and providers of remote sensing data for weather, climate, land use, and national security purposes.[20] Each space mission and other observations and measurements provide for models to better understand and predict how the biosphere, hydrosphere, and atmosphere work and interact. While satellite use is important in the monitoring of global warming, the increasing proposals for commercialization and mining of mining of asteroids and celestial bodies could break up asteroids, harm other satellites, spacecrafts, astronauts, and even life on Earth.

Orbital regions represent valuable resources because they have characteristics that enable spacecraft operating within them to execute their missions more effectively. Functional spacecraft share the near-Earth environment with natural meteoroids and the orbital debris that has been generated by past space activities. Meteoroids orbit the Sun and rapidly pass through and leave the near-Earth region (or burn up in the Earth's atmosphere), resulting in a fairly continual flux of meteoroids on spacecraft in Earth orbit.[21] In contrast, artificial debris objects (including non-functional spacecraft, spent rocket bodies, mission-related objects, the products of spacecraft surface deterioration, and fragments from spacecraft and rocket body breakups) orbit the Earth and will remain in orbit until atmospheric drag and other perturbing forces eventually cause their orbits to decay into the atmosphere.[22] Since atmospheric drag decreases as altitude increases, large debris in orbits above about 600 km can remain in orbit for tens, thousands, or even millions of years.[23] When satellites retire from use, some will remain in orbit for decades afterward, adding to space debris. Ideally, satellites would gradually drift down to lower orbits and burn up in Earth's atmosphere. However, the higher the orbit a satellite is operating in, the longer it takes to move down and burn up.

The possible mechanisms to regulate active space debris removal, including the issues arising in the implementation of active debris removal mechanism in law, and the necessity for international cooperation at all levels regarding space debris issue, has yet to be developed. This might involve strengthened coordination within the work of the UN COPUOS and its subsidiary bodies, and enhanced interaction between inter-governmental bodies. Nevertheless, the international community has yet to define the terms 'exploration' and 'utilization' and how they apply to space and space resources.[24]

The existing treaty law provides some main legal principles, which set the legal framework for human activities in outer space. However, instruments for the protection of the space environment from space debris are not specifically provided for. Neither is space debris defined or its production prohibited, nor are the mitigation and remediation of space debris considered in the binding law. Thus, the creation and the non-removal of space debris is not recognized at present to be an unlawful act.

Space debris is generally understood to be human-made objects, including their fragments and parts, which are in orbital space, re-entering the Earth's atmosphere, or reaching the Earth's surface, that are non-functional with no reasonable expectation of being able to assume their intended functions or any other functions for which they are or can be authorized.[25] This may include spent rocket stages and defunct satellites, as well as fragments from their disintegration, such as pieces of shielding. In accordance with international space law, all the above are considered space objects and their component parts [26]. As the functional status of a space object does not as such affect the applicability of rules of international space law, orbital debris remains subject to the same rules, which apply to space objects.

Some spacefaring States have voluntarily implemented non-binding space debris mitigation measures into their national space laws and technical standards as mandatory requirements.[27] For other States, such recommendatory instruments can serve as an indication of an expected standard of due regard. In implementing space debris mitigation measures on a voluntary basis, states are recommended to follow some of the existing non-binding guidelines and technical standards, which have been developed by international governmental and non-governmental organizations and other international forums.[28] In 2007, the UN General Assembly endorsed the Space Debris Mitigation Guidelines of the UN COPUOS[29] and agreed that these voluntary guidelines reflected the existing practices as developed by a number of national and international organizations, and invited States to implement those guidelines through appropriate national mechanisms.[30] States can continually update these standard practices to manage the integrity of the space-operating environment.[31]

States have a duty under Article VI of the OST regime, to authorise and continuously supervise the activities of its government and non-governmental (i.e. private) entities. As there are no mandatory international guidelines or standards of conduct of States and international organization specifically with respect to the creation of space debris, none of them can be used to definitely assess fault for the purpose of establishing international liability under Article III of the Liability Convention [32] or establish a universal standard of due regard. Under a distinct legal concept of State liability, States have a primary liability for damages caused by space objects to other space objects. In case damage is caused to other space objects in outer space, the liability is fault-based (Article III) or persons or property on the Earth or aircraft in flight (Article II). For instance, the question of autonomous operations raises issues most notably in relation to State's control of such activities and resulting responsibility and liability for such activities. The recovery and return of space objects, which in such circumstances are usually space debris, is a central focus of the Rescue Agreement.[33] In addition, it obliges the launching authority to immediately take effective steps to eliminate possible danger of harm, which is believed to be produced by its space object or its component parts of a hazardous or deleterious nature.

Article I, paragraph 2, of the OST [34] provides that outer space, including the Moon and other celestial bodies, shall be free for exploration and use by all States. However, there can also be a situation where a space operation of State A carried out near an asteroid generates a multitude of space debris orbiting around such asteroid on different planes thereby making it technically impossible for a scientific spacecraft of State B to complete its space mission by landing on this asteroid and collecting a probe. In this situation, State's A creating space debris infringes the freedom of exploration and use which can no longer be enjoyed, with respect to the asteroid in question, neither by State B, nor by any other State.

The second sentence of Article IX of the OST states that studies of outer space shall be pursued, and the exploration of outer space shall be conducted, so as to avoid its harmful contamination, and that States shall adopt appropriate measures for this purpose. Article 7, paragraph 1, of the Moon Agreement contains a similar provision – it obliges States Parties, in exploring and using the Moon, to take measures to prevent the disruption of the existing balance of its environment by its harmful contamination.[35]

It is not yet clear how a substantial risk should be defined so as to decide which fragments should be removed first. Art. II and III of the Registration Convention [36] provide that space objects have to be registered in a national register and be carried on a register maintained by the UNGA. Article IV requires that data describing the name of the launching state(s), the designator of the space object, the date and territory of launch, the general function of the space object, as well as basic orbital parameters of the space objects (including nodal period, inclination, apogee and perigee) [37] are provided. The orbital region is important because the debris flux encountered by a spacecraft varies greatly with orbital altitude and, to a lesser extent, orbital inclination.[38] However, these elements do not provide for the functionality and current status of the space object and, thus, cannot serve as absolute criteria to determine its eligibility for removal.

The legal framework does not provide standards to decide on whether an object constitutes space debris. It could be questionable what the criteria to define a space object as debris should be: its functionality, or its controllability? For example, it could be aimed at first removing objects which cannot be attributed to a state registry—e.g., because their origin cannot be identified, which would be the case for the majority of small debris fragments.

3. Corporate Social Responsibility (CSR)

In the recent LTS Guidelines there is only one mention of private actors, in the "Guideline C.1 Promote and facilitate international cooperation in support of the long-term sustainability of outer space activities" which states:

> States and international intergovernmental organizations should promote and facilitate international cooperation to enable all countries, in particular developing and emerging space faring countries, to implement these guidelines. International cooperation should, where appropriate, involve the public, private and academic sectors, and may include, inter alia, the exchange of experience, scientific knowledge, technology and equipment for space activities on an equitable and mutually acceptable basis.

The rest of the document refers to non-governmental entities broadly speaking and reaffirms "State responsibility for activities of non-governmental entities". This approach reiterates the existing international law of outer space, as stipulated by the Outer Space Treaty (1967) (OST) Article VI [39] and implying that outer space activities do not 'lift-off' from Earthy regulatory systems into a lawless anarchy of extra-terrestrial domain. Importantly, this includes regulatory principles emerging in response to orbital debris.

The LTS Guideline C.4 aims to "Raise awareness of space activities" which includes both, the "awareness of the important societal benefits of space activities" and "of the consequent importance of enhancing the long-term sustainability of outer space activities". To this end, the States should raise awareness among non-governmental entities as well, about national and international policies, legislation, regulations and best practices that are applicable to space activities. The LTS Guidelines do not identify or define the nature of non-governmental activities but rather emphasize the need for best practices.

Human activities in outer space and are arguably transcribing a variety of issues that remain unresolved in the Earth System. Despite the image of private actors' operations beyond or outside of State regulation (or jurisdiction), States act as important facilitators of movement of transnational, global, and now seemingly extra-terrestrial corporate interests.

Private economic relations and activities do not abandon/and are not abandoned by State regulation. Certainly, States represent only one of numerous actors that create international legal norms. The degree to which states do/not participate in the very decision making regarding the new reconfiguration of their involvement in private activities (including activities in outer space) is significant. In the area of business relations, systems of non-state rules have pre-existed and co-existed with state laws.[40] It is, however, specific doctrinal reforms in private international law that have promoted the autonomy of transnational dispute-resolution among private actors with respect to the key subjects of private international law. For instance, subnational interest groups including business actors and various service providers in the arbitration sector-were in favour of, and acted to promote, the expansion of the arbitration regime in international transactions.[41] Hence, the image of a global private actor that somehow exists beyond the state, and now also, beyond the Earth

System, does not consider the ongoing decision-making processes that do continue to take place at State level.

First, there is a need for better identification of needs and objectives of various space agencies and their possible participation in a discussion on sustainable corporate governance. This includes topics such as: due regard for stakeholder interests'; inclusion of issues such as human rights; and environmental pollution (including the Earth system, the orbit, and interplanetary contexts). Second, a more holistic approach to CSR in outer space is required. This would involve mitigating the corporate and financial risks of current and potential unsustainability (e.g., increase of orbital debris). This does not mean that we should only engage in ongoing bargaining and balancing among various private interests and 'stakeholders. Rather, a solid international regulatory framework for sustainable value creation is required. Finally, such a holistic approach would not be merely limited to companies, but also all undertakings in outer space.

Sustainable value creation [42] is an emerging concept in corporate law and corporate governance. This paper argues for an extension of this discussion to outer space activities. In the context of the Earth System, sustainable value creation would rely on interdisciplinarity and reflect the complexity of multifaceted aspects of different environments and their sustainability. These also need to include both, democratic political processes, and avoidance of activities that undermine democratic processes and laws.[43] It entails contributing to the economic basis of the global society and not only certain sectors. Creating shared value (CSV) [44] refers to the way in which enterprises seek to generate a return on investment for their owners and shareholders by means of creating value for other stakeholders and society at large. A hypothetical argument that outer space somehow exists apart from the 'Earthly' global society, and that such societal responsibility does not apply in the extra-terrestrial domain, is not viable for as long as there is a recognition of validity of international laws and their application to human activities in outer space. More specifically, this includes the recognition of human rights and plural ethical considerations in addition to social, environmental, and consumer considerations.

For instance, the European Commission's strategy on CSR, part of a package of measures on responsible business (see IP/11/1238) [45], also sets out how enterprises can benefit from CSR. The new definition is consistent with internationally recognised CSR principles and guidelines, such as the OECD Guidelines for Multinational Enterprises, the ISO 26000 Guidance Standard on Social Responsibility and the United Nations Guiding Principles on Business and Human Rights. Its aim is to provide a greater clarity for enterprises and contribute to greater global consistency in the expectations of businesses, regardless of where they operate.

As all space activities continue to be 'national activities' as per the Article VI of the Outer Space Treaty (OST). National activities are generally interpreted as activities of State nationals, including private persons and companies. In full: "States Parties to the Treaty shall bear international responsibility for national activities in outer space, including the moon and other celestial bodies, whether such activities are carried on by governmental agencies or by non-governmental entities, and for assuring that national activities are carried out in conformity with the provisions set forth in the present Treaty. The activities of non-governmental entities in outer space, including the moon and other celestial bodies, shall require authorization and continuing supervision by the appropriate State Party to the Treaty. When activities are carried on in outer space, including the moon and other celestial bodies, by an international organization, responsibility for compliance with this Treaty shall be borne both by the international organization and by the States Parties to the Treaty participating in such organization."

Hence, CSR should be applied regarding actions by companies in outer space over and above their legal obligations towards society and the environment (of both, the Earth System and outer space). Importantly, CSR is not meant to just 'fill the gap' where international law has yet to develop, especially if we presume compliance of all ongoing activities with existing laws.

Establishing and extending sustainable value creation beyond planetary boundaries would highlight the complex interactions between planet-level environmental processes, and in outer space. An estimation of impacts on stakeholders and the environment needs a clarified duty of care and the due diligence duty. These would be expected to have positive impacts on stakeholders and the environment, including in the supply chain. Finally, it can also be argued that CSR is likely to contribute to the long-term success of an enterprise. A CSR approach to outer space activities can bring benefits in terms of risk management, cost savings, access to capital, customer relationships, human resource management, and innovation capacity. It encourages more social and environmental responsibility from the corporate sector.

This commentary is meant to supplement some of the more recent initiatives to address orbital debris. There have been several ongoing attempts to address the issue of environmental pollution in the orbit, and to foster global standards in waste mitigation. For instance, the World Economic Forum has chosen a team led by the Space Enabled Research Group at the MIT Media Lab, the European Space Agency (ESA), University of Texas at Austin, and BryceTech to launch the Space Sustainability Rating (SSR), a concept developed by the Forum's Global Future Council on Space Technologies. The envisaged SSR aims to promote mission designs and operational concepts that avoid an unhampered growth in space debris. It promotes a future where environmental review would be taken into consideration during the early stages of design and development. The SSR concept intends to create a voluntary system of regulation that still operates based on "encouragement". Arguably, an additional framework for CSR in space would facilitate such initiatives and induce compliance.

4. Space sustainability rating (SSR)

The SSR is designed to ensure long-term sustainability by encouraging more responsible behaviour among countries and companies participating in space. When satellite operators design their satellites, they are able to choose which altitude to use, and for how long their spacecraft will operate. The nature of the operations is a factor because the same piece of debris that could cause serious damage to one type of spacecraft might do little harm to a spacecraft with a different configuration or orbital attitude. The accurate representation of the orbital state uncertainty is important, for example, to realistically estimate the risk of collision. Efficient algorithms exist especially for the case of Gaussian uncertainty distributions with other restrictions such as short encounter times. Satellite operators therefore have a responsibility to design their satellites to produce as little waste as possible in Earth's orbit. The SSR operates with the premise that it can create an incentive for companies and governments operating satellites to take all the steps they can to reduce the creation of space debris.

The long-term sustainability of the space environment and sustainable access to outer space is critical as our reliance on space-enabled technology and services become a part of our day-to-day lives. Given the exponential increase in objects in space over recent years coupled with an expected growth of large constellations of satellites, and an increase in the number of commercial and government space actors poses a significant challenge to current and future operations in the space environment. Figure 1.[46] shows the total number of objects in space and on-orbit over time, averaging 10 000 objects every decade. As a globally shared resource, the challenge posed by increasing number of space objects requires a globally supported solution in order to foster responsible behaviour by all actors to ensure long-term sustainability of the space environment.

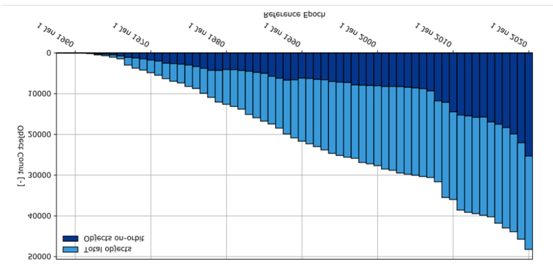

Figure 1. Evolution of number of orbiting object versus total number of objects

The SSR is aimed at providing a standardised and flexible tool for measuring the degree of sustainability of a mission to incentive the design of missions compatible with sustainable and responsible operations, as well as the in-orbit operations that reduce the potential harm to the orbital environment and the impact on other operators.

Over recent years, the adoption of rating systems have become increasingly popular to quantify the term 'sustainability' and act as a measure to publicly display sustainable practices and credentials. Based on the success of rating systems in other industries such as the green building rating system, Leadership in Energy and Environmental Design (LEED), the design methodology used for the SSR and in consultation with multiple stakeholders resulted in the first iteration of the SSR incorporating six modules based on key related decisions faced by space operators in all phases of the mission (i.e. design, in-orbit operation, and end-of-life phases). The six Modules include: Mission Index to calculate the Space Traffic Footprint; Collision Avoidance; Data Sharing; Detectability, Identification and Tracking; Application of Standards; and External Services. Additionally, an over-arching seventh verification module was included, allowing for operators to demonstrate the quality of the information they share of the six modules through technical documents, third party verification, or review by national governments.

The SSR is designed to be a voluntary mechanism and be based on a 'carrot' approach, whereby actors will receive a combined score based on the evaluation of individual modules (i.e. rated Silver, Gold, Platinum), and thereby being rewarded for design decisions and in-orbit actions taken to decrease the risk of debris creation and positioning oneself as a responsible actor. This in turn could be used to showcase to other stakeholders such as customers, insurance companies, or regulators, the level of sustainability that the given actor is willing to adopt when it comes to minimizing creation of orbital debris linked to their mission. By sharing their rating, the actor would thus provide a single point of reference externally for their mission, thereby increasing transparency and placing emphasis on their debris mitigation approach, without disclosing any mission sensitive or proprietary information.

Furthermore, the SSR is designed to support existing internationally accepted space debris mitigation measures such as the Inter-Agency Space Debris Coordination Committee (IADC) Space Debris Mitigation Guidelines published in 2002[47], and the LTS Guidelines. SSR complements the LTS Guidelines, which define the long-term sustainability of outer space activities as "the ability to maintain the conduct of space activities indefinitely into the future in a manner that realizes the objectives of equitable access to the benefits of the exploration and use of outer space for peaceful purposes, in order to meet the needs of the present generations while preserving the outer space environment for future generations", and encompass a) policy and regulatory framework; b) safety of space operations; c) international cooperation, capacity building and awareness; and d) scientific and technical research and development.[48] While the guidelines form a foundation for additional policy documents, national regulation, and derivation of technical standards, the need for a common standard for mitigation measures is critical to achieve transparency and comparable processes[49]. Examples of direct applicability of the SSR to the LTS include: a. the enhanced the practice of registering space objects; b. ability to provide updated contact information and share information on space objects and orbital events; c. improved accuracy of orbital data on space objects and enhance the practice and utility of sharing orbital information on space objects, captured as part of the composite indicator of the SSR; d. the ability to perform conjunction assessment during all orbital phases of controlled flight; and e. the design and operation of space objects regardless of their physical and operational characteristics.[50] In addition, regular conversations with stakeholders during the design and development phase of the SSR have resulted in the identification of key drivers of the SSR as a positive incentive in achieving long-term sustainability of the space environment including: a. supporting current and potential regulations that create an even playing field among space actors; b. the potential to lead to more positive customer and public perception; c. acting as a competitive advantage and greater prestige; and d. the use of the SSR in marketing and environmental, social and governance-style corporate reporting.

The concept of a rating system has additionally received support from numerous trade associations and governments. The Satellite Industry Association (SIA)'s Principles of Space Safety [51] noting "…SIA supports rating systems that assess and reward space safety practices of satellite stakeholders globally." Moreover, the Federal Communications Commission (FCC) of the United States' Fact Sheet on Mitigation of Orbital Debris in the New Space Age[52] specifically mentioned "...organizations such as the World Economic Forum's Global Future Council on Space Technologies are working toward other approaches to space debris, for example, a "Space Sustainability Rating" that would provide a score representing a mission's sustainability as it relates to debris mitigation and alignment with international guidelines."

Conclusion

New forms of access to remote areas of the Earth and outer space are increasingly facilitated by technological and scientific advances now combined with growing privatisation. With the growing buzz of new outer space activities and the excitement of 'new frontiers', there is also a need for sustainable and responsible human behaviour in outer space. The Earth's orbit is not an unlimited space.

While it is not possible to have precomputed and stored reactions for every possible situation, a recognition of complex interactive systems is necessary as is a focused and transdisciplinary, cooperative, and indeed, democratic approach to knowledge production on human activities in outer space. This involves the practical need for further studies of the complex area of the public and private activities beyond the Earth System. There are too many ways the cosmos could be, and there are too many sequences of precepts that one could have of the world. It is not possible to anticipate them all. With the emergent governance, therefore, there will also be a greater need for an understanding of long-term consequences.

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[13] This section is based on the outline of regulation applicable to orbital debris provided in Cirkovic supra note 5.

[14] For latest figures related to space debris, see European Space Agency's (ESA) Space Debris by Numbers Accessed on 02 April 2021 https://www.esa.int/Safety_Security/Space_Debris/Space_debris_by_the_numbers

[15] *International Cooperation in the Peaceful Uses of Outer Space*, UNGA, Res 73/91, 73 Sess, A/RES/73/91 (2018), preamble.

[16] U.N. Committee on the Peaceful Uses of Outer Space: Scientific and Technical Subcommittee, Space Debris Mitigation Guidelines of United Nations Committee on the Peaceful Uses of Outer Space, endorsed by G.A. Res. 62/217, U.N. Doc. A/RES/62/217 (Dec. 22, 2007).

[17] Compendium of space debris mitigation standards adopted by States and international organizations A/AC.105/C.2/2016/CRP.16. See also, Jan Wouters, Philip De Man, Rik Hansen (eds), *Commercial Uses of Space and Space Tourism: Legal and Policy Aspects* (Edward Elgar 2017)

[18] Martinez, L. (2019) Legal regime sustainability in outer space: theory and practice, *Global Sustainability* 2, 26.

[19] Space Climate Observatory (SCO), Accessed on 02 April 2021 https://www.spaceclimateobservatory.org/.

[20] Ibid.

[21] Ibid.

[22] Ibid.

[23] Ibid.

[24] The term "Space resource utilization" refers to either in-situ resource utilization or commercial appropriation of space resources.

[25] See, for instance, *Technical Report on Space Debris* adopted by Scientific and Technical Subcommittee of the United Nations Committee on the Peaceful Uses of Outer Space, UN Doc. A/AC.105/720 (1999), Introduction, sixth paragraph: 'Space debris are all man-made objects, including their fragments and parts, whether their owners can be identified or not, in Earth orbit or re-entering the dense layers of the atmosphere that are non-functional with no reasonable expectation of their being able to assume or resume their intended functions or any other functions for which they are or can be authorized'; *Space Debris Mitigation Guidelines of the United Nations Committee on the Peaceful Uses of Outer Space* endorsed by the United Nations General Assembly Resolution 62/217 of 22 December 2007, Background, first paragraph: 'For the purpose of this document, space debris is defined as all man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional'; *Space Debris Mitigation Guidelines of the Inter-Agency Space Debris Coordination Committee*, Revision 1 (2007), section 3.1: 'Space debris are all man-made objects including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional'; *Standard 24113 'Space systems – Space debris mitigation requirements'* of the International Organization for Standardization, second edition (2011), will be replaced by third edition; Introduction, first paragraph: 'Space debris comprises all non-functional, man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the Earth's atmosphere'; *European Code of Conduct for Space Debris Mitigation*, Issue 1.0 (2004). Annex 2 Terms and definitions, Space debris (synonym: orbital debris; synonym: debris): 'Any man-made space object including fragments and elements thereof, in Earth orbit or re-entering the Earth's atmosphere, that is non-functional'

[26] *Convention on International Liability for Damage Caused by Space Objects*, 29 March 1972, 961 UNTS 187, Art I(d) (entered into force 1 September 1972) *[Liability Convention]* and *Convention on Registration of Objects Launched into Outer Space*, 6 June 1975, 28 UST 695, 1023 UNTS 15, Art I(b) (entered into force 15 September 1976) *[Registration Convention]*

[27] See United Nations Office for Outer Space Affairs, online: *Compendium of space debris mitigation standards adopted by States and international organizations*, Part 1: National mechanisms <http://www.unoosa.org/oosa/en/ourwork/topics/space-debris/compendium.html>. See also *China National Industry Standard*, 'Requirements for Space Debris Mitigation' (2006); *National Standard of the Russian Federation* 'Space Technology Items. General Requirements for Mitigation of Near-Earth Space Debris Population' (GOST R 52925-2018, adopted by the Rosstandard Order No. 632-st of 21 September 2018)

[28] For an updated and detailed information in this regard, see United Nations Office for Outer Space Affairs, online: *Compendium of space debris mitigation standards adopted by States and international organizations*, Part 2: International mechanisms Accessed on: 02 April 2021 http://www.unoosa.org/oosa/en/ourwork/topics/space-debris/compendium.html For a discussion on Customary International Law and outer space law, please see Ram Jakhu and Steven Freeland The Relationship between the outer Space Treaty and Customary International Law'. While this chapter focuses on OST, the analysis of CIL may also offer some information on how soft law might gain status of CIL.

[29] *Space Debris Mitigation Guidelines of the United Nations Committee on the Peaceful Uses of Outer Space* endorsed by the United Nations General Assembly Resolution 62/217 of 22 December 2007

[30] *International Cooperation in the Peaceful Uses of Outer Space*, UNGA, Res 62/217, 62 Sess, A/RES/62/217 (2007)

[31] US, *Space Policy Directive 3 – National Space Traffic Management Policy*, Section 5(a)(iii) (2018).

[32] The Convention on International Liability for Damage Caused by Space Objects (entered into force on September 1, 1972) is unique in international law being the only fault-based liability regime.

[33] *Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched into Outer Space*, 22 April 1968, 672 UNTS 119 (entered into force 3 December 1968) *[Rescue Agreement]*

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

[35] *Agreement Governing the Activities of States on the Moon and Other Celestial Bodies*, 5 December 1979, 1363 UNTS 3, art 7, paragraph 1 (entered into force 11 July 1984) *[Moon Agreement]*

[36] *Supra* note 28.

[37] For general understanding of classic orbital elements, see for e.g. the US Federal Aviation Administration (FAA)'s guide to orbits, Accessed on: 02 April 2021 https://www.faa.gov/about/office_org/headquarters_offices/avs/offices/aam/cami/library/online_libraries/aerospace_medicine/tutorial/media/III.4.1.4_Describing_Orbits.pdf

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[39] Outer Space Treaty, art. II, Jan. 27, 1967, 610 U.N.T.S. 205 (entered into force 10 October 1967).

[40] On the history of Lex Mercatoria see Claire Cutler, *Private Power and Global Authority Transnational Merchant Law in the Global Political Economy* (Cambridge University Pres 2003), and on the global corporate culture and practice the seminal, John Braithwaite & Peter Drahos, *Global Business Regulation* (Cambridge University Press 2000)

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[43] Ibid.

[44] Porter, M.E. & Kramer, MR (December 2006) Strategy and Society: The link between competitive advantage and corporate social responsibility *Harvard Business Review*, 78-92 and (January-February 2011) Creating Shared Value *Harvard Business Review*

[45] European Commission, IP/11/469 Brussels, 13 April 2011 *Twelve projects for the 2012 Single Market: together for new growth* Accessed on: 02 April 2021 https://ec.europa.eu/commission/presscorner/detail/en/IP_11_469

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[47] Inter-Agency Space Debris Coordination Committee. Space Debris Mitigation Guidelines, 2002.

[49] United Nations Committee on the Peaceful Uses of Outer Space, "Report on the Sixty-Second Session of COPUOUS Operating in space: towards developing protocols on the norms of behaviour". June 12-21, 2019, Vienna. Accessed on 02 October 2020 https://www.unoosa.org/res/oosadoc/data/documents/2019/aac_1052019crp/aac_1052019crp_12_0_html/AC105_2019_CRP12E.pdf

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[52] Federal Communications Commission (FCC), Orbital Debris in the New Space Age, Report and Order and Further Notice of Proposed Rulemaking. 2020. Accessed on: 02 October 2020 https://www.fcc.gov/document/fcc-updates-orbital-debris-mitigation-rules-new-space-age-0