ATHENA

CRITICAL INQUIRIES IN LAW, PHILOSOPHY AND GLOBALIZATION

Space Sustainability in the Context of Global Space Governance

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ABSTRACT

The article aims at discussing the importance and role of space sustainability in the context of global space governance. After having presented the Outer Space Treaty provisions reflecting a global governance approach to space resources exploitation, as well as their interpretation by space law scholars, reference is made to State practice eventually posing challenges to a global approach on the use of space resources; such as, in the fields of asteroid mining and debris mitigation. Against this background, it is argued that the concept of space sustainability was developed to eventually remedy shortcomings of the said legal framework. The concept, based on a two-pronged approach, combines top-down and bottom-up initiatives; hence, it appears to provide a solution to the perceived inadequacy of (some) international space law institutions, taking additionally into account the needs of (private) investors and society –while using space resources–, as a result of its flexibility.

Keywords: space sustainability, global space governance, space resources exploitation, sustainability of space activities, protection of the space environment

ATHENA
Volume 2.1/2022, pp.29-72
Articles
ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

1. Introduction

In the framework of the 2nd Manfred Lachs International Conference on Global Space Governance – that was organized by leading international space law institutions –, 122 experts from 22 countries (space-faring and non-space-faring nations) involved in various aspects of space activity and regulation, took part in negotiations which led to the adoption on May 31st, 2014, of the *Montreal Declaration.*[1] In its Preamble, the participants recognized that the current space governance system, created during the 1960s -1970s, has not been thoroughly examined by the international community since its establishment.

The space governance system was defined as comprehensive, including "a wide range of codes of conduct, confidence-building measures, safety concepts, international institutions, international treaties and other agreements, regulations, procedures and standards"[2]. Bearing this in mind, the participants – having declared their willingness to examine in greater detail the long-term effects of space operations–, agreed to work in the direction of convening a wide international conference aimed at the establishment of a global governance regime, for the peaceful *and sustainable exploration and use of outer space*.

In adopting this decision, they took into account the strong growth that the space economy is currently enjoying, in conjunction with the fact that many activities pose threats to current and future space operations, as well as to the sustainable use of space for the benefit of all humankind (Montreal Declaration, *Preamble*). In this context, it was laid down that the core objective of sound and sustainable use of space resources would be given all

[1] The Montreal Declaration, adopted at the 2nd Manfred Lachs International Conference on Global Space Governance, May 29-31, 2014, Mc Gill University, Montreal, Canada, organized in collaboration with *inter alia* the United Nations Office for Outer Space Affairs (UNOOSA) and the Secure World Foundation, available at https://www.mcgill.ca/iasl/gsg/montrealdeclaration
[2] Montreal Declaration (Preamble).

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

the visibility and importance it deserves.[3]

However, whereas the "sustainable space exploration, use and exploitation for the benefit of all humankind" is established as a primary objective in the document,[4] there is not (yet) any commonly agreed definition of the concept. In fact, sustainability emerged as a means of addressing the worrying environmental consequences of the Great Acceleration triggered in the 1950s (Scarano, 2019; Michelsen et al., 2016). Bound with the concept of environmentalism – which refers to the belief in the value and fragility of the environment, with the intend to protect it (Lincoln, 2021; Slocombe, 1984) – ,sustainability was first discussed during the United Nations (UN) Conference on the Human Environment in Stockholm, Sweden, in 1972 (Michelsen et al., 2016), and put on the international agenda following the publication of the 1987 *Brundtland Report* (Scarano, 2019). In this report, the concept was described as "*development that meets the needs of the present without compromising the ability of future generations to meet their own needs*"[5], based on three coequal elements closely interdependent.[6] The term was further elaborated in the following years (Du Pissani, 2006; Barral, 2012) and established as a reference concept, allowing governments to regulate the intensity and type of use of resources, and/or the location of exploitation. In short order, it received significant academic and policy attention, with the aim to ensure the sustainable use of Earth resources.

At the same time, in a different environmental context –that is outer space, history almost repeated itself. The space era started with a first phase based on competition between the US and the USSR (Ehrenfreund and Peter, 2009), aimed at succeeding in exploring space and launching space objects.

[3] Montreal Declaration, 2014: "Hereby resolves by consensus to (…) ensure that the above-mentioned study examines inter alia: (iii) space opportunities and the need for sustainable and peaceful use, exploration and exploitation of space for all humankind".
[4] Montreal Declaration, 2014, Preamble.
[5] The Brundtland report provided "what came to be the best-known definition of the concept of sustainable development" (Michelsen G. et al., 2016, 11-12).
[6] Environment-economy-equity; sustainability can only be achieved by simultaneously protecting the environment, maintaining economic expansion and growth, and promoting equality *(*Portney, 2015, 6).

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

Following on from this exploratory phase, actors invested more heavily in improving space technology; space activity increased strongly, driven by both public and private actors (Williamson, 2012; Nirmal, 2012), allowing the development of numerous vital services and market products[7] on Earth. Nowadays, the promotion and use of new technologies, collecting and processing large amounts of space data, show new perspectives for expanding the uses of space resources (Soroka and Kurkova, 2019). Nonetheless, as a result of these developments, the near-Earth environment evolved into an increasingly congested and contested domain where space missions began to be at risk, due to the proliferation of space debris (Mejía-Kaiser, 2009).[8]

The growing dependance of Earth on space systems[9] – in a context of massive increase in debris population – became a cause of concern[10]. The question was raised on how to ensure the long-term sustainability of space activity and infrastructure, to the benefit of present and future generations. Hence, in seeking to provide a solution to this issue, space actors developed the concept of *space sustainability* and established it as high priority, as exemplified by the *Montreal Declaration*. The aim was *first* to ensure the protection of space assets in orbit (which remains, up to date, the principal concern for space-faring countries: Martinez, 2015),[11] *via* a balanced and safe exploitation of the (near-Earth) space environment, but also the right of non-space faring countries – and space users, in general – to benefit from space

[7] For an analysis of EU member States: Adriaensen, Giannopapa, Sagath and Papastefanou, 2015.
[8] Defined by the ESA as "(…) non-functional, artificial objects, including fragments and elements thereof, in Earth orbit or re-entering into Earth's atmosphere", ESA (2021). FAQ, *ESA / Safety & Security/Space Debris*, https://www.esa.int/Safety_Security/Space_Debris/FAQ_Frequently_asked_questions, accessed in June 2021. On risks caused by space debris, see OECD (2021). *Space Economy for People, Planet and Prosperity, OECD paper for the G20 Space Economy Leaders' Meeting, Rome, Italy 20-21 September 2021*.
[9] "In 2019, 95% of the estimated $366 billion in revenue earned in the space sector was from the *space-for-earth* economy: that is, goods or services produced in space for use on earth." (Weinzierl and Sarang, 2021). For benefits arising from Space resources exploitation, see OECD (2021) *supra* note 8.
[10] As regards the military, economic and scientific uses of space for all nations, see Lim, 2018.
[11] Given that space systems are now major global utilities which meet various societal needs.

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

activities on Earth and/or to ensure their future access to Earth orbits (Martinez, 2021).

Against this background, this article aims at discussing the importance and role of space sustainability in the context of space governance. More precisely, *Section 2* will examine the rules reflecting a global governance approach to space resources, initially as established in the *Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies* (Outer Space Treaty, OST)[12] – referred to as the *Magna Carta of Outer Space* and legally binding on States, because of both its high level of recognition and customary character (Hofmann and Bergamasco, 2020) – and then, as these are interpreted by space law scholars. Following this analysis, *Section 3* will make reference to State practice eventually posing challenges to a global approach on the use of space resources such as, for example, in the fields of asteroid mining and debris mitigation. Subsequently, *Section 4* will focus on the emergence of the concept of space sustainability, which is first considered to be rooted in the treaty but second, also further defined with the aim to complement the OST in a more practical way. *Section 5* will analyze the institutional and other sources of law determining the concept, which appears to be based on a two-pronged approach combining top-down and bottom-up initiatives. In *Section 6*, the substantive normative gaps filled by the concept of space sustainability will be addressed, as it provides a solution to the perceived inadequacy of (some) international space law institutions and allows to also take into account the needs of (private) investors and society while using space resources, as a result of its flexibility. In the final *Section 7*, some conclusions will be drawn.

[12] Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, January 27, 1967, U.N.T.S. 610 at 205 (entered into force on October 10, 1967), (Outer Space Treaty or OST).

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

2. Treaty Provisions Setting the Tone for a Global Governance of Space Resources and Their Limits

The adoption of the Outer Space Treaty (OST) regulating precisely[13] all types of activities carried out in space by the numerous operators was deemed necessary, given that "(n)ot all rules are directly translatable into the space environment" (Blount, 2008). Hence, the fundamental referencing basis for space activities is laid down in the OST, and further elaborated in related international space law instruments referred to as *corpus juris spatialis.*[14] On this basis, it appears that the OST provisions have set the framework for a global and sustainable use of space resources.

2.1 Basic Framework Rules for the Use of Space Resources to the Benefit of All

The fundamental freedom to explore and use outer space resources – more precisely, "outer space, including the Moon and other celestial bodies" –, was established in the first Articles (hereafter, Art.) of the OST. Precisely, Art. I para. 1 stipulates that "(t)he exploration and use of outer space (…), 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*"[15]. In addition to that, Art. I para. 2 clarified that space "shall be free for exploration and use *by all States without discrimination of any kind, on a basis of equality* and in accordance with international law, and there

[13] On the view that space law is *lex specialis, inter alia,* Jakhu and Freeland, 2016).
[14] In addition to the OST, four international treaties (and five sets of principles on space-related activities) have been adopted: (i) Agreement on the Rescue of Astronauts, the Return of Astronauts and the Return of Objects Launched in Outer Space ("Rescue Agreement"), 22 April 1968 UNTS 672 (p.119), entered into force on 3 December 1968; (ii) Convention on International Liability for Damage Caused by Space Objects ("Liability Convention"), 29 March 1972 UNTS 961 (p.187), entered into force on 1 September 1972; (iii) Convention on the Registration of Objects Launched into Outer Space ("Registration Convention"), opened for signature on 14 January 1975, entered into force on 15 September 1976 and (iv) Agreement Governing the Activities of States on the Moon and Other Celestial Bodies ("Moon Agreement"), opened for signature on 18 December 1979, entered into force on 11 July 1984.
[15] Emphasis added.

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

shall be free access to all areas of celestial bodies"[16]. At the same time, Art. II of the OST established *expressis verbis* that: "(o)uter space (…) *is not subject to national appropriation* (…) *by means of use* or occupation, or by any other means"[17]; this clause is referred to as the key principle of the non-appropriation of space and consists in one of the fundamental rules of international space law. As a result, outer space and space resources are regarded as *res communis* (Leepuengtham, 2017, 14; Trimble, 1984, 17), and more precisely, as the *common heritage of mankind*; namely, "a new category to be added to the tripartite division of the world made by traditional international law: national territory; res nullius; and res extra commercium"[18].

Furthermore, on one hand, Art. III stated that "States Parties to the Treaty shall carry on activities in the exploration and use of outer space (…) in accordance with international law (…), in the interest of maintaining international peace and security and *promoting international cooperation and understanding*"[19]. On the other hand, the OST promoted international collaboration in particular, by enshrining principles such as the obligation to cooperate, provide mutual assistance and undertake appropriate international consultation before proceeding with any potentially harmful activity (Art. IX of the OST)[20], and to inform the UN Secretary General as well as the public and the international scientific community, to the greatest extent feasible and practicable, of the nature, conduct, locations and results of their space activities (Art. XI of the OST) (Stelmakh, 2015).

The said OST rules on the use and governance of space resources are further elaborated in relevant instruments of international space law, on

[16] Emphasis added.
[17] Emphasis added.
[18] "The concept of CHM [*i.e., common heritage of mankind*] is applicable to areas which not only in themselves are not subject to national appropriation in a territorial sense, but the fruits and resources of which are also deemed the property of mankind at large" (Williams, 1987).
[19] Emphasis added.
[20] OST, art. IX: any State party must "undertake appropriate international consultations before proceeding with any (…) activity or experiment" it has reasons to believe would cause potentially harmful interference with the activities of other States Parties. If such action is planned by another State, each State party to the treaty "may request consultation concerning the conduct of this activity or experiment".

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

specific aspects of space activity. *Inter alia*, they are reiterated and detailed in the International Telecommunication Union (ITU)[21] Constitution,[22] aimed at regulating the use of orbits and frequency bands for radio services. In particular, Art. 44.2 of the ITU Constitution underlines that such use must be made taking account of the interests of all countries:

> (i)n using frequency bands for radio services, Member States shall bear in mind that radio frequencies and any associated orbits, including the geostationary-satellite orbit, are *limited natural resources and that they must be used rationally, efficiently and economically* (…) so that countries or groups of countries may have equitable access to those orbits and frequencies, taking into account the special needs of the developing countries and the geographical situation of particular countries[23].

In this context, it is clear that "the governance of such a 'global commons' (…) *cannot follow from the authority of a single nation*"; a global governance approach is established, and the substance of any limitation may come from international treaty law, such as the OST, or other relevant sources of international law (Von der Dunk, 2020). Practically, the core of the global governance structure for outer space and activities carried out in that realm "lies in the role that each state has to fulfill *with respect to activities by other categories of legal subjects active in this 'global commons*'" (*Idem*).

[21] The ITU (International Telecommunication Union) is the UN specialized body established to "facilitate international connectivity in communications networks, (…) allocate global radio spectrum and satellite orbits, develop the technical standards that ensure networks and technologies seamlessly interconnection etc.", see 'About International Telecommunication Union (ITU)' at https://www.itu.int/en/about/Pages/default.aspx, accessed on September 2021.
[22] *Constitution and Convention of the International Telecommunication Union*, 22 December 1992, UNTS 1825, 1826 (entered into force 1 July 1994).
[23] Emphasis added.

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

2.2 Diverging Interpretations of the Fundamental Non-appropriation Principle

The OST provides a basis of commonly agreed principles to regulate the conduct of space activities, in line with the agreement of States that the domain of outer space is *res communis* (Martinez, 2015, 262). At the same time, more and more voices are being raised to criticize the existing legal framework for being poorly adapted to regulate newly emerging fields of activity – which are strongly attracting both public and private stakeholders – , ranging from space exploration to asteroid mining.[24] Against this background, the development of low-cost small satellites and high-tech robotics (made much easier thanks to cheaper manufacturing techniques and to the growth of commercial off-the-shelf components: Scatteia, Frayling and Atie, 2020) allowed the promotion of space uses showing the greatest potential for the future.

As a result, various aspects relating to the interpretation of the key principle of non-appropriation of space, laid down in Art. II of the OST (establishing that "*Outer Space, including the Moon and other celestial bodies, is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means*") have been at issue and further discussed. In particular, questions arised in relation to the exact scope of its application, mainly in the light of asteroid mining. Whereas the provision clearly prohibits national appropriation of territories on the Moon or other celestial bodies, the issue of the regime applying to the extraction of mineral or other resources remains open (Cheney, 2019).

In this context, a first view advocates that all types of use, exploitation and mining of space resources are clearly prohibited by international space law. Indeed, to allow and/or regulate resource mining and similar activities

[24] "The resources of just one asteroid in our solar system could be worth up to $95 trillion, significantly higher than the world's total GDP in 2016 (…) Most do not consider the consequences of removing part of the mining industry from Earth altogether, which could benefit the environment by reducing terrestrial mining activities, thus preserving the planet's limited resources." (Iliopoulos and Esteban, 2020, 87).

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

(eventually on the basis of Art. VI of the OST, establishing that States are responsible for their national activities in outer space, thus required to regulate them), a State should first have jurisdiction over the said area; this is, however, prohibited *expressis verbis* by Art. II of the OST. This approach is also based on the general view that space resources are part of the global commons, hence their use and exploitation require an international regime to be authorized (*Idem*, 142). From this viewpoint, mining and exploitation activities are regarded as resulting on an acquisition of (some parts/elements of) the celestial body in which the resources are found, and the extraction of these resources an infringement to Art. II of the OST.

However, following a second approach, in case the space resources being removed amount to a small proportion of the celestial body and/or are extracted without causing any (important) damage, the extraction activities would not necessarily consist in an infringement of the said provision (*Idem*, 112). To corroborate this second view, it is argued that (i) States adopting national laws allowing asteroid mining are acting in line with Art. VI of the OST – which is *not specifically prohibiting* States from adopting legislation on mining activities – (*Idem*, 143) and that (ii) the Moon Agreement did elaborate further the non-appropriation principle established in Art. II of the OST,[25] based on the premise that mining activities would most probably (at some time) take place (Leepuengtham, 2017, 15). In particular, the Moon Agreement provides, in Art. 11 para. 5, for the establishment of an international regime to regulate resources exploitation and calls for their equitable sharing (Art. 11 para. 7.d).[26]

Thus, the OST set the general framework within which space actors may carry out activities aimed at the use and exploration of space resources and established the rules for their global governance. Nevertheless, the Treaty was

[25] Moon Agreement, Art. 11.2 ("The Moon is not subject to national appropriation by any claim of sovereignty, by means of use or occupation, or by any other means").
[26] "The Moon Agreement has received much less support than the Outer Space Treaty. Nevertheless, it provides a starting point for the formulation of an international mechanism governing the exploitation of space resources" and, therefore, cannot be (Jinyuan Su, 2017, 994).

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

adopted at a time where space activity was principally conducted by States, mainly for scientific and military purposes. Today, given the divergent interpretations of the OST, the questions arise of whether the legal framework on the use of space resources is sufficiently flexible to be adapted to economic and technological developments in space activities.

3. State Practice Posing Challenges to the Global Approach on Space Exploitation

In practice, the global governance of space resources – to the benefit of all – is challenged by the divergent interpretations of the OST rules, as a result of the divide between space-faring (or developed) and non-space-faring countries. *Inter alia*, voices are raised to underline that space exploitation is, currently, mainly benefiting to leading space-faring nations.

Developing infrastructure to exploit space resources requires significant investment – due to the high technical standards and costs required for space robotics[27] – and can be provided only by a few States. Hence, it is probable that a further exploitation of space resources will serve to increase the gap between developed and developing countries.[28] As a result, it appears that a global approach to space resources utilization is challenged, *first*, by policies and practices on mining activities adopted by (and favoring) particular space-faring nations and *second*, by different approaches and levels of ambition as regards space debris and the protection against hazards occurring in space.

[27] "(…) despite increasing number of new entrants to space activities or usage, barriers to entry still exist, largely disguised as security constraints, and lack of enablement to increase capacity emerges through restricted international cooperation or technology transfer, even where commercial." (Aganaba-Jeanty, 2016, 3).

[28] "Given that the exploitation of natural resources in outer space is ultimately a hi-tech and costly enterprise, only a small number of private entities or States will have the capability to do so. States not directly involved in the exploitation may ask for a share of the benefits derived, as well as for technology transfers so that they can carry out exploitation themselves in the future." (Jinyuan Su, 2017, 1007).

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

3.1 Policies and Practices Aimed at Reframing the Right of Access to Space Resources

Frameworks creating the conditions for the exploitation of natural resources with the aim to generate income – and requiring (in addition to expensive infrastructure) well-organized mechanisms –, already exist in other fields of international law. As an example, the exploitation of the seabed and subsoil and its natural resources is regulated in detail in the Law of the Sea Convention (LOSC) signed in 1982,[29] and may eventually be used as a point of reference.

In particular, the LOSC vested a specific body (i.e., the Authority) with the power to act on behalf of States, so as to adopt rules, regulations and procedures for the exploitation of specific sea resources.[30] In this sense, it appears that the OST adopted a completely different approach for the exploitation of space natural resources (no specific body was created by the OST); the LOSC provisions are only comparable to the ones adopted in the Moon Agreement, which required *expressis verbis* the adoption of an international regime to govern exploitation activities.[31] However, the Moon Agreement which leaves open the question of future space resources exploitation and "remains the only international law treaty that contemplates at all the issue of ownership in space" (Iliopoulos and Esteban, 2020), has been ratified by very few States. Hence, in the absence of such mechanism for space resources exploitation – and in the absence of a new international agreement eventually amending or clarifying Art. II of the OST –, States have

[29] United Nations Convention on the Law of the Sea ("LOSC") 10 December 1982, UNTS Vol. 1833 (p. 3), entered into force on 16 November 1994.
[30] See, for instance, LOSC, Art. 137.2 ("All rights in the resources of the Area *are vested in mankind as a whole, on whose behalf the Authority shall act*. These resources are not subject to alienation. The minerals recovered from the Area, however, may only be alienated *in accordance with this Part and the rules, regulations and procedures of the Authority*") and Annex III titled "Basic conditions of Prospecting, Exploration and Exploitation".
[31] "Article 11 of the Moon Agreement provides a valuable framework for the development of an international coordination and benefits-sharing mechanism for the exploitation of space resources" (Jinyuan Su, 2017, 999).

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

to take into account the non-appropriation principle laid down in the OST, when programming this type of activity.

Against this background, some State parties adopted the second approach to Art. II of the OST, to promote measures – namely proposals and space missions –, with the aim to encourage specific (commercial) uses of space natural resources, such as in the form of asteroid mining. For example, the US Commercial Space Launch Competitiveness Act, adopted in 2015 (Freeland, 2017),[32] addressed for the first-time space resource mining operations, by way of its Title IV entitled Space Resource Exploration and Utilization. It laid down that US citizens and entities are "entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell the asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of the United States"[33], allowing property rights on space resources on a first-come, first-served basis (Von der Dunk, 2018, 429). At the same time, it underlined that "the United States does not thereby assert sovereignty or sovereign or exclusive rights or jurisdiction over, or the ownership of any celestial body"[34].

In the same line of thinking, Art. 1 of the Luxembourg law on the use of Space Resources, adopted in 2017,[35] stipulates that such resources are capable of being owned and lays down a licensing process for space resource companies to receive approval from the Luxembourg government (Cheney, 2019, 119). As in the case of the US Commercial Space Launch Competitiveness Act, the law raised concerns as to its compatibility with Art. II of the OST. In reality, both (US and Luxembourg) initiatives paved the way

[32] Public Law 114 - 90 - U.S. Commercial Space Launch Competitiveness Act (titled "An act to facilitate a pro-growth environment for the developing commercial space industry by encouraging private sector investment and creating more stable and predictable regulatory conditions, and for other purposes"), available at https://www.govinfo.gov/app/details/PLAW-114publ90.
[33] U.S. Commercial Space Launch Competitiveness Act, § 51303.
[34] U.S. Commercial Space Launch Competitiveness Act, SEC 403 entitled "Disclaimer of Extraterritorial Sovereignty".
[35] Law adopted on the 20 July 2017 on the exploration and utilization of space resources, published at the Journal Officiel du Grand Duché du Luxembourg / Memorial A n° 674 dated 28 July 2017; Art. 1 stipulates that: "Space resources are capable of being *owned*".

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

for a more pragmatic approach to space exploitation; other governmental and non-governmental entities, established in Japan, China and the United Arab Emirates (Hofmann and Bergamasco, 2020; Jinyuan Su, 2017, 992), promoted likewise a series of similar measures and proposals, in parallel to resource exploitation projects.[36]

Overall, it is argued that such practices will eventually provoke the development of customary international law regarding space resource exploitation (Cheney, 2019, 127). However, until the scope of Art. II of the OST is clarified, there is a risk that divergent national approaches will remain, to the detriment of a global approach. At the same time and from a more practical perspective, countries hold different views and operate at different scales (and with different ambitions) also with regard to risk mitigation.

3.2 Different Levels of Ambition in Reference to Risk Mitigation: Debris and Threats

In regulating access to and use of space resources, States must also take into account (in addition to the rules of international law) such practical factors as the significant –and constantly growing – number of space debris, obstructing the use of the Low Earth Orbit (LEO) and the Geostationary Orbit (GEO).

According to the United Nations Office for Outer Space Affairs (UNOOSA), the competent UN authority to promote international cooperation in the peaceful use and exploration of space, space debris are "all man-made objects, including fragments and elements thereof, in Earth orbit or re-entering the atmosphere, that are non-functional"[37]. They consist in non-cooperative elements which are difficult to capture (Shan, Guo and Gill, 2016), varying from small pieces to very large ones; according to the Kessler

[36] With regard to these initiatives, it appears that one of their central elements is the development of a legal and regulatory framework confirming certainty about the future ownership of minerals extracted in space (Hofmann and Bergamasco, 2020, 2), in the context of what is referred to as "the most recent space mining boom" (Cheney, 2019, 126).

[37] UNOOSA, Space Debris Mitigation Guidelines of the Committee on the Peaceful Uses of Outer Space, UN, Vienna, 2010, available at https://www.unoosa.org/pdf/publications/st_space_49E.pdf.

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

effect (Adilov, Alexander and Cunningham, 2020), in case of collision between them or with other space objects, the resulting debris cloud will be particularly dense and create a cascade of collisions without end. Despite the fact that space debris have long been identified as key threats to space activity, they still occur in the context of civilian or military operations, such as in the case of the Russia's anti-satellite missile test in November 2021.[38]

The Secure World Foundation – a US private entity collaborating with *governments, industry and international organizations to promote* cooperative solutions for space sustainability[39] – underlined that the growing number of debris resulting from accidents and intentional destructive events, or arising in the context of routine operations, could "quickly lead to a sharp decrease in our ability to sustain the benefits that space systems provide to the entire world"[40]. In truth, any deterioration in the conditions of use of the orbits would consist in (irreversible) environmental damage and give rise to a wide array of security challenges *that cross national boundaries.*[41]

In reality, addressing the space debris problem requires complex and expensive-to-maintain surveillance networks and tracking systems, eventually composed of "ground and space-based radars, lasers and telescopes that currently track some 23 000 orbiting pieces of debris larger than 10 cm in low-earth orbit (LEO) and 30 cm in geostationary orbit (GEO)"[42]. Practically, such networks and/or tracking systems may be developed by leading space-faring countries or through effective partnerships

[38] "Russia conducted a direct-ascent anti-satellite (ASAT) test on Nov. 15 to destroy one of its own satellites (…), creating a field of at least 1,500 trackable pieces of debris in low orbit and threatening space operations and human spaceflight" (Bugos, 2021).
[39] Secure World Foundation – Promoting Cooperative Solutions for Space Sustainability, available at https://swfound.org/about-us/
[40] Secure World Foundation (October 29, 2018), Space sustainability - A practical guide, available at https://swfound.org/resource-library/space-sustainability-challenges/ accessed in December 2021, p. 4.
[41] "As more countries integrate space into their national military capabilities and rely on space-based information for national security, there is an increased chance that any interference with satellites could spark or escalate tensions and conflict in space or on Earth." (Secure World Foundation, 2018, *supra*, p. 5).
[42] OECD (2019). Space exploration and the pursuit of Scientific Knowledge (Chapter 5), in *The Space Economy in Figures*, OECD Publishing Paris, available at https://www.oecd-ilibrary.org/sites/d2d4146e-en/index.html?itemId=/content/component/d2d4146e-en

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between them, namely between space-faring countries and/or their space agencies; such as in the case of the European Space Surveillance and Tracking (SST) Consortium established in 2014,[43] and composed of the national space entities of seven EU member States.[44] Non-participating countries may have access to such data only on the basis of a data-sharing agreement; by way of illustration, "in 2017, the US Strategic Command issued hundreds of warnings to their partners, with more than 80 confirmed collision manoeuvres from satellite operators"[45]. From this perspective, access to information on orbiting pieces of debris remains a critical challenge for non-space-faring countries [which could be, however, expected to have an interest as (small) satellite owners].

This relatively uneven development is explained by the fact that information on space debris is of key importance to space-faring countries, as they require it to carry out their space activities with safety. Hence, they prioritize the effort to develop surveillance networks and to establish norms of (responsible) behaviour in space. On the contrary, developing States are lagging behind. In addition to economic issues, they also have to face policy and implementation challenges; they may lack the proper means to tackle space issues, such as capacity in government or experience in the regulation of space activity, or due to a "general lack of awareness among policy makers" on space sustainability issues (Martinez, 2020; Johnson, 2020, 5) (and may miss out on critical opportunities, to the detriment of their national interests).

Hence, as regards more practical issues as well, States adopt (in reality) different approaches, as in the case of regulating asteroid mining. At the same time, it seems that the international community agrees on the identification of an issue of common interest that all space actors wish to resolve.

[43] The Space Surveillance and Tracking (SST) Support Framework was established by the European Union in 2014 with Decision no 541/2014/EU of the European Parliament and of the Council of 16 April 2014 *Establishing a Framework for Space Surveillance and Tracking Support (SST Decision), OJ L 158, 27.5.2014, p. 227–234.*
[44] EU SST, "What is EU SST?", available at https://www.eusst.eu/ accessed in January 2022.
[45] OECD (2019), *supra* note 42.

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4. Emergence of the Concept of Space Sustainability

In addition to divergent national policies on specific space matters, there remains a considerable grey area between legal – e.g., scientific research for purposeful purposes – and clearly prohibited space operations (such as placing in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction).[46] Thus, against the background of an unprecedented development of space endeavours and the growing awareness of (space) environmental constraints, the challenge was first to agree on the characteristics of sustainable space operations, to the benefit of all.[47]

In this regard, the concept of space sustainability was promoted and said to be rooted in the OST, particularly in the provisions making reference to the protection of the space environment *lato sensu* (as the OST prohibits uses which are highly destructive to the outer space environment *per se*: Gabrynowicz and Serrao, 2004, 230). However, as the treaty provisions on the subject remain rather general, the concept was further developed and defined through the elaboration of more practical guidelines.

4.1 Treaty Provisions on the General Protection of the Outer Space Environment

A clear requirement for sustainable use of space resources appears to be *prima facie* absent from the OST or other international space law treaties. However, even though:

> (t)he UN space treaties do not specifically address the concept of 'sustainability' as such or provide a definition of the term (…) *it would fall short of the UN space treaties' spirit to deny that they*

[46] OST, Art. IV.
[47] OST, Art. I para. 1: "The exploration and use of outer space (…) shall be carried out for the benefit and in the interest of all countries".

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> *would not include any forward-looking, environmental concern altogether* (Palmroth et al., 2021; emphasis added).

In fact, the essence of such a concern may be found in OST provisions regulating specific aspects of space activities, such as Art. IV of the OST prohibiting the use of space for particular military purposes;[48] Art. VI of the OST stating that States parties bear international responsibility for all their activities in outer space[49] and Art. VII of the OST laying down the launching State's international liability for damage caused to other States (or to their natural or juridical persons) by their space objects or component parts in space.[50] Finally, Art. IX of the OST appears to also reflect this approach, stating that:

> (i)f a State Party (…) has reasons to believe that an activity or experiment planned by it or its nationals in outer space (…), would cause potentially harmful interference with activities of other State Parties in the peaceful exploration and use of outer space (…), it shall undertake appropriate international consultations before proceeding with any such activity or experiment.

From a certain perspective, it would appear that Art. IX of the OST was adopted to tackle environmental and safety issues in space, "by creating a

[48] OST, Article IV, para. 1: "States Parties to the Treaty undertake not to place in orbit around the Earth any objects carrying nuclear weapons or any other kinds of weapons of mass destruction, install such weapons on celestial bodies, or station such weapons in outer space in any other manner" and para. 2: "(…) the testing of any type of weapons and the conduct of military maneuvers on celestial bodies shall be forbidden".
[49] OST, Article VI: "States Parties to the Treaty shall bear international responsibility for national activities in outer space (…) 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 (…) shall require authorization and continuing supervision by the appropriate State Party to the Treaty".
[50] OST, Article VII: "Each State Party to the Treaty that launches or procures the launching of an object into outer space (…) is internationally liable for damage to another State Party to the Treaty or to its natural or juridical persons".

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'proscriptive positive legal obligation' for States to (1) avoid harmful contamination of celestial bodies and (2) undertake international consultations in advance before any potentially harmful interference may arise from their activities" (Chung, 2018). However, the provision is also criticized for not being sufficiently precise as regards the type of degradation which should be prohibited and to what extent. In particular, it is understood that it would hardly cover "alteration of the topography and geology of a celestial body, which could be a consequence of large-scale human activities such as space mining" (Hofmann and Bergamasco, 2020, 4).

In truth, a closer look at Art. IX of the OST suggests that the wording is vague and poorly adapted to the requirements for an effective framework for environmental space protection,[51] given that no precise and legally binding rules can be derived on space sustainability as such (Palmroth et al., 2021, 4). For instance, Art. IX does not specify when contamination –of the Outer Space, including the Moon and other celestial bodies– is harmful, if all contaminations must be considered as harmful and/or what kinds of adverse changes in the Earth environment must be avoided. At the same time, the OST does not provide for any specific liability regime for *environmental damage* in general, or for damage resulting from the violation of Art. IX of the OST.

Given the difficulty of using this rule as a basis for the application of environmental recovery (Taylor, 2006, 76), Art. IX of the OST has even been regarded "as an impotent provision because it fails to set standards in the field of the space environment or, at a minimum, entrust a regulatory body to do so" (Chung, 2018). In theory, the general obligation deriving from Art. IX of the OST, and aiming at the protection and preservation of the outer space environment, could have been set aside. However, contrary to that, space actors worked together to establish common standards, to allow the OST initial environmental concern to be practically implemented.

[51] The generic terms 'appropriate measures' and 'where necessary' further water down any rigorous content of the obligation: Hofmann and Bergamasco, 2020, 4; Chung, 2018.

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4.2 Developing Space Sustainability to Complement the Treaty Provisions

The said legislative lacunae in space environmental protection, – eventually explained by the fact that space law treaties were negotiated before the emergence of (and the knowledge emanating from) environmental law[52] –, were therefore filled by the concept of space sustainability. As it was first unclear "what components make up a sustainable space environment (or) what steps should be taken in order to achieve this desired result" (Williamson, 2012), several results-based initiatives were taken, starting from the premise that the long term management perspective is the most prominent need in the view of space actors[53] and should be defined. Thus, the concept was set up gradually, in cooperation with the operators involved.

In June 2007, G. Brachet, Chairman of the UN COPUOS – which is the Committee of the General Assembly dealing exclusively with international cooperation in the peaceful uses of outer space[54] – suggested a series of initiatives, focusing amongst others on the topics of "contribution of satellite technology to sustainable development" and "long-term sustainability of space activities" (Brachet, 2012). After several attempts to take the issue further, the French delegation to COPUOS formally proposed the topic of 'Long-term Sustainability of Outer Space Activities' as a new agenda item, in 2010. Hence, during its 47th session, the COPUOS created a formal working group to precisely address this challenge, chaired by Dr. Peter Martinez.[55]

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[52] "The traditional legal framework for outer space activities does not contain specific environmental standards, as it was developed well ahead of the codification of environmental law. Rather, environmental protection was considered – if thought was given at all – as a hindrance to the emerging space activities at that time. (…) The same Earth-centric perspective can be found in the Liability Convention (…). Other norms of the UN space treaties – such as Article 7 of the Moon Agreement – refer to the environmental considerations related to the exploitation of natural resources in outer space" (Bohlmann and Petrovici, 2019, 4).

[53] UNOOSA (May 2021), *Space Sustainability: Stakeholder Engagement Study - Outcome Report*, p. 10.

[54] The COPUOS is the UN body responsible for developing policies related to outer space on behalf of the Un Member states. It does not deal with military space issues, UNOOSA, 'Committee on the Peaceful Uses of Outer Space (COPUOS)' at https://www.unoosa.org/oosa/en/ourwork/copuos/index.html accessed in September 2021.

[55] The Working Group on the Long-term Sustainability of Outer Space Activities, *idem*.

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After several proposals for draft reports and preliminary sets of draft guidelines prepared by the said working group,[56] the *Guidelines for the Long-Term Sustainability of Outer Space Activities* of the Committee on the Peaceful Uses of Outer Space (LTS Guidelines) were finally adopted in 2019,[57] reflecting the latest global consensus on what responsible and sustainable space activities should look like.[58] The value of the LTS (non-binding) Guidelines was to provide authoritative guidance to space actors, taking into account that governments are responsible for the authorization and ongoing supervision of space activities conducted by entities under their jurisdiction or control[59], as established in international space law.

The LTS Guidelines adopted a comprehensive approach providing that the long-term sustainability of space activities is defined 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.[60]

This definition is in accordance with the objectives of the *Declaration of Legal Principles Governing the Activities of States in the Exploration and*

[56] *Inter alia*, UNCOPUOS - Working Group on the Long-term Sustainability of Outer Space Activities (2014), *Proposal for a draft report and a preliminary set of draft guidelines of the Working Group on the Long-term Sustainability of Outer Space Activities - Working paper by the Chair of the Working Group*, STSC 51st session, UN Doc A/AC.105/C.1/L.339; UNCOPUOS -STS (2015), *Updated set of draft guidelines for the long-term sustainability of outer space activities*, UN Doc A/AC.105/C.1/L.340.
[57] UNCOPUOS, *Report of the Committee on the Peaceful Uses of Outer Space COPUOS* 62nd session, UN Doc A/74/20 (2019).
[58] UNOOSA (May 2021), *supra* note 53, p. 5.
[59] "(T)he guidelines can have a legal character in the sense that States may choose to incorporate elements of the guidelines in their national legislation, as has been the case with the UN COPUOS space debris mitigation guidelines" (Martinez, 2021, 102).
[60] See UNCOPUOS (2019), *supra* note 57, p. 50 - Annex II: Guidelines for the Long-term Sustainability of Outer Space Activities of the Committee on the Peaceful Uses of Outer Space, Part I. "Definition, objectives and scope of the guidelines", [emphasis added].

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Use of Outer Space adopted in 1963,[61] the Outer Space Treaty (OST) signed in 1967 and takes into account the recommendations contained in the *Report of the Group of Governmental Experts on Transparency and Confidence-Building Measures in Outer Space Activities,* established in 2013.[62]

From a private entity perspective, the Secure World Foundation stated that space sustainability generally refers to the ability of "all humanity to continue to use outer space for peaceful purposes and socioeconomic benefit over the long term"[63]. It is clear that this second view is less precise than the one established in the LTS Guidelines.[64] However, the two approaches do share a common feature, as they both mainly focus on "protecting the ability of *current and future* space and non-space actors to use space for their benefit, in accordance with international law" (Lopez, 2016, emphasis added).

On the basis of this (clearer and more precise) definition of space sustainability, State and non-State space-actors were able to negotiate and promote a more specific framework for the practical implementation of the concept. In practical terms, space sustainability was developed to combine institutional guidance and dialogue, with knowledge coming from space operators' practical experience.

5. Institutional and Other Sources of Law Determining the Concept

The rules applying to the use of space resources are of immediate and practical relevance to both public and private stakeholders. Indeed, on the one hand, States are responsible for the authorization and control of space

[61] Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space, GA Res 1962 (XVIII), UNGAOR, 18th session, 1963.
[62] GA, Group of Governmental Experts on Transparency and Confidence-Building Measures in Outer Space Activities, UN Doc A/68/189 (2013).
[63] Secure World Foundation, 2018), *supra* note 40, p. 4.
[64] This view is also criticized for taking as a premise that "(1) all humanity thus far is using space for peaceful purposes and for socioeconomic benefit; (2) this use is threatened; (3) measures must be taken to protect it; and (4) all humanity currently possesses the ability, in the sense of having a skill or the capacity, to ensure space sustainability for peaceful purposes" (Aganaba-Jeanty, 2016, 10).

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activities, pursuant to Art. VI (and VII) of the OST. On the other hand, private companies have more resources to invest in space activities; hence, having invested a lot of effort and funds in developing space infrastructure, they seek to ensure that they will be able to deliver the optimum in terms of productivity. It is, therefore, reasonable to assume that both institutional and non-institutional sources of law will have an impact on how the concept is being developed.

5.1 Top-down Development of the Concept: Contribution of the COPUOS and the 'Working Group on the Long-term Sustainability of Outer Space'

In the framework of its powers and in order to "comprehensively address the present challenges in using outer space for peaceful purposes pertaining to the long-term sustainability of space activities"[65], the COPUOS Scientific and Technical Subcommittee (STS) established, in 2010, a specific body named *Working Group on the Long-term Sustainability of Outer Space Activities* (Brachet, 2012). Within this body, four Expert Groups were tasked to provide supporting work to the working group by covering specific aspects of space sustainability, with the aim to develop efficient approaches (Martinez, 2015, 266).[66]

The working group focused on the sustainability of space operations in the context of the broader framework of sustainable development on Earth; on the state of ongoing practices, functional procedures, technical standards, and policies associated with space sustainability and safety and on the existing UN treaties and principles governing space activities as a legal framework

[65] UNCOPUOS, *Fiftieth anniversary of the United Nations Conference on the Exploration and Peaceful Uses of Outer Space: the Committee on the Peaceful Uses of Outer Space and global space governance*, COPUOS 59th session, UN Doc A/AC.105/2016/CRP.4 (2016), para. 62.

[66] Expert Group A focused on "*Sustainable Space Utilization Supporting Sustainable Development on Earth*"; Expert Group B focused on "*Space Debris, Space Operations, and Tools to Support Collaborative Space Situational Awareness*"; Expert Group C examining "*Space Weather*" and Expert Group D, on "*Regulatory Regimes and Guidance for Actors*".

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(Martinez, 2015, 264 ff.).[67] Based on such preparatory work, the working group released a set of guidelines – the *Guidelines for the Long-Term Sustainability of Outer Space Activities* (or LTS Guidelines) –, officially adopted in 2019.[68]

As regards their content, the LTS Guidelines are not binding[69] but they do provide –after a long debate (Palmroth et al., 2021, 5) – a commonly accepted approach to space sustainability.[70] Additionally, States and international intergovernmental organizations are encouraged to voluntarily adopt rules, which will ensure that the guidelines are implemented to the greatest extent feasible and practicable (taking into account, of course, the needs of States, their specific conditions and capabilities, and their obligations under international law).[71]

In particular, the document contains 21 guidelines, divided into four main categories, consisting in specific guidance to governments, to help them establish a better adapted legal framework;[72] guidelines on how to design safe space operations;[73] guidance on how to develop international cooperation, capacity building and awareness[74] and finally guidance in relation to scientific and technical research and development.[75] The LTS Guidelines take into consideration the growing concern about orbital debris and the risks they pose

[67] More precisely, the four expert groups –created to discuss specific issues and to propose candidate guidelines– concentrated on: (a) Sustainable use of space that supports sustainable development on Earth; (b) Space debris, space operations and tools to support cooperation in space space-related activities, tools, and support for the development of space-based technologies and support for space-related activities; (c) Space weather and (d) Regulatory regimes and guidance for new actors in space; see also the 2019 Fact Sheet on UN COPUOS Guidelines for the Long-Term Sustainability of Outer Space Activities.
[68] See, *supra* note 57.
[69] LTS Guidelines, para. 15.
[70] LTS Guidelines, para. 5 and *supra* note 57.
[71] LTS Guidelines, para. 16.
[72] LTS Guidelines, "A. Policy and Regulatory Framework for Space Activities", guidelines A.1 to A. 5.
[73] LTS Guidelines, "B. Safety of Space Operations", guidelines B.1 to B. 10.
[74] LTS Guidelines,"C. International cooperation, capacity building & awareness", guidelines C.1 - C. 4.
[75] LTS Guidelines, "D. scientific and technical research and development", guidelines D.1 and D. 2.

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to space operations, with the aim to propose specific measures and solutions.[76]

Finally, the LTS Guidelines also build on the achievements already made, as non-governmental entities are encouraged to adopt other instruments on more specific issues (related to space sustainability), such as the *COPUOS Space Debris Mitigation Guidelines*.[77] This latter document was released in 2007, focusing on specific aspects, such as that (a) States should take into account debris mitigation during the design of a space object;[78] (b) the amount of debris produced during operation and after mission should be minimized[79] and particular attention be given to space objects in the geosynchronous and low Earth orbit regions;[80] (c) adjustment of the launch time and on-orbit avoidance manoeuvre should be considered if a potential collision is known[81] and (d) intentional destruction of space objects should be avoided.[82]

The specific reference to the *COPUOS Space Debris Mitigation Guidelines*, made in the LTS Guidelines, shows a continuum in the normative activity and convergence of approaches, first of all at the institutional level.

5.2 Bottom-up Initiatives and Space Operators' Contributions

Contrary to institutional approaches – such as the one adopted by the COPUOS in the LTS Guidelines –, market participants and space operators seem to focus more on operational and technological aspects of space sustainability. As non-governmental actors are growingly involved in space

[76] *Inter alia*, the LTS Guidelines encourage States and international intergovernmental organizations to develop and use relevant technologies for the measurement, monitoring and characterization of the orbital and physical properties of space debris (Guideline B.3.1) and adopt new measures, including technological solutions, to address the evolution of and manage the space debris population in the long term (Guideline D.2.1).
[77] LTS Guidelines, Guideline C.4: "Non-governmental entities (…) can play important roles in increasing international awareness of issues associated with space sustainability, as well as promoting practical measures to enhance space sustainability. Such measures could include adoption of the Space Debris Mitigation Guidelines of the COPUOS".
[78] COPUOS Space Debris Mitigation Guidelines, Guidelines 1–3.
[79] *Idem*, Guidelines 1, 2, 5.
[80] *Idem*, Guidelines 6, 7.
[81] *Idem*, Guidelines 3.
[82] *Idem*, Guidelines 4.

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activity, it is beyond doubt that these practical approaches provide important information to be taken into account.

Space agencies and companies appear to aim, initially, at further clarifying the scope of application of space sustainability, as well as practical aspects concerning its implementation. *Inter alia*, they promote the idea that the concept is applicable to the sustainability of the Near-Earth environment – and mainly the LEO and GEO – and the sustainability of economic growth on Earth, but also to the sustainability of celestial bodies (even though this was qualified as a non-pressing issue).[83] It is noteworthy that, contrary to that, the sustainability of celestial bodies is not really developed in the LTS Guidelines, despite being a key requirement for future space activity like space mining. In practice, space sustainability seems to reflect (thus far) the differences of opinion between space stakeholders; it is addressed locally, "as there is an increasing tendency to find practical implications on what sustainability means for the actors in terms of requirements and applications in their domestic contexts"[84].

In a more concrete and tangible way, the *Inter-Agency Space Debris Coordination Committee (IADC)* – which is a network of space agencies, authorized governmental or inter-governmental entities for the coordination of activities related to human-made and natural debris in space –[85], released in 2002 a set of voluntary guidelines, later endorsed by the UN General Assembly.[86] The IADC Guidelines reflected a series of existing standards, practices and codes developed by national and international organizations, and aimed at reducing the creation of space debris during routine operations. In short, the purpose of the IADC Guidelines was to gather the best expertise available, in order to minimize the potential for accidental on-orbit breakups,

[83] UNOOSA (May 2021), *supra* note 53, p. 11.
[84] *Idem*, p. 14.
[85] For the members of IADC, see 'Inter-Agency Space Debris Coordination Committee' at https://www.iadc-home.org/what_iadc accessed in September 2021.
[86] UNCOPUOS Scientific and Technical Subcommittee (STS), *Inter-Agency Space Debris Coordination Committee space debris mitigation guidelines*, 40th session, UN Doc A/AC.105/C.1/L.260 (2003).

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https://doi.org/10.6092/issn.2724-6299/13756

regulate the disposal of spacecraft post-mission, prevent on-orbit collisions and to avoid intentional destruction and other harmful activities.[87]

From a different perspective, but still as a bottom-up (here, regional) initiative aimed at facilitating and promoting the sustainable use of space resources, the EU released a draft *International Code of Conduct for Outer Space Activities (ICoC)*, in 2008 (Lopez, 2016). The draft, which was revisited and modified several times, mentions as its purpose – in the 2014 version – "to enhance the safety, security, and *sustainability* of all outer space activities pertaining to space objects, as well as the space environment"[88]. Detailed rules are laid down, such as that States should minimize the risk of accidents in space, or collisions between space objects (Art. 4.1); or refrain from any action which brings about, directly or indirectly, damage or destruction of space objects, unless such action is justified (Art. 4.2). The code serves to clarify how sustainability may be applied in space, where the nature of acceptable activities is not always apparent and remains a key soft law instrument to consider in the discussion on space resources exploitation.

The numerous bottom-up initiatives give an overview of space operators practical approach to space sustainability, showing a high degree of participation; they develop voluntary guidelines, rules of engagement or rules of conduct, involving *more and more* non-state agencies and complementing the OST provisions. These initiatives improve the efficiency of the concept and may be viewed as an important step allowing to create a wide and inclusive notion, able to provide practical and well-adapted solutions in the context of space resources exploitation.

[87] On the importance of the IADC guidelines, see UNOOSA, Space Debris Mitigation Guidelines of the COPUOS, *supra* note 35, para. 2: "The Committee on the Peaceful Uses of Outer Space acknowledges the benefit of a set of high-level qualitative guidelines, having wider acceptance among the global space community (...)".

[88] EU, Draft International Code of Conduct for Outer Space Activities – Version 31 March 2014, Art. I para. 1.1., available at https://eeas.europa.eu/archives/docs/non-proliferation-and-disarmament/pdf/space_code_conduct_draft_vers_31-march-2014_en.pdf accessed in January 2022.

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https://doi.org/10.6092/issn.2724-6299/13756

6. Substantive Normative Gaps Filled by the Concept of Space Sustainability

Having clarified how the concept of space sustainability was built up and developed, it is necessary to also examine its normative contribution. In practice, space sustainability was developed as a dynamic policy instrument, with the purpose to eventually remedy the shortcomings in international policy coordination.[89] The perceived inadequacy of some international space law institutions, in conjunction with the need to take into account the newly emerging needs of space industry and society, paved the way for a more flexible approach that would complement the OST provisions.

6.1 The Perceived Inadequacy of (some) International Space Law Institutions

The number of space-faring countries increased and diversified, as new space-faring States joined the network of existing ones to gradually create a "more polycentric governance" (Aganaba-Jeanty, 2016, 6). More and more States – such as Nigeria (in 2010), Finland (in 2017), Greece (in 2018) and Portugal (in 2019) – adopted legislation on space matters (Tapio, 2018; Von der Dunk, 2020); this development resulted in a rapidly rising number of members in international fora, and in the strengthening of pluralism.[90] At the same time, the strong influence exercised by leading space-faring nations in the previous decades was being criticized, *inter alia*, as being an impediment to the development of newly emerging space activities.

[89] In raising the awareness of space sustainability, "China emphasized that the participating States should not blindly pursue a quick adoption of the ICoC [i.e. Code of Conduct] but conduct in-depth discussions on the text of the ICoC, and the consultation process should ensure equal participation of all interested States" (Rong Du, 2017, 8).

[90] "There are good reasons to be optimistic that we are moving in the direction of multilateralism rather than unilateralism regarding the regulation of mineral exploitation in outer space." (Jinyuan Su, 2017, 1008). Also, "At the UN, membership of the Committee on the Peaceful Uses of Outer Space (COPUOS), the leading UN intergovernmental forum for space policy discussions, has seen membership rise by over 25% since 2017 – one of the fastest-growing multilateral policy-making fora in the entire UN system", UNOOSA (May 2021), *supra* note 53, p. 5.

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However, any change to the current legal framework applicable to space activity requires international agreement. As outer space is *res communis*, an agreement is required even on such specific issues as "in which country should corporations operating in outer space be paying tax to, given that their extra-terrestrial activities take place in an environment of ambiguous geopolitical boundaries" (Iliopoulos and Esteban, 2020, 90). Against this background, practice showed that reaching an international agreement on the regulation of (newly emerging) space activities is proving difficult. Effectively, no further treaties have been concluded – through the UNCOPUOS or other international space law fora – since the Moon Agreement adopted in 1979; at the same time, this allowed the development (or made it necessary to develop) soft law guidelines and codes of conduct.[91]

Practically, certain States fear that in the absence of commonly agreed rules, space activities would be carried out to the benefit of space-faring countries, allowing a "potentially disruptive economic impact of space resources exploitation activities on existing global inequality"[92]. It is argued that space-faring countries seem reluctant (until now) to share benefits[93] arising from space exploitation, based on the absence of a clear legal obligation to do so.[94] Similarly, proposals to establish a right to participate in the sharing of the benefits stemming from the exploitation of space resources – such as by sensed States over their remote sensing data (i.e., on data

[91] "There has been a strong tendency towards the development of soft law guidelines and 'codes of conduct' for space-related matters, notwithstanding the inherent risks that this (potentially) brings of greater 'non-compliance" (Jakhu and Freeland, 2016).
[92] Following this line of argumentation, a working document was submitted, for example, to the COPUOS Legal Subcommittee by Belgium and Greece, suggesting that an international regime for the sustainable use of Outer Space resources is necessary, see Hofmann and Bergamasco, 2020, 2.
[93] This in one of the main criticisms against space resources exploitation. See *inter alia*, "(…) imagine if the exploitation of large quantities of plutonium, a highly strategic material, were monopolized by a few States or even private entities. Even if the use serves all, the resulting inequality might be so grave that the additional material benefits enjoyed by the disadvantaged group would be negligible in comparison with the heightened inequality between them and the advantaged group" (Jinyuan Su, 2017, 1003).
[94] "We do not know the scope and meaning of the "legal right" to benefit from space activities" (Aganaba-Jeanty, 2016, 8).

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collected over, and related to, their own territory) – were rejected, *inter alia* when the Remote Sensing Principles were being discussed.[95]

Therefore, as commercial interests are not directly addressed in the international space law treaties (Hertzfeld, 2009), the most complicated and crucial issues are yet to be negotiated. However, given a strongly rising commercial space market (and divergent State interests), it is argued that the potential of international space law institutions –such as the UN COPUOS or the legal subcommittee of UN COPUOS[96] – is not fully used. Particularly as regards the protection of the outer space environment, it is likewise underlined that there are no "environmental agencies with clear regulatory powers for the extra-terrestrial environment"[97].

At the same time, space programs and activities "slowly migrate from government-owned and controlled projects to profitable commercial ventures" (Hertzfeld, 2009). Thus, in addition to the perceived inadequacy of (some) international space law institutions, a second challenge posed is to better take into account emerging space actors, such as non-leading space-faring nations[98] and private or other entities. The current legal regime was "remarkably good over the past forty years in helping to maintain a peaceful and productive international space environment", but the needs of new stakeholders must also be met.

[95] To find solutions, "Peter and Rathgeber proposed bridging the participatory gap through cooperation and other forms of exchange (*n.b. of the south*) with the north and established space actors, including data sharing, knowledge transfer, and discussion fora and core groups" (*idem*, 13).

[96] "(T)he legal subcommittee of UNCOPUOS, where space governance issues are deliberated, finally recognized that it is in a state of flux and needs to re-invent itself" (Aganaba-Jeanty, 2016, 7).

[97] For this reason, any consultation with regulatory authorities will be complicated, see Mustow, 2018, 475.

[98] "It was in this discussion [i.e. at the 1972 Stockholm Conference] that the formula "poverty is the biggest polluter" emerged. This made it possible for developing and undeveloped countries to become engaged in environmental protection without having to make compromises regarding their development goals. Furthermore, it became clear that the environmental problems recognized in the 1972 Conference (e.g., the destruction of the rainforest or pollution of the oceans) could not be solved without taking social and economic perspectives into account" (Michelsen et al., 2016, 9).

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6.2 Additional Needs to Take into Account While Using Space: Investors & Society

In the current state of the law, a *first* remark to be made is that the State-centric regulatory regime applied to space activity – and resulting initially from Art. VI and VII of the OST – is not entirely in tune with the needs of the commercial space sector. On one hand, space resource exploitation is highly promising; the field attracts a wide range of investors, who expect the most from their investments. On the other hand, resource exploitation requires numerous pilot experiments, based on highly specialized and expensive technology, as planetary missions consist in energy-intensive, long-distance[99] and long-timeline[100] operations. An example of this is the Interstellar Probe[101] which would be "a multi-generational effort;[102] it might reach fruition in the lifetime of people working on it now, but (…) would certainly exceed the span of any researcher's active career" (Powell, 2021). Missions aimed at the exploration or exploitation of space should, therefore, plan for a multigenerational approach from the beginning (Benningfield, 2020), in addition to the significant funds that must be invested.

From this perspective, the OST regulatory regime seems to be poorly adapted to the purpose of protecting the value of private investments in space. In truth, the treaty only established a set of *a posteriori* measures, such as the

[99] For example, "A half-century after launch, Interstellar Probe would reach a distance of 1,000 astronomical units from the Sun. (An astronomical unit is the average Earth-Sun distance, equal to almost 150 million kilometres.)" (Benningfield, 2020).
[100] "Another aspect is that the duration of space exploration missions is often unknown. The achievement of milestones (e.g. building an outpost on the Moon) requires a step-by-step approach including the construction of launch and crew vehicles, development of infrastructures, astronaut training and many others. Therefore 'sustainability' would be a better term to express the time scale of activities in space exploration" (Ehrenfreund and Peter, 2009, 249).
[101] "A launch technologically possible in the 2030s would propel an Interstellar Probe farther and faster than any spacecraft before it, leading to new and inspiring exploration across heliophysics, astrophysics and planetary science – helping us understand our home in the galaxy and representing humanity's first deliberate step into the sea of space between our Sun and other potentially habitable systems." (The Johns Hopkins University, 2021).
[102] "They're trying to design a spacecraft to launch around 2030 and get a thousand AU [astronomical units] from Earth in 50 years," said Janet Vertesi, (…) "The problem is, by then they'll all be dead." (Benningfield, 2020).

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international liability of States for damage arising from their activities in space[103] (which is at the same time criticized for discouraging several initiatives)[104]. No concrete and binding *a priori* measures were really laid down; a system of international consultations was established to avoid harmful interference between space activities (Hoffman and Bergamasco, 2020, 3),[105] but the provision is too vague to impose clear obligations – such as, standards, controls or procedures – on States[106], to efficiently protect (private or public) space infrastructure. Hence, due to the high value of space technology, a legal solution had to be found to protect (and encourage) the growing participation of private-sector companies as well.

Second, the issue of protecting the broad range of societal benefits derived on Earth from space science and technology was also raised. In particular, pursuant to Art. I of the OST, the use of outer space must be carried out *for the benefit and in the interest of all countries, irrespective of their degree of economic or scientific development*. Hence, space resources, such as the LEO and GEO, cannot be used in a predatory way or at the expense of other State or non-State actors (such as, in the context of cross-border GIS and/or remote sensing activities: Deekshatulu, Raghu and Chandrasekhar, 1995; West, 1990).

[103]Liability for outer space activities can be established under the Outer Space Treaty (Article VII) and more precisely under the dual liability regime of the Convention on International Liability for Damage Caused by Space Objects (the "Liability Convention"), applicable to States (Art. II for damage caused on the surface of Earth [in this case, an absolute liability regime applies] and Art. III for damage caused elsewhere [here, a fault-based liability regime].

[104] "There is a growing need to address the troublesome problem of national liability with regard to launched 'space objects' that is actually serving to retard efforts to undertake active debris removal" (Pelton, 2013, 26).

[105] OST, art. IX: "In the exploration and use of outer space (…) States Parties to the Treaty shall be *guided by* the principle of cooperation and mutual assistance and shall conduct all their activities in outer space, including the Moon and other celestial bodies, with due regard to the corresponding interests of all other States Parties to the Treaty (…). If a State Party to the Treaty has reason to believe that an activity or experiment planned by it or its nationals in outer space, (…) would cause potentially harmful interference with activities of other States Parties (…) it shall undertake appropriate international consultations before proceeding with any such activity or experiment".

[106] See, also, *supra* note 51.

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By way of illustration, a case of unwanted interference caused almost damage in 2010, when:

> Galaxy 15, an Intelsat communications satellite in geosynchronous orbit, failed to operate properly and began to pose a frequency interference risk to the operations of other satellites in its vicinity. Although Intelsat responded to the emergency immediately and worked quickly to limit possible interference with other nearby satellites the incident still underscored the potential risk of inadvertent signal interference to communications satellites (Williamson, 2012, 155).

Thus, to avoid irreparable losses, the International Communication Union (ITU) has developed and formulated specific conditions for the sustainable use of frequency bands for radio services, to the benefit of all (these must be used "*rationally, efficiently, and economically*").[107] In addition to that, the ITU competent bodies formulate the technical and operational conditions for the use of the radio spectrum, as well as elements of standardization (Lyall and Larsen, 2018, 208).

From this perspective, it is clear that the OST regime applying to space resources exploitation must be complemented; tighter standards and specific rules are necessary to allow space operators to make optimum use of the resources and infrastructure available and to ensure the fair and equitable sharing of benefits among users, on *both* an inter-nation (between developed and developing States) and inter-generational basis (Bohlmann and Petrovici, 2019; Spijkers, 2018),[108] in recognition of the limitation of space resources (Martinez, 2015, 259-260). Hence, as a solution to the difficulty and length of time needed to reach international law agreements on these topics,

[107] See, also, *supra* notes 21 and 22.
[108] The concept of inter-generational equity is being mentioned in art. 7.1 of the Moon Agreement.

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stakeholders focused on the concept of space sustainability as a possible way of managing the said issues.

6.3 Space Sustainability as a Solution: A Flexible & Task-oriented Concept

In theory, it is not clear whether sustainability – and other international law concepts – can be applied in space under the same terms and conditions as in the context of Earth activities, due to the unique characteristics of activities conducted in the extra-terrestrial environment.[109] However, unanticipated problems and gaps surfaced in the space law regime. The concept of space sustainability gradually emerged in an effort to overcome the rigidity in the State-centric international space law framework. Based on economic reality, it is aimed at the participation of all actors involved in this field, like States and national space agencies, but also industries, universities, research institutions, and other non-governmental organizations (NGOs).

In practice, space sustainability seems to have gained widespread acceptance, and at the same time some autonomy from the complex space governance structure as defined in the *Montreal Declaration.*[110] In the absence of a provision making clear the obligation of States to protect the space environment, voices are raised to apply *mutatis mutandis* relevant principles of international law to space activities –under the concept of space sustainability, and in line with the meaning of Art. IX of the OST– to allow an *ad hoc* approach.

By way of illustration, S. E. Mustow argues in favour of conducting Environmental Impact Assessments (EIA) of space activity projects namely, to investigate and evaluate the environmental impact of the proposed projects or actions before they go forward (Yang, 2019), and propose actions to mitigate them. The view is based on the concern that, in relation to space

[109] However, "Principle 21 of the 1972 Stockholm Declaration and Principle 2 of the 1992 Rio Declaration on Environment and Development refer to 'areas beyond the limits of national jurisdiction', which can be considered to include outer space" (Bohlmann and Petrovici, 2019).
[110] See, *supra* notes 1 and 2.

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environmental protection, "although a number of existing laws apply, such as Article IX of the Outer Space Treaty, the level of legal protection is inadequate" (Mustow, 2018). Hence, the obligation to conduct an EIA may be established and developed in national law.[111] In a similar way, Professor Olavo de O. Bittencourt Neto supports the full application of the precautionary principle in space law matters, given that "conceived upon a prospective approach, (it) seeks the protection of the environment from specific human activities involving grave risks, even when scientific knowledge on that regard may seem insufficient to fully comprehend the particularities of the resulting threat to nature" (Neto, 2013). The need to apply the precautionary principle to space activities would arise from the continuing degradation of the space environment, resulting from the growing number of space debris and pending the adoption of a binding treaty rule establishing a clear obligation to mitigate the production of debris (*Idem*).

Nevertheless, the concept of space sustainability should not only be viewed as an instrument to ensure the optimal use of the LEO and GEO. Having regards to the latest developments in the field of space activity, it is apparent that space environmental protection is an issue of great strategic importance. In particular, it is already alleged that the emerging consensus on the need to protect the space environment from specific threats, such as space debris, should be "channelled into more robust action, and its focus extended beyond the LEO" (Newman and Williamson, 2018). In this context, it would appear that space sustainability, as a flexible, evolving and task-oriented instrument, could be likewise used to address possible future threats to the space environment *lato sensu*.[112]

[111] "The legal frameworks of Belgium and France are exceptions as they require that EIA considers extraterrestrial impacts. Belgium's Law on the Activities of Launching, Flight Operation or Guidance of Space Objects (Kingdom of Belgium 2013) requires that an EIA be submitted prior to the launch, assessing the effects of the action on both the Earth and any celestial body affected (Kramer 2014) etc." (*ibid*, 468).

[112] "(C)rewed missions introduce a human population to the extraterrestrial environment which requires consideration of population and human health effects, which may be significant due to exposure to high natural radiation levels and other health risks. The

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7. Conclusions

The persistent problem in relation to space resources exploitation consists in the fact that:

> global governance would help improve the situation (…) and strengthen space sustainability. Yet no global authority exists to govern the (…) issue *per se* with verification mechanisms and powers and funding to monitor and manage violations. Still, elements of a (…) regime have emerged on a voluntary basis (Trur, 2021).

The argument relates to the specific issue of space debris, which is a key threat to the unhindered use of Earth orbits, but applies equally well to other space resources exploitation issues.

Against this background, the concept of space sustainability may be characterized as an "element of a regime" emerging on a voluntary basis. Contrary to the mechanism applying to the space debris issue,[113] space sustainability is a broader and more flexible notion. It may be described as an umbrella concept, and more particularly a dynamic and changing one which is constantly expanding[114] in an effort to combine scientific development and discovery[115] with economic progress.

introduced population may also be a receptor for noise, vibration, visual and other impacts" (Mustow, 2018, 472).

[113] "The governing mechanisms in place for tackling the global debris issue are characterized by their mostly voluntary nature and the absence of a global authority equipped with the mandate and resources to direct and implement an international response to the debris problem. Some elements of a debris regime have emerged, yet a binding regime is still work in progress" (Trur, 2021).

[114] "(…) a new wave of space expansion advocates is using sustainable development in an alternative way. 'Sustainable' is used to refer to self-perpetuating private economic activities off-world. 'Sustainable' is also employed to refer to permanent space habitats that rely on the harvest of local (but unrenewable) space resources. Finally, 'sustainable' is used to describe forms of extra-terrestrial extractivism —e.g., strip-mining asteroids — which would be carried out with the aim of offsetting Earth-side resource deficits" (Tabas, 2021).

[115] "Hence, the definition for space exploration utilized in this paper merges the concepts of 'development' and 'discovery', as employed in NASA's Strategic Plan 2018" (Iliopoulos and Esteban, 2020, 86).

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As a concept, space sustainability is rooted but not limited to Art. IX of the OST. Its strengthening allows to establish rules complementing the protection of the space environment – *via* the sustainable use of space resources –, taking into account the treaty's objectives but also its shortcomings. Its flexibility allows for the incorporation of existing environmental law principles (Navalgund, 2020) on the sustainable use of resources, without first requiring a global authority that would be responsible to adopt and implement an international regime for space resources exploitation, or to coordinate State and/or non-State actors initiatives. In parallel, space sustainability is regarded as the legitimate basis for a wide range of initiatives – each time in line with all space stakeholders' needs and requirements –, varying from space situational awareness to space safety.[116]

Under this concept, practical steps are taken to establish cooperative mechanisms for an effective protection of space resources on an *ad hoc* basis[117] and taking into account (environmental law) best available knowledge. In truth, due to:

> competing uses of outer space, the methods of reaching sustainability *require methodological innovation*. Outer space is open to all states that wish to operate in the realm peacefully; it will consequently also require the willingness of states to give up

[116] "(T)here is no agreed definition on space sustainability. It often appears in association with space safety and space security or encompasses the meaning of safety and security in outer space, with an emphasis on the long-term impact of current space activities and due considerations deserved by future generations" (Rong Du, 2017). In the same line of reasoning, "(…), the concept of space sustainability is also used interchangeably with the following: (1) space security, which entails access to space and freedom from threats; (2) space stability addressing space situational awareness; (3) space safety, which is protection from all unreasonable levels of risk (primarily protection of humans or human activities); and (4) responsible uses of space" (Aganaba-Jeanty, 2016). See also, Newman and Williamson, 2018).

[117] See, for example, the ongoing effort to tackle the space debris issue: "The current international legal regime regulating space activities has proven to be incapable of handling this issue progressively. The international community needs to come together and undertake certain responsibilities to solve this issue and evolve future plans to prevent the creation of large amounts of debris" (Haroun et al., 2021).

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> some freedom of action in order to reach a greater collective good than can't otherwise be achieved (Williamson, 2012, 155).

From this perspective, space sustainability may be defined as a remarkable set of good practices promoting an *ad hoc global approach* to space resources exploitation, and relying on legal and scientific knowledge, on efficiency and lessons learned, and on efficient and effective cooperation among states. Its final aim remains to ensure to the maximum feasible extent the sustainability of space exploitation activities,[118] to the benefit of all, and in a very practical way while consolidating confidence in this domain.

References

Adilov N., Alexander P.J., and Cunningham B.M. (2020), The economics of orbital debris generation, accumulation, mitigation, and remediation, in *Journal of Space Safety Engineering* n. 7.

Adriaensen M., Giannopapa C., Sagath D., and Papastefanou A. (2015). Priorities in national space strategies and governance of the member states of the European Space Agency, in *Acta Astronautica*, n. 117.

Aganaba-Jeanty T. (2016). Space Sustainability and the Freedom of Outer Space, in *Astropolitics*, n. 1.

Barral V. (2012). Sustainable Development in International Law: Nature and Operation of an Evolutive Legal Norm, in *The European Journal of International Law*, Vol. 23:2.

Benningfield D. (2020). Preparing for a Handoff, in *EOS.Science News by AGU*, https://eos.org/features/preparing-for-a-handoff.

[118] Space missions should be "(…) capable of long-term survival in uncertain, remote environments, and converge on accomplishing the most relevant and useful mission, informed by intermediate results and experience in the operation environment. (…). Sustainable architectures accomplish their missions, remain relevant for long durations and show adequate investment planning; they must include 'system effectiveness, reliability, safety, and affordability as new technologies and discoveries emerge." (DeLaurentis, Sindiy and Stein, 2012).

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

Blount P.J. (2008). Limits on space weapons: incorporating the law of war into the Corpus Juris Spatialis, in *Proceedings of the 51st Colloquium on the Law of Outer Space*, 2009, https://ssrn.com/abstract=1393321.

Bohlmann U.M., and Petrovici G. (2019), Developing planetary sustainability: Legal challenges of Space 4.0., in *Global Sustainability*, n. 2.

Brachet G. (2012). The origins of the "Long-term Sustainability of Outer Space Activities" initiative at UN COPUOS, in *Space Policy*, n. 28.

Bugos S. (2021) Russian ASAT Test Creates Massive Debris, in *Arms Control Association*, https://www.armscontrol.org/act/2021-12/news/russian-asat-test-creates-massive-debris.

Cheney T. (2019). There's no rush: developing a legal framework for space resource activities, in *Journal of Space Law*, n. 43.

Deekshatulu B.L, Raghu V. and Chandrasekhar M. G. (1995), Overview of the Legal Aspects of Remote Sensing, in *Journal of the Indian Society of Remote Sensing*, n. 23.

DeLaurentis D.A., Sindiy O.V. and Stein W.B. (2012), Developing Sustainable Space Exploration via a System-of-Systems Approach, in *American Institute of Aeronautics and Astronautics (AIAA) 2006-7248*, https://arc.aiaa.org/doi/abs/10.2514/6.2006-7248.

Du Pissani J.A. (2006). Sustainable development – historical roots of the concept, in *Environmental Sciences*, n. 3.

Ehrenfreund P., and N. Peter N. (2009). Toward a paradigm shift in managing future global space exploration endeavors, in *Space Policy*, n. 25.

Freeland S. (January 30, 2017). Common heritage, not common law: How international law will regulate proposals to exploit space resources, in *Questions of International Law – QIL*, http://www.qil-qdi.org/common-heritage-not-common-law-international-law-will-regulate-proposals-exploit-space-resources/.

Gabrynowicz J.I., and Serrao J. E. (2004). An Introduction to Space Law for Decision Makers, in *J. Space L.*, n. 30.

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

Gordon C. (2018). The Emergence of Environmental Protection Clauses in the Outer Space Treaty: A Lesson from the Rio Principles, in A. Froehlich (eds.), *A Fresh View on the Outer Space Treaty* (Springer).

Haroun F. et al. (2021), Towards the Sustainability of Outer Space: Addressing the issue of Space Debris, in *New Space*, n. 64.

Hertzfeld H. (2009). Current and future issues in international space law, in *ILSA Journal of International & Comparative Law*, n. 15.

Hofmann M., and Bergamasco F. (2020) Space Resources Activities from the Perspective of Sustainability: Legal Aspects, in *Global Sustainability*, n. 3.

Iliopoulos N., and Esteban M. (2020). Sustainable space exploration and its relevance to the privatization of space ventures, in *Acta Astronautica*, n. 167.

Jakhu R. S., and Freeland S. (2016), The relationship between the Outer Space Treaty and customary International Law, in *Proceedings of the 67th International Astronautical Congress* (Publisher: International Astronautical Federation, IAF 2016).

Jinyuan S. (2017). Legality of unilateral exploitation of space resources under international law, *International and Comparative Law Quarterly*, n. 66.

Johns Hopkins University Applied Physics Laboratory (The) - LLC (2021). Humanity's Journey to Interstellar Space, in *Interstellar Probe*, https://interstellarprobe.jhuapl.edu/.

Johnson K. (September 1, 2020). Space Sustainability and Debris Mitigation, in *Key Governance Issues in Space*, Center for Strategic and International Studies – CSIS.

Leepuengtham T. (2017). *The Protection of Intellectual Property Rights in Outer Space Activities* (Edward Elgar Publishing).

Lim J. (2018). The Future of the Outer Space Treaty – Peace and Security in the 21st Century, in *Global Politics Review* n. 4.

Lincoln A., Environmentalism, in *The Concise Oxford Dictionary of Politics*, https://www.oxfordreference.com/view/10.1093/oi/authority.20110803095753607.

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

Lopez L. D. (2016). Space sustainability approaches of emerging space nations: Brazil, Colombia, and Mexico, in *Space Policy* n. 37.

Lyall F., and Larsen P.B. (2018). *Space Law: A Treatise* (2017) (Routledge).

Martinez P. (2015). Space Sustainability, in K. U. Schrogl et al. (eds), *Handbook of Space Security - Policies, Applications and Programs* (Springer Science and Business Media New York).

Martinez P. (2020). UN COPUOS Guidelines for the Long-Term Sustainability of Outer Space Activities: Early implementation experiences and next steps in COPUOS, in *Proceedings of the 71st International Astronautical Congress (IAC), 12-14 October 2020.*

Martinez P. (2021). The UN COPUOS Guidelines for the Long-term Sustainability of Outer Space Activities, *Journal of Space Safety Engineering*, n. 8.

Mejía-Kaiser M. (2009). Informal Regulations and Practices in the Field of Space Debris Mitigation, in *Air and Space Law*, n. 1.

Michelsen G., Adomßent M., Martens P., and von Hauff M. (2016). Sustainable Development – Background and Context, in H. Heinrichs, P. Martens, G. Michelsen, A. Wiek (eds.), *Sustainability Science* (Springer).

Mustow S. E. (2018). Environmental impact assessment (EIA) screening and scoping of extraterrestrial exploration and development projects, in *Impact Assessment and Project Appraisal*, n. 36.

Navalgund R. (2020). Reduce, Reuse and Recycle: An Environmental Law Approach to Long-term Sustainability of Outer Space, in *Air and Space Law*, n. 45.

Neto O.D.O.B. (2013). Preserving the Outer Space Environment: The 'Precautionary Principle Approach' to Space Debris, in *International Institute of Space Law*, n. 4.

Newman C.J, and Williamson M. (2018). Space Sustainability: Reframing the Debate, in *Space Policy*, n. 46.

Nirmal, B.C. (2012). Legal Regulation of Remote Sensing: Some Critical Issues, in *Journal of the Indian Law Institute,* n. 4.

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

Palmroth M. et al. (2021). Toward Sustainable Use of Space: Economic, Technological, and Legal Perspectives, in *Space Policy* n. 57

Pelton J.N. (2013). Different approaches to the Space Debris Problem, in J. N. Pelton, W. H. Ailor (eds.), *Space Debris and Other Threats from Outer Space* (Springer).

Portney K. E. (2015). Sustainability (MIT press).

Powell C.S. (2021). Interstellar Probe mission would go twice as fast and far as the Voyagers, in *Astronomy*,
https://astronomy.com/news/2021/02/interstellar-probe-mission.

Rong D. (2017). China's approach to Space sustainability: Legal and policy analysis, in *Space Policy*, n. 42.

Scarano F.R. (2019). The Emergence of Sustainability, in Wegner L., Lüttge U. (eds), *Emergence and Modularity in Life Sciences* (Springer).

Scatteia L., Frayling A., and Atie T. (2020). The role of emerging space nations in supporting sustainable development and economic growth (Report), in *PwC. PricewaterhouseCoopers France et Maghreb*,
https://www.pwc.fr/en/industrie/secteur-spatial/pwc-space-team-public-reports-and-articles/emerging-space-nation.html.

Shan M., Guo J, and Gill E. (2016), Review and comparison of active space debris capturing and removal methods, in *Progress in Aerospace Sciences* n. 80.

Slocombe D. S. (1984), Environmentalism: a modern synthesis, *The Environmentalist* n. 4.

Soroka L., and Kurkova K. (2019). Artificial Intelligence and Space Technologies: Legal, Ethical and Technological Issues, in *Advanced Space Law*, n. 3.

Spijkers O. (2018). Intergenerational Equity and the Sustainable Development Goals, in *Sustainability*, n. 10.

Stelmakh O. (2015), Global Space Governance for ensuring responsible use of Outer Space, its sustainability and environmental security: Legal Perspective, in *58th IISL Colloquium on the Law of Outer Space (E7), Joint*

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

IAF-IISL Session on the Legal Framework for Collaborative Space Activities, https://swfound.org/media/205386/global_space_governance_paper_iac2015_iisl_proceedings_fv.pdf

Tabas, B. (2021). Outer Space, Expansive Sustainable Development, and the Future of the Environmental Humanities, in *CFDT Centre de Formation Sur la Formation et le Travail*, https://hal-bioemco.ccsd.cnrs.fr/CDFT-CNAM/hal-03150750v1.

Tapio J. (2018). The Finnish Space Act: En Route to Promoting Sustainable Private Activities in Outer Space, in *Air and Space law*, n. 43.

Taylor M. W. (2006). *Orbital Debris: Technical and Legal Issues and Solutions* (LL.M. thesis).

Trimble J. (1984). International Law of Outer Space and Its Effect on Commercial Space Activity, in *Pepperdine Law Review*, n. 113.

Trur A. (2021). Governance aspects of space sustainability: The role of epistemic actors as enablers of progress, in *Acta Astronautica*, n. 180.

Von der Dunk F.G. (2018), Billion-dollar questions? Legal aspects of commercial space activities, in *Uniform Law Review n. 23*.

Von der Dunk F.G. (2020), Structuring the Governance of Space Activities Worldwide, in *Georgia Journal of International and Comparative Law* n. 48, n. 3.

Weinzierl M. and Sarang M. (2021). The commercial Space Age is here. Private space travel is just the beginning, https://hbr.org/2021/02/the-commercial-space-age-is-here.

West R. J. (1990), Copyright Protection for Data Obtained by Remote Sensing: How the Data Enhancement Industry Will Ensure Access for Developing Countries, in *Nw. J. Int'l L. & Bus*. n. 11.

Williams S. M. (1987). The Law of Outer Space and Natural Resources, in *The International and Comparative Law Quarterly* n. 36

Williamson R.A. (2012). Assuring the sustainability of space activities, in *Space Policy*, n. 28

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756

Yang T. (2019). The Emergence of the Environmental Impact Assessment Duty as a Global Legal Norm and General Principle of Law, in *Hastings Law Journal*, n. 70.

ISSN 2724-6299 (Online)
https://doi.org/10.6092/issn.2724-6299/13756