Sky full of Stars or Satellites: The Impact of Mega-Constellations on Ground-Based Astronomy

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Abstract

Satellite mega-constellations are becoming very popular. Nevertheless, their deployment entails the potential to negatively impact the pristine view of the night sky and - by extension - to hamper ground-based astronomical observations. This paper evaluates the applicability of existing legal instruments towards achieving greater protection of space sciences *vis-a-vis* commercial space activities. Firstly, it examines whether the term "space activities" can be interpreted so as to include ground-based astronomy, in an effort to understand how different needs and the freedoms of exploration and use of Outer Space (OS) can be best balanced. Furthermore, the paper reviews the application of environmental law principles and discusses the obligation of States to conduct EIAs in order to minimize light pollution and protect the Dark and Quiet Skies under the "due regard" principle of Article IX OST. Finally, this paper discusses pragmatic proposals towards the preservation of the space environment and the sustainability of space activities.

1. Introduction

The growing demand for fast and affordable wireless communications has rendered satellite mega-constellations a popular solution, with commercial projects such as Starlink, OneWeb and Kuiper promising to bring global high-speed broadband internet connectivity. Specifically, mega-constellations are revolutionary systems composed of dozens to thousands of artificial satellites orbiting the Earth, working together for a common mission. Recent estimates for the upcoming launch of commercial constellations,

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especially in LEO,[1] are causing serious concerns, as they pose unprecedented challenges to space sustainability.[2] SpaceX alone has obtained permission to deploy 4,408 satellites for its Starlink network and is seeking approval to add nearly 30,000 more. OneWeb has acquired permission for 648 satellites and wishes to deploy roughly 7,000 satellites. Amazon and Samsung have also announced similar plans.[3] It is worth mentioning that the total number of objects in Earth orbit has doubled since SpaceX started launching Starlink satellites in 2019. [4]

2. The impact on ground-based astronomy

Apart from the issues relating to orbital congestion and space debris, the proliferation of space objects is also an increasing source of artificial night sky brightness. Under the present international law regimes, there remains a lack of clear limits to the extent that constellations can be deployed and operated to the detriment of other legitimate uses of OS, such as astronomy. This phenomenon has given rise to many questions regarding our traditional understanding of the space environment and the pristine view of the natural night sky. Specifically, the initial batch of SpaceX's Starlink satellites caused alarm to the astronomical community, as they shone surprisingly bright at dusk and dawn due to their reflective surfaces.

Their random orientation causes them to act as mirrors, scattering and reflecting light,[5] resulting, *inter alia*, in scientific miscalculations in the methodical observation of the night sky.[6] The bright appearance of sun-illuminated lines - visible even through the naked eye - threatens to hamper astronomical observations at optical wavelengths, resulting in considerable financial losses. Those bright "strings of pearls" are mostly observable near the horizon and during astronomical twilight. Their passage across the field of a photographic plate may ruin an observation; they cause different degrees of damage to the data collected depending on the type and

1 J.C.Liou & N.L.Johnson, Instability of the present LEO satellite populations, Advances in Space Research 41 (2008), p. 1047.

2 J. Zhang, et al., LEO Mega Constellations: Review of Development, Impact, Surveillance, and Governance, Space: Science & Technology (2022), p. 1.

3 Satellite Missions catalogue, eoPortal, by ESA, at: https://www.eoportal.org/satellite-missions/starlink (accessed: 02.09.2022).

4 The UNOOSA index of objects launched into OS lists around 9500 objects in Earth orbit (as of the time of writing) whereas in 2019 it listed less than 5300 objects.

5 O.R.Hainaut & A.P.Williams, Impact of satellite constellations on astronomical observations with ESO telescopes in the visible and infrared domains, 636 Astronomy & Astrophysics A121 (2020), p. 5.

6 See for instance, the launch of balloons 'Echo 1', 'Echo 2' and PAGEOS.

size of the telescope.[7] According to studies, wide-field imaging observations on large optical telescopes, such as the Vera C. Rubin Observatory[8] and science programs requiring twilight observations, such as searches for NEOs are severely affected.[9]

Undoubtedly, the said LEO constellation disproportionately impacts certain science activities conducted on Earth. Nevertheless, in light of the fundamental principle of free access to OS, States and non-governmental entities cannot be prohibited from deploying satellite systems.

3. Legal instruments in the protection of astronomy

This situation raises, primarily, the question whether ground-based astronomical observations could be considered as a "space activity" and thus fall under the scope of the OST, so that they may be protected by the obligations of due regard and prevention of harmful interference. This paper will argue in favour of this proposition and will discuss the available legal guarantees. The authors will then propose pragmatic solutions towards achieving greater protection of space sciences *vis-a-vis* commercial space activities, while ensuring space sustainability.

3.1. Freedoms of "exploration, use and scientific investigation": a balance of rights

First, the freedoms of exploration and use of OS are both enshrined in Article I OST. Specifically, according to par.1 "*the 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*". Moreover, as *per* par.3, there shall be freedom of "*scientific investigation in outer space*".

The aforementioned freedoms are of equal legal value, nevertheless, when it comes to legitimate but rather colliding interests, certain limitations shall be imposed so as to achieve a fair balance. Instead of creating an activity hierarchy, it is crucial to understand how astronomy and commercial space activities can be best coordinated through the mechanisms of the Space Treaties. To do so, we shall first examine whether the language relating to the "*freedom of scientific investigation*", can be interpreted so as to implicitly include ground-based astronomy.

7 G.Halferty et al., Photometric Characterization and Trajectory Accuracy of Starlink Satellites: Implications for Ground-Based Astronomical Surveys, Monthly Notices of the Royal Astronomical Society, p. 1.

8 Rubin Observatory Project Science Team 2020, Impact on Optical Astronomy of LEO Satellite Constellations, Document-33805.

9 C.Walker et al., Impact of Satellite Constellations on Optical Astronomy and Recommendations Toward Mitigations, 52 Bulletin AAS 2 (2020), p. 5.

3.2. Astronomy as a space activity

It is widely accepted that the terms "*exploration, use and scientific investigation*" cover a vast range of activities that make use of OS in one way or another,[10] irrespective of whether they are conducted from the earth's surface or in space. The main areas of space activities, besides the launch and operation of satellites, include scientific space research and shall be interpreted so as to encompass earth-based activities that operate in connection with space.[11] Besides, astronomy's main goal is to understand the Cosmos and explore the wonders of the universe without discrimination and for the benefit of all countries. For example, the recent discovery and visualization of black holes illustrates the importance of exploration and discovery[12] and the magnitude of astronomy's contribution to the way we view our position in this world. Moreover, astronomical observations play a critical role in the exploration and use of OS as they contribute to the preparation and planning of space missions.[13]

In accordance with the customary treaty interpretation rules,[14] as reflected in Article 31 VCLT, subsequent state practice shall be taken into consideration. In this context, a number of national space legislations seem to favour a rather broad definition of space activities so as to include any activity that aims at the development of scientific knowledge of space.[15] Astronomy is also a relevant subject for international fora discussing space activities such as the UNCOPUOS,[16] which showcases its relevance to space exploration. The above point towards a wide perception of what constitutes a space activity, falling under the scope of the Space Treaties.

Given that astronomy is indeed part of the applicable space law regime, it is the authors' view that satellite operators shall be obliged to protect the Dark Skies from light pollution, for the general benefit and interest of all countries. Based on this idea of putting certain limitations to the advantage of all mankind, the analysis will proceed with examining the application of environmental law principles, such as the maxim *sic utere tuo ut alienum non laedas* and analyzing the obligation to conduct environmental impact

10 S. Hobe, Article I: S. Hobe, B. Schmidt-Tedd, K.-U. Schrogl, Cologne Commentary on Space Law 1, 2009, p. 30 [hereinafter Cologne Commentary I].

11 G.Rotola, A.Williams, Regulatory Context of Conflicting Uses of Outer Space: Astronomy and Satellite Constellations,46 Air and Space Law 4 (2021), p. 555.

12 P.B.Larsen, Outer Space: How Shall the World's Governments Establish Order Among Competing Interests? (2019), p. 13.

13 N.Frischauf, Space exploration, C.Brunner, A.Soucek, Outer Space In Society, Politics and Law, (2011), p. 98.

14 Kasikili/Sedudu Island (Botswana v. Namibia) (Judgment) I.C.J. (1999).

15 e.g. the Russian legislation defines space activities as "any activity immediately connected with operations to explore and use outer space".

16 Dark and quiet skies have been tabled as a formal agenda item by UNCOPUOS; 59th Session of the STSC | Item 18: Dark and Quiet Skies.

assessments (EIAs) in order to minimize light pollution in favour of astronomy, mainly under the "due regard" principle of Article IX OST.

3.3. The principle of due regard

Article IX OST constitutes the best available legal tool for the protection of astronomy in the *corpus juris spatialis*. Specifically, Article IX OST requires States to conduct space activities "*with due regard to the corresponding interests of all other States and conduct exploration of them so as to avoid their harmful contamination and to [...] adopt appropriate measures for this purpose*". Additionally, an obligation to undertake international consultations is established in case of potential "*harmful interference with activities of other States in the peaceful exploration and use of Outer Space*". Although States made an early attempt to address the general issue of space environmental protection through said provision, the space community has only recently started to appreciate the logic of a sustainable approach with respect to the preservation of the night sky for future generations.

3.3.1. The West Ford Experiment

However, examining the drafting history of Article IX reveals the relevance of said provision with regards to astronomy. According to Article 31 VCLT "*a treaty shall be interpreted in the light of its object and purpose*", and in such a manner so as to assure the *effet utile* of a provision.[17] Article 32 VCLT stipulates that "*recourse may be had to supplementary means of interpretation, including the preparatory work of the treaty and the circumstances of its conclusion.*" Besides, as the ICJ has stipulated in several occasions,[18] the meaning of a treaty's terms must be seen in the light of its context[19] in order to identify its object and purpose.[20] Article IX originates from the negotiations following the West Ford Experiment, which consisted of the dispersion of an artificial orbiting belt of copper needles into LEO to create dipole antennas reflecting long-range radio waves from ground

17 Continental Shelf Case (Nicaragua v. Colombia) (Judgment) I.C.J.(2016); M.E.Villiger, Commentary on the 1969 Vienna Convention on the Law of Treaties, 2009, p. 427.
18 Gabčikovo-Nagymaros Case (Hungary v. Slovakia) (Judgment) I.C.J.(1997).
19 ICJ Ambatielos Case (Greece v UK) (Preliminary) (1952).
20 Barcelona Traction Case (Preliminary) I.C.J.(1964), Aegean Sea Continental Shelf Case (Greece v. Turkey) (Judgment) I.C.J.(1976).

stations. [21] The experiment was met with negative reactions from the international community as radio-astronomy was impacted.[22]
Therefore, the drafters' intention to protect astronomical observations, even those conducted from Earth, is evident. It follows that, when conducting space activities, States are obliged to take into account the interests of the astronomical community, as well. This freedom of exploration and use of OS is neither unlimited nor absolute, but is rather determined by the rights and interests of other States and humanity as a whole.[23]

3.3.2. The relevance of space sustainability

More concretely, the "due regard" requirement constitutes an obligation to take into account the legal rights of other States both prior to planned and during ongoing space activities.[24] In this context, Article 4 MOON further clarifies that due regard should be paid to "*the interests of present and future generations as well as to the need to promote higher standards of living […]*".
Notably, Long-Term Sustainability Guideline A.4(3) urges States to "*ensure that their space activities are conducted in such a manner as not to cause harmful interference [...] as one of the means of promoting the long-term sustainability of outer space activities*". These provisions emphasize the intra-generational equity of sustainable development in the space domain;[25] that being, the consideration of the interests of the entire international space community aside from realizing one's own interests,[26] as well as the ability of all humanity to continue deriving socioeconomic benefits from the use of OS in the long term. The deliberate degradation of the night skies - which are considered a resource for humanity - [27] infringes upon equity and impacts

21 W.Liller, Optical Effects of the 1963 Project West Ford Experiment, 143 *Science* 3605 (1964) pp. 437-441; C.Wiedemann et al. Modeling of copper needle clusters from the West Ford Dipole experiments, Proc. 3rd EU Conference Space Debris, ESOC, ESA (2001), p. 1.
22 Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space, UNGA 1962 (XVIII) (1963); Resolution No. l2, IAU, XIth General Assembly(1961).
23 O. Ogynbanwo, International Law and Outer Space (1975) p. 66.
24 Article 1(c), The Space Millennium: Vienna Declaration on Space and Human Development, 1999, UNISPACE III, A/CONF.184/6.
25 M. Hofmann, The Role of Cospar Guidelines in Interpreting Article IX OST, IISL Proceedings (2011), p. 311.
26 Z. Guobin, A Discussion on "Due Regard" in the UNCLOS, China Oceans Law Review 2 (2014) p. 76; Fisheries Case (UK v. Iceland) (Judgment) I.C.J. 3(1974).
27 C.Walker, P. Benvenuti, Dark and Quiet Skies for Science and Society II, WG Reports (2022), p. 137.

the interests of others by diminishing the possibility to explore OS through astronomy.[28]

UNCOPUOS recently included a presentation by the IAU with respect to the impact of Satellite Constellations on Astronomy on its agenda for "Long-Term Sustainability of Outer Space Activities".[29] This inclusion underlines the relevance of protecting the Dark Skies as a part of space sustainability efforts. Therefore, and for our purposes, "due regard" should be understood as the obligation to deploy mega-constellations with a certain standard of care and observance, meaning that States must prove beyond reasonable doubt that everything possible was undertaken to prevent harmful consequences to astronomy.[30] At any rate, night skies should be maintained in a substantially unimpaired condition for the enjoyment and benefit of future generations.[31]

3.4. The obligation to undertake consultations to avoid harmful interference

What is more, Article IX establishes a requirement for States to undertake "*appropriate international consultations*" before proceeding with a planned space activity that might cause "*potentially harmful interference*" with the space activities of others. The said consultation clause primarily aims to safeguard human space activities. Yet, an additional spill-over effect may be better environmental protection,[32] through the application of environmental law principles via Article III OST. The duty of due regard, EIA and prior notification[33] concerning space activities is part of a general duty of environmental prevention of customary character.[34] States must demonstrate due diligence while procuring activities in areas under their jurisdiction and control that may cause transboundary harm, namely a "significant", "substantial" or "appreciable" harm to areas beyond territoriality.[35]

The notion of harmful interference remains undefined in the Space Treaties. However, it is defined in the ITU Radio Regulations as any *"interference which endangers the functioning of a radionavigation service […] or seriously*

28 G.Hackett, Space Debris and the Corpus Iuris Spatialis. Forum Air and Space Law, Volume 2, Marietta Benkö (ed. W.Graaff) (1994) pp. 72-72.

29 Report of the COPUOS 65th session A/77/20, GA Records 77Sess.Supplement 20(2022) p. 21.

30 S. Marchisio, Article IX: Cologne Commentary I, p. 175.

31 D.Tan, Towards a New Regime for the Protection of Outer Space as the "Province of All Mankind", 25 Yale J.Int.L.(2000) p. 164.

32 L.Viikari, Environmental Aspects of Space Activities: F. Dunk, F. Tronchetti, Handbook of Space Law, 2015, p. 730.

33 H.Xue, Transboundary Damage In International Law (2003) p. 165.

34 Daniel G. Partan, the "Duty" to inform in International Environmental Law, 43 Boston Un. Int'l L. 43 (1988) p. 51.

35 C.Schwarte, 'No-harm rule' and climate change, Legal Response Initiative (2012).

degrades, obstructs, or repeatedly interrupts a radiocommunication service operating in accordance with these Regulations." Harmful interference does not deal with the legitimacy of the interference *per se* but with the effects of the action in question,[36] and may occur when the interference is deep and/or long enough to deteriorate the services of the affected systems.[37] In general, the concept of harmful interference could be extended to encompass observational interference (including terrestrial based astronomical observations).[38]

Moreover, the view has been supported in international law literature that consultations lack normative value. Nevertheless, their appearance in numerous environmental conventions proves a consistent State practice.[39] In the *Nicaragua* v. *Costa Rica* case, consultations were proven "*necessary to determine the appropriate measures*" for the prevention of transboundary damage.[40] This decision is even more significant when considered in the environment of the "global commons" where no State sovereignty exists and international cooperation is of substantial nature. Consequently, the authors are of the opinion that consultations shall be deployed before the launch of relevant projects in order to avoid the above damages.

3.5. Notification and coordination of activities

Additionally, Article XI provides for a notification mechanism that consists of the coordination and sharing of information relating to the nature, conduct, locations and results of planned space activities. This would allow the astronomical community to perform better coordination with the affected stakeholders and to schedule their observations around the expected satellite trails so as to avoid unwanted reflections. Moreover, Article XI could be utilized as the means for States to consult with the scientific community to build commonly accepted measures in the form of guidelines. Although not legally binding, soft law instruments generate expectations that their rules will be complied with, [41] especially when they are adopted by *consensus* and may progressively assist in the formation of international custom.[42] They

36 S.Marchisio, Legal Dimension of the Sustainability of Outer Space Activities: The Draft International Code of Conduct on Outer Space Activities, 55 Proc.IISL 3 (2012), p. 14.

37 R.Acharya, Satellite Signal Propagation, Impairments and Mitigation (2017) p. 274.

38 M.Mineiro, Article IX's Principle of Due Regard and International Consultations: An Assessment in Light of the European Draft Space Code-of-Conduct, 53 Proc.IISL. (2010) p. 679.

39 P.Sands, Principles of International Environmental Law (2003), p. 839.

40 Construction of a Road in Costa Rica along the San Juan River (Nicaragua v. Costa Rica) (Judgment) I.C.J.(2015).

41 F.Tronchetti, Soft Law, in Outer Space In Society, Politics and Law(2011), p. 623.

42 It has been argued that this was the case with the Debris Mitigation guidelines.

could thus be used as a common reference for the establishment of comprehensive national licensing regimes.
Notably, the Starlink team has shown good intention to collaborate with the scientific community reiterating their commitment to continuing their project without causing serious impediments to astronomical research, through the adoption of mitigation strategies decreasing the satellites' brightness without however achieving a satisfactory outcome.[43] It is thus evident that relying solely on business "good practices" does not suffice.

4. Environmental considerations

Light pollution is not just a problem for astronomy but constitutes a serious environmental concern for OS.[44] Unfortunately, the Space Treaties have proven inadequate to face these environmental issues, even though environmental law principles are directly applicable in the space environment. General principles constitute a source of international law in accordance with Article 38(1) of the ICJ Statute [45] and are of utmost importance in environmental law.

4.1. Sic utere tuo, ut alienum non laedas

The customary "no-harm rule" derives from the Roman maxim *sic utere tuo, ut alienum non laedas*, meaning "*use your own in such a way that you do not harm that which belongs to another*"[46] and has been affirmed by the ICJ in numerous cases.[47] Furthermore, the principle obliges States to "*ensure that activities within their jurisdiction and control respect the environment of other states or of areas beyond national control*".[48]
A parallel can be drawn between the *sic utere* formula as embodied in Principle 21 of the Stockholm Declaration and 2 of the Rio Declaration and the literature of Article IX OST, as they encourage a more responsible conduct based on a State's general duty of care.[49] The scope of this obligation applies not only to the responsibility to refrain from causing environmental

43 H.Krantz, et al., Characterizing the All-Sky Brightness of Satellite Mega-Constellations and the Impact on Astronomy Research AMOS (2021), p. 4.
44 See the work of the International Dark-Sky Association, https://www.darksky.org/.
45 Pellet, A.Zimmermann et al. (eds), The Statute of the IICJ (2nd Edition): A Commentary, p. 1110.
46 A.Fellmeth, M.Hoewitz, Guide to Latin in International Law, 2009, p. 263.
47 Nuclear Tests Case 1974, ICJ (1995); Corfu Channel (UK v. Albania) (Judgment) I.C.J.(1949).
48 Legality of the Threat or Use of Nuclear Weapons (Advisory) I.C.J.(1996).
49 G.Petrovici, Satellite Constellations and the Sustainable Use of Outer Space, Legal Aspects Around Satellite Constellations ESPI, 2021, p. 131.

damage, but also to the development of national environmental policies.[50] Specifically, they impose an obligation for States to take suitable preventive measures to protect global commons, such as the OS, especially given that the nations with the technical knowledge and resources to conduct space activities also have the means to respond to harmful interference with their space assets.[51]

4.2. The precautionary approach

Due diligence in the preservation of environmental integrity is further advanced by Principle 15 of the Rio Declaration, which establishes the precautionary approach. The essence of the latter is that lack of sufficiently convincing, conclusive or definite scientific evidence does not constitute an excuse for postponing measures to prevent environmental degradation. States have the positive obligation to take measures that reduce real and immediate risks, even if such impacts would only materialize years later.

This positive obligation is further justified by Articles 2 and 8 ECHR, in light of the ECtHR' jurisprudence which indirectly recognizes a right to a healthy environment. [52] The precautionary approach covers the full range of preventive measures, aiming at securing the fundamental rights of future generations.[53]

The focal question is at which point the obligation to take preventive measures arises. In order for States to meet their due diligence obligations, they are requested to prevent foreseeable significant interference.[54] Hence, some international treaties attempt to provide more detailed guidance as to the threshold of harmful effects that would be enough to necessitate action. In the case of protecting Dark Skies, due to the uncertainty and complexity of the impact of mega-constellations, the standard of proof required in order to take preventive action should be lowered. If the threshold is set too high, serious harm may occur prior to the initiation of preventive measures. [55]

50 Sands, Principles of International Environmental law, W.Birnie, A.E.Boyle, International Law and the Environment, Oxford University Press, 2004, p. 110.

51 S.Black, No Harmful Interference with Space Objects: The Key to Confidence Building, 1 Security in Space The Next Generation-Conference (2008).

52 Urgenda v. Netherlands, 20 Dec. 2019; Neubauer, et al. v. German; Taskin and others v. Turkey.

53 Constitutional complaints against the Federal Climate Change Act (1 BvR 2656/18, 1 BvR 288/20, 1 BvR 96/20, 1 BvR 78/20).

54 ILA Study Group on Due Diligence in International Law, First Report, March 7, 2014, p. 2.

55 Southern Bluefin Tuna (Provisional Measures) ITLOS No 3, 4 (1999).

4.3. Environmental Impact Assessment (EIA)

EIA constitutes the basis for a rigorous precautionary policy.[56] The UNEP has defined EIA as "*an investigation, analysis, and evaluation of the activities planned with a view to sustainable and respectful development with the environmen*t". The Espoo Convention describes it as *"a national procedure for evaluating the likely impact of a proposed activity on the environment."* The purpose of the mechanism is to provide information to national authorities of potential environmental consequences prior to granting authorization for an activity.

The issue of EIA was raised in the Pulp Mills case,[57] where it was declared "*a requirement under general international law to undertake an environmental impact assessment where there is a risk that the proposed industrial activity may have a significant adverse impact in a transboundary context, in particular, on a shared resource*", such as the natural night skies. The Court also concluded that the monitoring of the project's environmental impact should be undertaken throughout its life. In the context of the deployment of mega-constellations, it can be argued that States must carry out an EIA prior to each and every launch, so as to minimize, amongst others, their impact on the Dark and Quiet Skies.

Although the customary duty to conduct EIAs[58] has been incorporated in several international conventions, in soft-law instruments and in the ILC Articles on Prevention of Transboundary Harm, there is very little guidance with respect to its content. Therefore, there is no common understanding of what should be examined during the said procedure and which parameters should be taken into account. It is rather left at the discretion of each State to adopt domestic laws and specify the content of the assessment. Notably, with respect to Starlink, it has been argued that "*a significant amount of the outcry could have been avoided if there had been an impact study done in advance.*"[59] In the same vein, the FCC has been criticized for arbitrarily excluding[60] from its environmental impact review commercial satellite projects in violation of the U.S. National Environmental Policy Act.[61]

56 S.Boutillon, The Precautionary Principle: Development of an International Standard, 23 Mich.J.Int'l.L., p. 448.

57 Pulp Mills Case (Argentina v. Uruguay) (Judgment) I.C.J. (2010).

58 Certain Activities Carried Out by Nicaragua in the Border Area (Costa Rica v. Nicaragua) ICJ (2015); M. N. Shaw, International Law (2017), p. 657.

59 See Statement of astrophysicist Jessie Christiansen, https://bit.ly/3WCWRqo.

60 R.Ryan, The fault in our stars: Challenging the FCC's treatment of commercial satellites as categorically excluded from review under the national environmental policy act, 22 Vand.J.Ent. & Tech.L. 4, p. 923 (2020).

61 51442 U.S.C. 4321, J.Hermida, Legal Basis for a National Space Legislation, (2004) p. 93; C.Kersten, Rethinking Transboundary Environmental Impact Assessment, 34 Yale J. Int'l L.(2009), p. 176.

Governments shall put in place a clear evaluation of risks and predictive impacts on ground-based astronomical observatories and shall make any space activity subject to an EIA at the early stage of planning.[62] For example, India's proposed national space act[63] includes environmental safeguards and provides for the punishment of satellite operators who cause damage or pollute the environment in violation of the applicable rules. This way the proposed bill could help mitigate the impact of constellations on astronomy, provided that more concrete national policies and technical standards are implemented in the national regulatory framework.

5. International initiatives and national regulations

UNESCO has recognized, as early as 1992, that "*future generations have the right to an uncontaminated and undamaged Earth, including pure skies*", with the adoption of the Laguna Declaration.[64] Moreover, the night sky has been recognized as "*an inalienable right of humankind equivalent to all other environmental, social, and cultural rights*", by a number of intergovernmental organizations in the Starlight Declaration.[65] Additionally, the IAU in collaboration with UNESCO have started the Astronomy and World Heritage Initiative suggesting that ground-based astronomical sites are designated as heritage sites to be protected under the World Heritage Convention. A plethora of other international initiatives aiming to raise awareness around the issue of light pollution have resulted in the adoption of relevant policies and guidelines.

Nevertheless, national regulations seem to largely ignore the impact of orbital objects to the human environment, including the night sky. Indicatively, the national policies of space-faring nations such as Canada, Australia and the U.S. seem to disregard light pollution aspects in the context of authorizing private operators to launch and deploy satellites.

Domestic regulators must adopt a comprehensive regulatory framework, introducing specific standards, so as to ensure that satellite manufacturers and operators adopt technical measures to neutralize the negative impact caused by satellites to the Dark Skies. The ultimate goal is to ensure the harmonious coexistence of technological advancements in LEO with the conditions that enable humankind to continue space observation. However, this cannot be done *in abstracto*, as it rather requires collective efforts.

62 F.Lyall, P.B.Larsen, Space Law: A Treatise, 2nd ed., 2018, p. 179.
63 PRS Legislative Research (2021, September, 21) Draft Space Activities Bill, 2017.
64 Article 1, A/CONF.157/LACRM/7, 1992.
65 Declaration in Defense of the Night Sky and the Right to Starlight, La Palma, Spain (2007).

6. Conclusion; the way forward

The unrestrained deployment of satellite constellations may pose significant risks to ground-based astronomy, which qualifies as a legitimate use of OS. As satellite operators cannot be prohibited from further deploying their networks, a balance of rights is required, resulting in the imposition of certain limitations. In this context, States shall pay due regard to the corresponding interests of astronomers and shall be obliged to adopt appropriate measures to avoid any detrimental scenarios.

In the light of Articles IX and XI OST, all space actors are encouraged to engage in international dialogue, exchange information regarding their planned activities and explore in good faith practical and commonly agreed solutions that can safeguard the large-scale investments made in cutting-edge ground-based astronomy facilities.

States shall require the introduction of comprehensive EIAs before the authorization of commercial satellite projects. To this respect, the formulation of soft law instruments could serve as a guiding tool and guarantee a uniform approach towards ensuring the sustainability of the space environment. What remains beyond doubt is that relying solely on the good intentions of the parties involved cannot offer a permanent solution. After all, protecting the natural Dark Skies is not only a measure for the advancement of astronomy, but also constitutes a necessary guarantee of the peoples' right to a pure and starry night sky.